



Quantum Physics in Consciousness Studies

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Introduction in quantum aspects of brain function

Since the development of QM and relativistic theories in the first part of the 20th century, attempts have been made to understand and describe the mind or mental states on the basis of QM concepts (see **Meijer, 2014, Meijer and Korf, 2013**). Quantum physics, currently seen as a further refinement in the description of nature, does not only describe elementary microphysics but applies to classical or macro-physical (Newtonian) phenomena as well. Hence the human brain and its mental aspects are associated to classical brain physiology and are also part of a quantum physical universe. Most neurobiologists considered QM mind theories irrelevant to understand brain/mind processes (e.g. **Edelman and Tononi, 2000; Koch and Hepp, 2006**).

However, there is no *single* theory on QM brain/mind theory. In fact a spectrum of more or less independent models have been proposed, that all have their intrinsic potentials and problems. The elements of quantum physics discussed here are summarized in Table 1 and 2; details of the various QM theories have been described elsewhere (**Meijer, 2012; Meijer and Korf, 2013**).

Some QM mind options assume some sort of space-time multidimensionality, i.e there are more than the four conventional space-time dimensions. Other options assume that one or more extra dimensions are associated with a mental attribute or that the individual mind is (partly) an expression of a universal mind through *holonomic* communication with quantum fields (**Fig.1**). The latter idea has led to holographic (holonomic) theories (**Pribram 1986, 2011**). The human brain is then conceived as an *interfacing* organ that not only *produces* mind and consciousness but also *receives* information. The brain or parts of the brain are conceived as an *interference hologram* of incoming data and already existing data (a “personal universe”). If properly exposed (“analyzed”), information about the outer world can be distilled.

In neurobiological terms, the existing data is equivalent to the subject’s memory, whereas the “analyzer” is cerebral electrophysiology. Bohm hypothesized that *additional dimensions* are necessary to describe QM interference processes, thereby circumventing probabilistic theories and consciousness-induced collapse of the wave function. In this theory, the universe is a giant superposition of waves, representing an unbroken wholeness, of which the human brain is a part (**Bohm, 1990**). Accordingly, the individual mind or consciousness is an inherent property of all matter (and energy), and as such being part, or rather an expression, of this universal quantum field. The apparently diffuse time/space localization of mental functions argues in favor of an underlying multidimensional space/time reality. **Bohm and Hiley (1987)** also proposed a two-arrow (bidirectional) time dimension. In this concept the stochastic (or double stochastic) character of quanta is explained by an underlying quantum field: *the implicate order*. This concept implies entanglement (non-locality) as well.

Another hypothesis, having the potential to couple wave information to mental processes, proposes that wave information is transmitted from and into the brain by wave resonance. Through conscious observation they collapse locally to material entities (**Stapp 2009; Pessa and Vitiello, 2003; Schwartz et al., 2004**). **Stapp (2012)** argued that this does not represent an interference effect between *superposed states* (as assumed by **Hameroff and Penrose, 1996**), but that through environmental de-coherence, super-positions become informative to the brain/organism. A complementary implication of these theories is that mental processes are not necessarily embedded in entropic physical time. In line with this QM idea is that memories are not stored as a temporal sequence, but rather a-temporally.

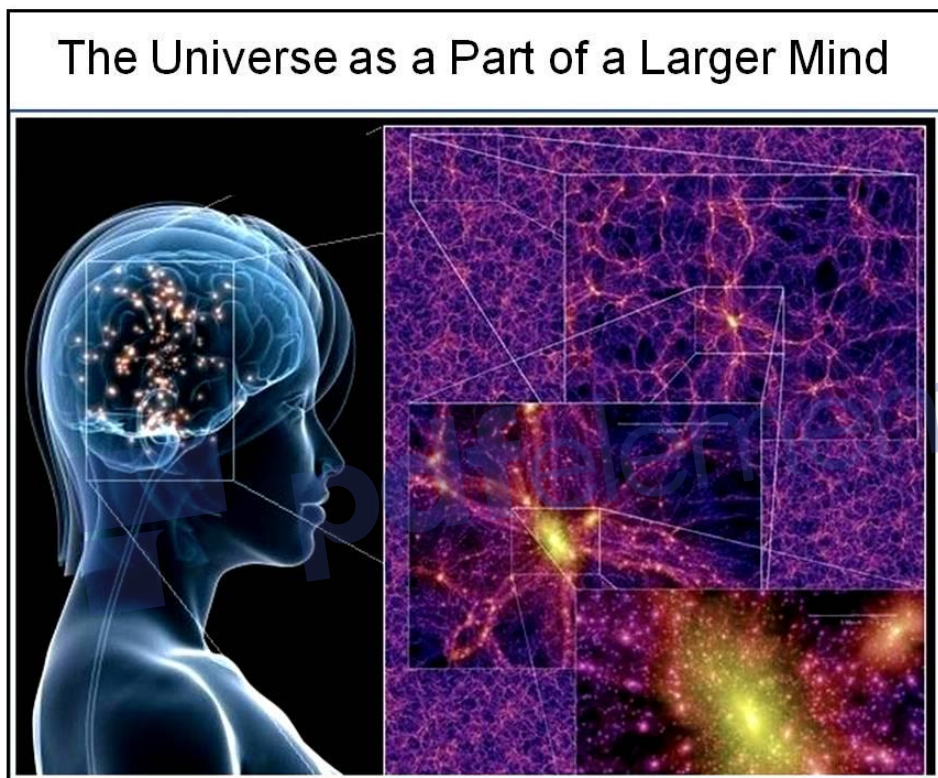


Fig. 1: The hypothesis that the universe and our minds are integral parts of a universal consciousness

Some QM mind theories suppose the possible involvement of specific molecules. A spectrum of ions and molecules has been suggested to operate in a quantum manner (**Tuszinsky and Woolf 2010**). For instance QM theories have been based on *micro-tubular proteins* (**Penrose 1989; Hameroff 2007**), proteins involved in *synaptic transmission* (**Beck and Eccles 1992; Beck 2001**), including *Ca ion-channels* (**Stapp 2009**) and channel proteins instrumental in the initiation and propagation of action potentials (*potassium-ion channels*, **Bernroider and Roy 2004**). There is also the hypothesis that synaptic transmission represents a typical (quantum) probability state that becomes critical for an all or none neuronal response (**Beck and Eccles 1992; Beck 2001**). Attributing non-linear and non-computable characteristics of consciousness,

Hameroff and Penrose, 2011, 2013, argue against mechanisms of all or none firing of axonal potentials (**Beck and Eccles, 2003**). They rather prefer the model of **Davia (2010)**, proposing that consciousness is related to waves traveling in the brain as a uniting life principle on multiple scales. According to some QM mind theories (**Woolf and Hameroff, 2001**), tunneling was proposed to facilitate membrane/vesicle fusion in neural information processing at the synapse.

Kauffman relates quantum processes in the biological matrix of the brain to the emergence of mental processing (**Kauffman 2010; Vattay et al. 2012**). This theory, mainly based on chromophores detecting photons, assumes that the coherence of some quantum configurations adhered to proteins is stabilized or is maintained by re-coherence. This principle may have guided evolutionary selection of proteins. Accordingly, mind and consciousness are both quantum mechanical and an expression by the classical neural mechanisms. The underlying coherent quantum states provide the potentiality for the collapse to the de-coherent material state, resulting in classical events such as firing neurons, that are at least to some extent, a-causal, i.e. beyond classical determinacy. The quantum system (of the brain) interacts with a quantum environment, the phase information is lost and cannot be reassembled. By entanglement, the quantum coherence in a small region, e.g. the cell or the brain, might have spatial long-range effects (**Vattay et al. 2012; Hagan et al. 2002**). Kauffman accepts long-lived coherence states in biological molecules at body temperature (now 750 femto-seconds in chlorophyll at 77K) to be potentially enabling parallel problem solving as major challenges for further investigations. The question is also which neurons or neuronal structures are in particular associated to the coherence/de-coherence brain model of consciousness.

The question is often put as to why quantum theory should be involved in discussions of consciousness at all, and also as to why it should be treated as something special. In thinking about quantum theory, it is important not to be bullied into viewing it as something weird and peripheral that can be ignored (**Atmanspacher, 2011**). Unfortunately, this allows the more superficial thinkers to dismiss all theories of quantum consciousness. This sort of practice has recently been criticized as 'pseudoscepticism', a parallel form to pseudoscience. Pseudo-skepticism (see **Wikipedia**) similarly uses denunciation in the name of science or scientific affiliation without citing any evidence or possible experimentation to establish this criticism, (see **Uttis and Josephson, 1996**). The features of quantum theory that make it special and also possibly relevant to consciousness can be summarized as follows:

- 1.) Quantum theory describes the fundamental level of energy and matter. In contrast to higher levels, the quantum level has aspects, such as mass, charge and spin that are given properties of the universe, not capable of further reduction or explanation. In quantum theories of consciousness, it is suggested that consciousness is such a fundamental property existing at this level. Some theories are additionally linked to the structure of spacetime, which

is nowadays seen as being interconnected with the nature of the quanta(see **Chalmers, 2000; Nagel, 2012**)

2.) The other fundamental aspect of the universe is spacetime, as described by the special and general theories of relativity. Although both relativity and quantum theory have both been tested to very high degrees of accuracy, they are nevertheless incompatible with one another. The gravitational force is the main problems, since the smooth continuous curvature of space that describes gravity in general relativity is incompatible with the discreteness of particles/waves that is fundamental to quantum theory. String theory and loop quantum gravity have attempted to bridge this gap, but neither are yet regarded as giving a complete picture. (see **Smolin, 2004; Penrose, 2004**)

3.) In traditional versions of quantum theory, the wave form of the quanta is conceived as a superposition of the many possible positions of a quantum particle. When the wave function collapses the choice of a particular position for the particle is random. This choice of position is an effect without a cause. The property of randomness is not in itself particularly useful in theories of consciousness, but it does open a chink in the deterministic structure of the universe, which is exploited in particular by the **Penrose/Hameroff model, 2013**, see also **Stapp, 2009, 2012**)

4.) Non-locality is the remaining special feature of quantum theory. Classical physics comprises only so-called billiard ball relationships, with bits of matter and energy bumping into one another. These relationships are local, in that they involve immediate contact. Such relationships are also normal in quantum physics. However, quantum physics also possesses non-local relationships. This applies where two particles have been in some close relationship, such as two electrons in the same orbital. In this case they can become correlated. For instance the spin on two particles may always be opposite, if one spins up, the other spins down. This is not a problem while the particles are in a wave form, as both will be in a superposition of up and down. However, if the wave function of one particles collapses, that particle chooses one or the other superposition. When that happens, the other particle will choose the opposite position. In experiment, this is shown to happen when the two particles are out of range of a signal travelling at the speed of light. No matter, energy or conventional information is transferred, and the experiment is not regarded as a violation of relativity, but it is demonstrated that quantum properties can correlate instantaneously over any distance.(see for a basic introduction to QM: **Thomas A, link internet**.)

The Failure of Modern Consciousness Studies

The study of consciousness was a taboo in academic circles through much of the 20th century, at least in part due to the long reign of behaviorism. Even the study of emotion being largely proscribed, with brains conceived as being reasoning machines and nothing else. This started

to lift in the late 1980s and at first this seemed to be a marvelous opportunity for the advances made in other areas of science to be applied to the neglected area of consciousness. What followed, however, can be seen as an overall negative in establishing orthodoxies which appear to have negligible chance of success in explaining consciousness, while discouraging explanations that relate to new areas of physics or neuroscience.

The traditional explanation for consciousness or the soul in more traditional language is known as dualism. This posits a separate spirit stuff and physical stuff, with the spirit stuff capable of acting on the physical stuff, as when the soul commands the body. The core argument against dualism was that for the spirit stuff to act on the physical stuff it would need to have some physically relevant quality and would therefore not be pure spirit stuff. Vice versa looks to apply for physical stuff. The failure of dualism is one of the few points of agreement between mainstream consciousness studies and those that identify consciousness with a fundamental of the universe. **(Thompson, 2000)**

Functionalism was at least in the 1990s the dominant explanation for consciousness, driven by the success of computers as problem solving and memory storage machines. The main proposal is that any system or machine that processes information in the same way as the brain will be conscious, regardless of what it is made of. The biological matter and structure of the human brain was deemed irrelevant. In reality, and despite its popularity, this appears as a pseudo-theory, kicking the problem of consciousness further down the road. It does not explain how consciousness arises in the brain and nor does it explain how consciousness might at some point arise in silicon or other matter. It seems, however, that functionalism has had a malign effect in making mainstream consciousness studies practitioners think it unnecessary to take any notice of modern developments in neuroscience or biology.

Identity theory may have been the next most popular theory after functionalism in the 1990s. This declared that consciousness was identical to the brain or identical to its processing. However, it made little attempt to explain why it was identical to the brain, but not to any of the other physical structures in the universe. Nor did it attempt to define what it meant by the brain, despite the fact that our understanding of the physical processing of the brain was changing dramatically. It was further undermined by the discovery that much neural processing such as the dorsal stream governing spontaneous movement could be brought to completion outside of consciousness, which was seen to be more closely related to longer-term evaluations and planning.

Epiphenomenalism was and remains another popular idea. The theory proposes that consciousness is a by-product of neural processing that has, however, no function. Despite its popularity this concept is beset by at least three major problems. It conflicts with evolutionary theory in that it is hard to see why evolution should select for something that had no function,

particularly as neural processing is exceptionally energy-hungry. The theory also conflicts head on with physics in which there is no acausality, with every object or process having influences elsewhere. Finally, there is the problem that even granting the idea of a functionless by-product, there is still no physical evidence for what produces such a thing in the brain. Like functionalism it appears to be a pseudo-theory.

In the present century, there seems to have been a tacit recognition that functionalism and identity theory would have difficulty in becoming the consensus of a wider public. This appears to have given rise to two more theories that avoid treating consciousness as a fundamental. Consciousness resulting from embodiment has been possibly the most fashionable of these ideas. Initially embodiment ideas did represent a genuine step forward in both consciousness studies and psychology as a move away from the brain as a computer in a vat. It now accepted that mental events could influence the body and that visceral events could feed back on the brain. It also accepted that emotion is a relevant aspect of mental life. However, there was an over-reach in suggesting that the body somehow drove consciousness that the brain could not produce. This seemed to assume some kind of undefined special property in the body that was not present in the brain. More specifically it ignored the fact apart from the sense of touch, signals entered the brain directly from the environment and were consciously processed in the higher sensory and frontal cortex before being signaled to the viscera.

The attempt to classify consciousness as a form of information or information processing has also become fashionable in this century. Interestingly, there are innumerable examples of non-conscious information, especially when we look at modern technology, with no apparent specification as to how conscious information would differ from non-conscious information. (Meijer, 2012, 2013a, 2014)

At a more philosophical level, there is a core difference between information and reality, in that information embraces only what we happen to know, while it can also be defined as an attempt to describe nature's behavior and microscopic make up that comprises reality. Thus the hunter-gatherer in ancient Africa, glancing up at the sun is only aware of its glare, heat and position in the sky. A fuller understanding of its reality has to wait for modern science.

A popular but poorly based concept is to call consciousness an emergent property: The idea of consciousness as an emergent property of classically described matter is superficially plausible, and as such can sometimes look like the best shot of modern consciousness studies. Emergence is a familiar process in physics. Thus liquidity is an emergent property of water. The individual component hydrogen and oxygen atoms do not have the property of liquidity. However, when they are bound together in a sufficiently large number of water molecules, the property of liquidity emerges.

The problem for this as an explanation of consciousness is that when emergent properties such as liquidity arise in nature, the emergence can be traced to the component particles and forces, such as the electromagnetic interactions between the water molecules. The macroscopic liquidity is an effect of the microscopic electrical charges and the resulting charge relationships. The problem for consciousness as an emergent property is no arrangement of such particles and forces has been identified that could produce consciousness. Many continue to furiously assert that this is possible, but the claim being made here is in fact the same as dualism, where two things that have no common property are required to act on one another. Anybody who thinks this is possible in physics could simplify their search for consciousness by accepting the idea of dualistic spirits (**Murphy, 2007, 2011, Auletta et al, Clayton and Davies, 2006**).

In the last two decades, consciousness studies has gone off in a different direction from physics or neuroscience. Much of consciousness studies is dominated by philosophers and psychologists who have only a scant interest in what has been happening in brain science, let alone physics. In many cases, they see it as their duty up to prop a nineteenth century Newtonian world view, while dealing in abstractions that take limited account of neuroscience or physics. Neuroscientists have meanwhile been pressured into treating consciousness as not part of their remit, deferring to philosophers when it was necessary to discuss consciousness, even when the philosophy was contradicted by the neuroscientists own discoveries. More fundamental approaches have fallen victim to black propaganda against them. It seems likely that mainstream consciousness studies, if it survives at all, will reach the end of the 21st century without having achieved consensus on a theory that has explanatory value.

The Descent into the Quantum World

Suppose one were to ask for a scientific description of your hand. Biology could describe it in terms of skin, bone, muscles, nerves, blood etc., and this might seem a completely satisfactory description. However, if you were just a bit more curious, you might ask what the muscle and blood etc. were made of. Here you would descend to a chemical explanation in terms of molecules of protein, water etc. and the reactions and relations between these. If you were still not satisfied with this, you would have to descend into the quantum world. At this level, the solidity and continuity of matter dissolves. The molecules of protein etc. are made up of atoms, but the atoms themselves are mainly vacuum. Most of the mass of the atom lies in a small nucleus, comprised of protons and neutrons, which are themselves made up of smaller particles known as quarks. The rest of the mass of the atom resides in a cloud of electrons orbiting around the nucleus (**see Fig.2**).

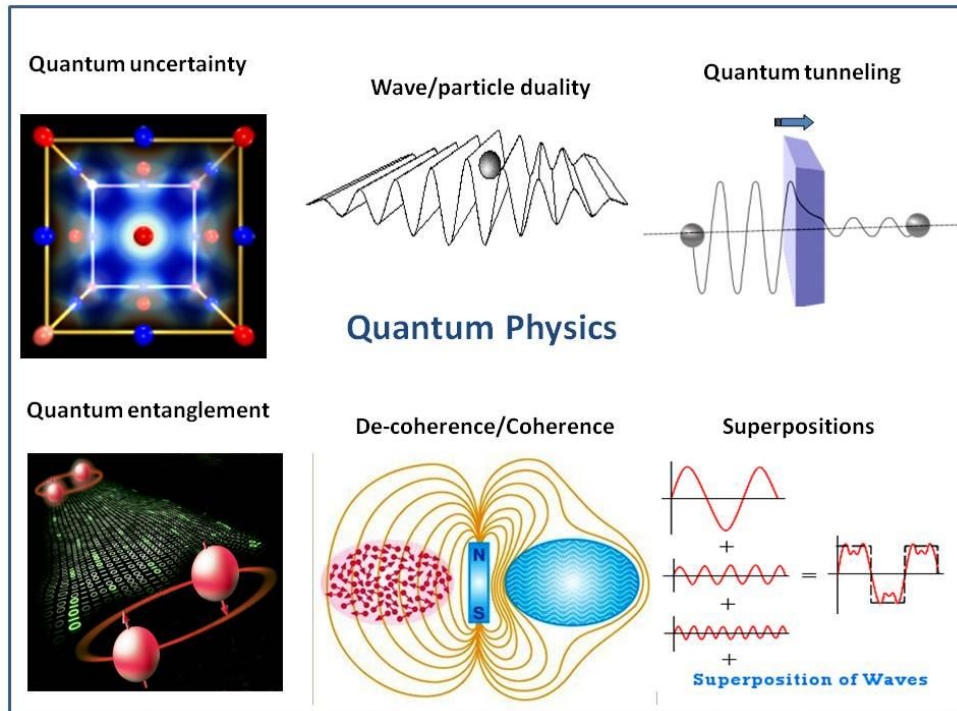


Fig.2 : Some central elements of quantum physics: uncertainty of position of particles, wave / particle duality as demonstrated in the double-slit experiment (upper part), as well as entanglement (non-locality) of particles at great distances, the phenomenon of coherence/decoherence and superposition of waves (lower part).

The fundamental particles are bound together by the four forces of nature, which are gravity, electromagnetism and the strong and the weak nuclear forces. The strong nuclear force binds together the particles in the nucleus of the atom, and acts only over the very short range of the nucleus itself. Gravity is a long-range force that mediates the mutual attraction of all objects possessing mass. The electromagnetic force is perhaps the force most apparent in everyday life. We are familiar with it in the form of light, microwaves and X-rays. It holds together the atom through the attraction of the opposite electrical charges of the electron and the proton. It also governs the interactions between molecules. Van der Waals forces, a weak form of the electromagnetic force is vital to the conformation of protein and thus to the process of life itself. In contrast to the nuclear forces, gravity and electromagnetism are conceived of as extending over infinite distance, but with their strength diminishing according to the inverse square law. That is, if you double your distance from an object, its gravitational attraction will be four times as weak. The quanta can be divided into two main classes, the fermions, which possess mass and the bosons which convey energy or the forces of nature. The most fundamental fermions are the quarks making up the nucleus and the circling electrons, while gluons and photons are the most prominent bosons. The gravitons, which may intermediate the gravitational force remain hypothetical.

The Quantum Wave

The quantum particles or quanta are unlike any particles or objects that are encountered in the large scale world. When isolated from their environment they are conceived as having the property of waves, but when they are brought into contact with the environment, there is a process of decoherence, in which the wave function is described as collapsing into a particle. The wave form of the quanta is different from waves in matter in the large scale world, such as the familiar waves in the sea. These involve energy passing through matter. By contrast, the quantum wave can be viewed as a wave of the probability for finding a particle in a specific position. This probability wave also applies to states of the quanta such as momentum. While the quanta remains in its wave form, it is viewed as a superposition of all the possible positions that the particle could occupy. At the peak of the wave, where the amplitude is greatest, there is the highest probability of finding a particle, when the wave eventually collapses. However, the choice of position for each individual particle is completely random, representing an effect without a cause. This comprises the first serious conceptual problem in quantum theory.

The Two-Slit Experiment in Quantum Mechanics

The physicist Richard Feynman said that this classic experiment contained all the problems of quantum theory. In the early nineteenth century, an experiment by Thomas Young showed that when a light source shone through two slits in a screen, and then onto a further screen, then a pattern of light and dark bands appeared on a further screen, indicating that the light was in some places intensified and in other reduced or eliminated. Where two waves of ordinary matter, for instance waves in water, come into contact an interference pattern forms, by which the waves are either doubled in size or cancelled out. This appearance of this phenomenon in Young's experiment demonstrated that light was a wave, contrary to most scientific opinion prior to the experiment.

Later, the experiment was refined. It could now be performed with one or two slits open. If there was only one slit open, the photons or light quanta, or any other quanta used in the experiment behaved like particles. They passed through the one open slit, interacted with the screen beyond and left an accumulation of marks on that screen, signifying a shower of particles rather than a wave. But once the second slit was opened, the traditional interference pattern, indicating interaction between two waves, reappeared on the screen. The ability to generate the behavior of either particles or waves, simply according to how the experiment was set up, showed that the quanta had a perplexing wave/particle duality.

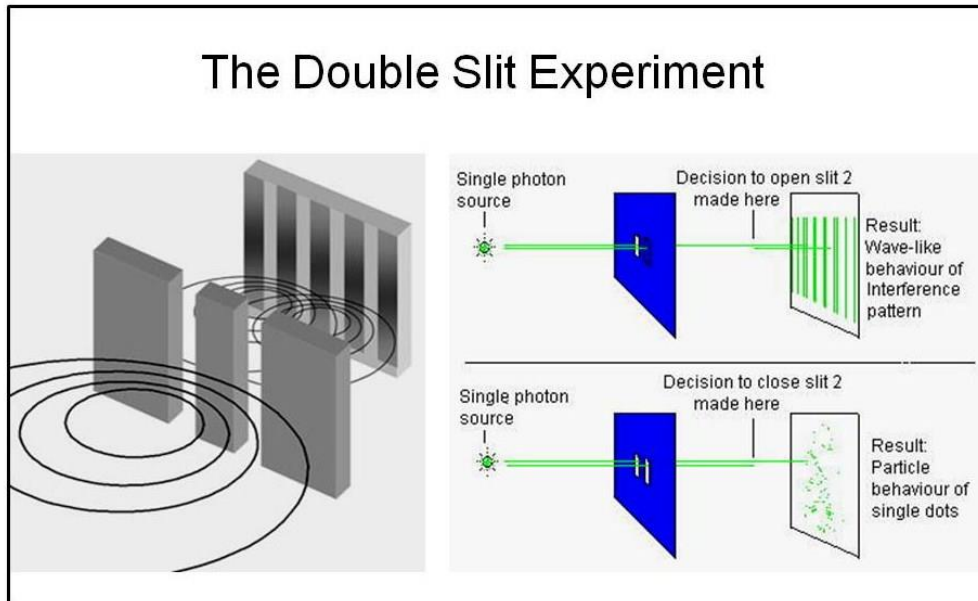


Fig. 3: The famous double slit experiment: single particles behave like a wave front that show interference pattern on the screen (a), even after passing the two slits decisions to open or close a slit influences the final pattern (b).

The wave/particle duality was shocking enough, but there was worse to come. Technology advanced to the point where photons could be emitted one at a time, and therefore impacted the screen one at a time (**Fig. 3**). What is remarkable is that with two slits open, but the photons impacting one at a time, the pattern on the screen formed itself into the light and dark bands of an interference pattern. Somehow the photons 'knew' to arrange themselves into a pattern indicative on the interaction of waves. The question arose as to how the photons emitted later in time 'knew' how to arrange themselves relative to the earlier photons in such a way that there was a pattern of light and dark bands, indicative of interacting waves.

The obvious solution was to place photon counters at the two slits in order to monitor what the photons were up to. However, as soon as a photon is registered by a counter, it collapses from being a wave into being a particle, and the wave related interference pattern is lost from the further screen. The most plausible way to look at it may be to say that the wave of the photon passes through both slits, or possibly that it tries out both routes, and after doing this the divided wave interferes with itself (see **Fig. 3**).

The EPR Experiment and the Copenhagen Interpretation

Einstein disliked the inherent randomness involved in the collapse of the wave function. This was despite the fact that his revival of the idea of light in the form of discrete particles or quanta had contributed to the foundation of quantum theory. He sought repeatedly to show that quantum theory was flawed, and in 1935 he seemed to have produced a masterstroke in

the form of the EPR (Einstein, Podolsky, Rosen) experiment. At the time this was only a 'thought experiment', a mental simulation of how a real experiment might proceed, but since 1982 it has been possible to perform this as a real experiment (Fig.4).

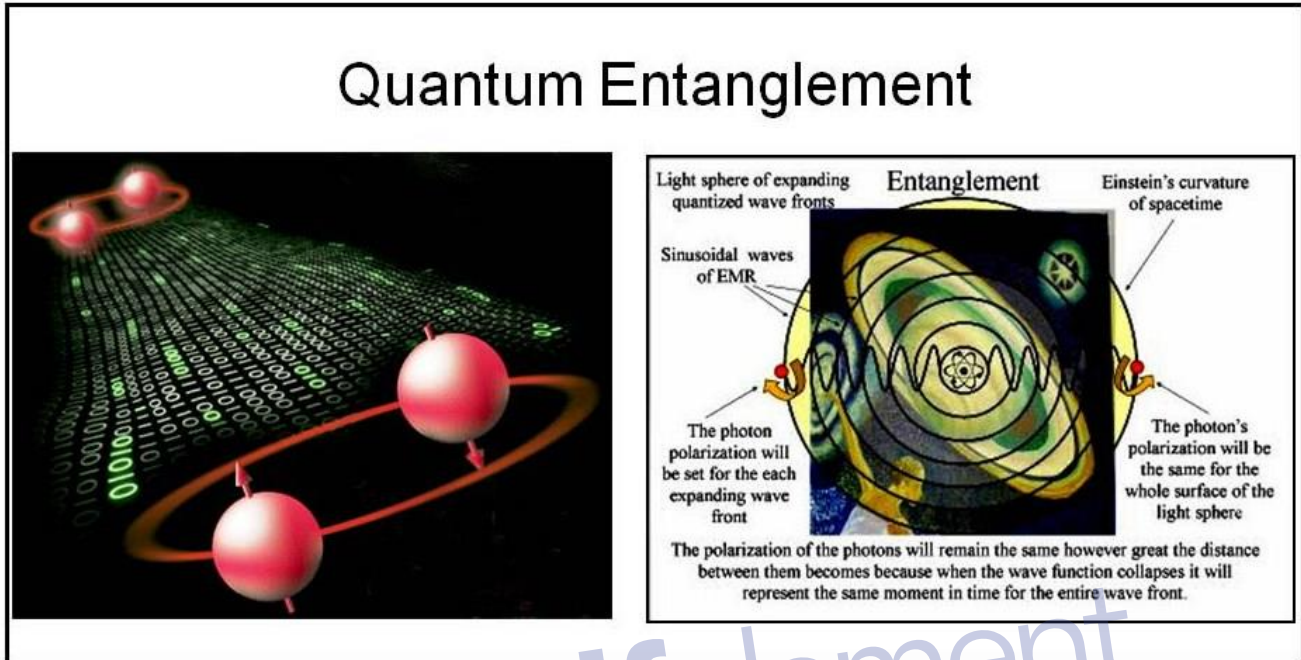


Fig.4: Quantum entanglement in a pair of distant elementary particles with regard to spin

The challenge to quantum theory presented by the EPR experiment hinges on the concepts of locality and non-locality. Locality comprises the idea of normal cause and effect under which objects or particles move or change as a result of being impacted by other objects or particles, or of being directly acted on by energetic forces such as the electromagnetic force. It is local because the object or force producing the action or change has to be in direct contact with the object or particle acted on. Moreover, where a force emitted by one object acts on another distant object such as light emitted from the Sun acting on the Earth, the force passes between the two objects at a speed not greater than that of light. By contrast, non-locality involves the ability of one particle to determine the behaviour of another distant particle instantaneously, and without any matter or energy passing between the two. Einstein termed this 'spooky action at a distance'.

With the EPR experiment it was shown, that as it stood, quantum theory violated the principle of locality, which is normally regarded as basic to scientific thinking and even to common sense. Quantum theory indicated that when two quanta had been closely related to one another, for instance in the same electron orbital, they could be regarded as quantum entangled. In this state, certain aspects of their behavior in relation to one another became

fixed. For instance, quantum particles have a property of spin, which is partly analogous to the spinning of large-scale objects. Quanta can have the property of spin-up or spin-down. In an entangled state particles could have the relationship that when one had spin up, the other would always have spin down. However, as quanta, while they remained in a wave form, they both represented a superposition of spin-up and spin-down, and therefore neither of them had a defined spin (**Fig. 4**).

The EPR experiment proposed that two such wave-form particles are moved apart. This could be a few meters along a laboratory bench or to the other side of the universe. The relevant consideration is that the two locations should be out-of-range of a signal travelling at the speed of light. Now, if an observation is made on one of the particles, its wave function collapses, and it acquires a defined spin, let's say spin-up in this case. Now when an observation is made on the other particle, it will always be found to have the opposite spin. This defies the normal expectation of classical physics that a random choice of spin would produce approximately 50% the same spin and 50% different. Therefore, there is seen to be some non-local connection between the two particles, although it is not possible to describe or detect this in terms of a normal physical transfer of energy or matter. This non-locality and the randomness of the outcome of the wave function collapse constitute the two main puzzles in quantum theory.

The Copenhagen interpretation and the EPR Experiment

The idea of non-locality, which appeared to deny much of what the science of the previous three hundred years had been trying to establish, was as repugnant to the leaders of the quantum movement, such as Neils Bohr, as it was to Einstein as an opponent of quantum indeterminism. Some modern analysis suggests that Bohr changed his own view of the quantum world in a crucial manner after encountering the EPR challenge. Bohr's interpretation is known as the Copenhagen Interpretation, and the form of this that emerged after 1935 essentially denied the objective existence or reality of the quantum wave. Bohr said that there was no quantum world, there was no deep reality. The quanta only achieved objective reality when they were the subject of an experiment or observation (**Interpretations of quantum mechanics, Wikipedia; Genovese, 2010**).

The concept of reality or objective existence is here taken to mean that something exists even when it is not being observed by anyone. The Copenhagen Interpretation denies that sort of reality to the wave form of the quanta. The wave was to be seen only as an abstract mathematical expression allowing one to predict the probable position of a particle. If the wave form had no real existence, EPR type situations did not involve any physical action at a distance, and the problem could be deemed to have gone away,(see **Kumar M ,2009**).

The Aspect Experiment and Non-locality



Alain Aspect

The question returned to the fore in the 1980's as technology overtook the original EPR thought experiment. In 1969 John Bell's Theorem had shown mathematically how EPR could be tested, and in 1982, (**Alain Aspect, 1982**). **Aspect's** experiment demonstrated the physical reality of EPR. The Aspect experiment did not invalidate Copenhagen, but it transferred the whole debate from the hypothetical to the scientifically tested level. It presented physics with a stark choice. Either one could accept the Copenhagen Interpretation in which the locality of interactions was preserved, but the components of matter and energy were unreal, or one could have a world that was real, but in part governed by non-local influences, Einstein's dreaded 'spooky action at a distance'.

In fact, recent decades have seen a growing challenge to the orthodoxy of Copenhagen. This leaves us without a generally agreed interpretation of quantum theory. The Copenhagen Interpretation preserved us from non-locality, but the concept of the quanta as mathematical abstractions that suddenly produced physical particles may be viewed as troubling. It seems to propose a sort of dualism, comparable to the relationship between spirit stuff and physical stuff. How could mental constructs, such as mathematical formula, become physical without having had some physical reality in the first place.

Other interpretations have come more to the fore in recent decades. Decoherence has become particularly popular as a substitute for the traditional 'measurement' always referred to in the Copenhagen version. In decoherence, the collapse of the wave function happens of its own accord, as a result of the wave becoming entangled with the rest of the environment. In some recent versions, it is suggested that there is no collapse, the information in the wave simply gets lost in the larger scale environment. In some quarters, this is argued to provide a connection to the 'Many Worlds' interpretation. In this, there is also no collapse, but a branching of reality into separate universes. So in the Schrodinger cat paradox, for instance, the universe splits into one universe with a live cat and one with a dead cat.

Quantum Gravity and the Search for Reality

The success of quantum theory (see examples in Fig. 5), which describes matter and energy, and of relativity, which describes space and time, have both been marred by the incompatibility of these two key theories. Relativity describes gravity as the smooth, continuous curvature of space under the influence of massive objects, while quantum theory is based on the idea of energy and matter coming in discrete discontinuous units. Mathematically these contrasting features lead to infinities, indicating that something is wrong. The attempt to overcome these problems has led to new theories, such as string theory, and loop quantum gravity (Smolin, 2005).

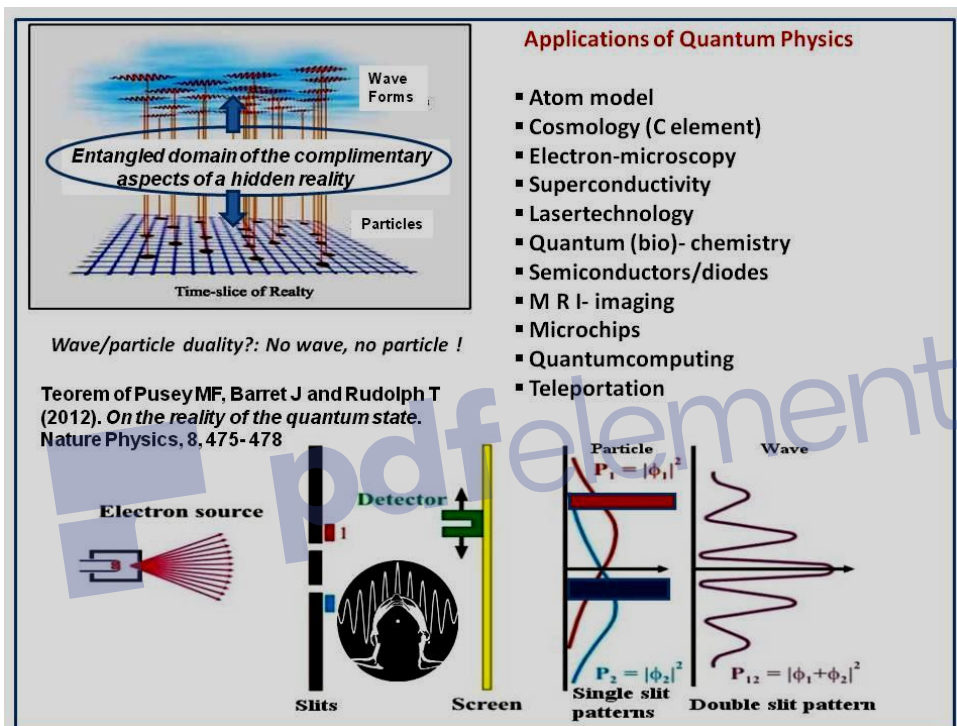


Fig. 5: Wave/ particle duality in Quantum physics should be rather seen as a state in which a particle and wave forms are complementary features in an hidden reality (up left), and Pusey et al showed that the wave form is a physical reality (middle left). Principles of Quantum physics are presently used in a large variety of technologies (up right). The conscious observer or a detector that observes the double slit system and provides interpretable data collapses the wave function to a single slit pattern.

String theory proposes that the fundamental particles are not point particles, as had been assumed, but one-dimensional strings extending into higher dimensions, beyond the normal four dimensions. The extra dimensions are usually deemed to have been rolled up very small in the Big Bang, which accounts for them never having been detected. The manner in which the strings vibrate determines the nature of the particle involved. The analogy is that of the strings of a violin, where the vibration of the string determines the nature of the note. While

this may appear both speculative and improbable, it has the advantage of being described by mathematics that would allow quantum theory and relativity to be compatible (see **String Theory; M-theory in Wikipedia**).

The two main criticisms of string theory are that it produces 10^{500} possible universes, and that it operates against the background of a fixed spacetime, a concept that relativity showed to be invalid. An alternative approach is provided by loop quantum gravity (LQG). This approaches the problem from the direction of relativity and concepts of spacetime, in contrast to string theory, which approaches from the the point of view of particles and quantum theory (**Smolin, 2004**).

LQG proposes that spacetime is quantized or in discrete units. Spacetime is suggested to be created out of a network, or a lattice, or a series of loops. This theory has drawn on the earlier spin network theory developed by Roger **Penrose (1994, 2004)**, and moves towards viewing particles and spacetime as dual aspects of the same thing.

Problems and Opportunities in Quantum Theory

We have emphasized three problematic aspects of the theory, a causality in the randomness of the wave function collapse, a causality in the non-local influences demonstrated by EPR type experiments, and the resulting lack of agreement as to the underlying reality of the physical universe. At the quantum level, we find properties of mass, charge and spin that are given properties of the universe lacking cause or explanation. If we ask, what is the charge on the electron, what is it, not what does it do, the answer will be a resounding silence. The quanta and related spacetime appear to be the only level of the physical universe where it might be possible for science to insert consciousness as an additional fundamental property, (see for reviews **Vannini and Di Corpo, 2008, Hu and Wu, 2010, and Tarlaci, 2010, Meijer and Korf, 2013, Pereira, 2003 Atmanspacher, 2011**).

Timescales for Neural Processes and Consciousness

In looking at the possible physical underpinnings of neuroscience, Georgiev contrasts what is for consciousness studies the still dominant Newtonian orthodoxy of deterministic causes and effects, with quantum physics, in which there is a multitude of potential outcomes, rather than a single determined outcome. **Georgiev, 2003** discusses epiphenomenalism, the theory that consciousness is a by-product of brain processing having only an illusion of causal influence. He points out the evolutionary argument against this view, to the effect that evolution would not select for something that conveyed no selective advantage. In general, he sees the idea that we have no freedom or moral responsibility as counterintuitive. Such a counterintuitive result is seen as the inevitable consequence of explanations based on deterministic classical physics.

Quantum mechanics does, however, provide a non-deterministic alternative, in which consciousness underlies the neural processes of making choices and thus effecting future possibilities. The author goes on to discuss the vexed question of the possibility of quantum coherence in the brain. Mainstream consciousness studies has managed to fabricate an orthodoxy, to the effect that quantum coherence cannot occur in organic matter. A paper by the physicist, Max Tegmark, is often quoted in this respect. Tegmark asserted what was already an established position, to the effect that quantum coherence in the brain would be too short lived to have a functional role in neural processing(**Tegmark, 2000**).



Max Tegmark

Tegmark's paper was aimed at refuting Hameroff's Orch OR theory, (**Hameroff and Penrose, 2011**) which required quantum coherence to be sustained for 25 ms. Thus Tegmark did not show that coherence over shorter timescales could not support consciousness, because he was directing his argument at the longer timescales of Hameroff's theory. Georgiev here queries whether there is any evidence that consciousness has to arise over a milliseconds timescale. If consciousness could operate over a picosecond or shorter timescale then Tegmark's calculations do not present any problem for quantum consciousness. It is pointed out that all neuroscience has been able to show to date is that consciousness does not operate on a scale slower than milliseconds.

Tests show that there is a minimum timescale of about 30 ms needed for a subject to distinguish two sensory inputs as being separate. This means that consciousness cannot be slower than 30 ms. However, patients with time agnosia, who have subjective experience of the passage of time, confirm that it is physically possible to have consecutive conscious steps that are experienced as simultaneous. From this it is argued that the real units of consciousness could be at the picoseconds level, although such units cannot be discerned by the conscious subject.

It is argued here that the upper possible bound of the timescale of consciousness need not be its actual scale. As an analogy, Georgiev takes the example of the operation of a personal computer. The computer screen is on a millisecond timescale with the screen refreshing perhaps every 10 ms. But this is not indicative of the performance of the processor, which may

operate on a picoseconds timescale. All that the refresh rate of the monitor can tell us that the processor does not operate on a slower than 10 ms timescale. In the brain, the millisecond timescale applies to the brain's communications with sensory organs and muscles, but this may not say much about its internal processing.

The author goes on to argue that if consciousness arises at the quantum level some of the conventional arguments of mainstream consciousness theory fail. He contrasts classical and quantum information. Classical information can be copied and stored. A DVD encoded on a string of 0's and 1's, which can be read by an external observer, is an example of classical information. With the qbits of quantum information, it is impossible to read them because any interaction with them would alter them. All that can be done is to swap or move the information without deleting it. This inability for third parties to observe quantum information is similar to our inability to observe first person consciousness, while in contrast such inability is alien to classical information systems.

The author argues that it is impossible to copy minds that are based on quantum states because of the no-cloning theorem, which demonstrates that attempts to copy quanta result in the quanta being corrupted. In mainstream consciousness studies, philosophers and others have sought to create wonderment by arguing that it is possible to copy minds, and this appears to be true in principle, if consciousness is based on classical physics. However, if conscious arises from quantum states this becomes impossible. The possibility of copying a mind has also been used as a somewhat convoluted argument against the existence of the self,

Table 1: The History of Quantum Physics and Quantum Brain Theory

1805: Young: Double- Slit experiment	1925: Schroedinger: Wave equation for Electromagnetic particles
1860: Maxwell: Electromagnetism Laws	1925: Heisenberg: Uncertainty principle in Quantum physics
1870: Bolzman: Gas laws/Movement of particles	1925: Uhlenblick/Goudsmit: Electron spin phenomenon
1900: Planck: Quantum aspects of Energy	1926: Born: Statistic description of wave/particle duality
1905: Einstein: Special Relativity Theory	1927: Bohr: Measurement in QM Copenhagen interpretation
1908: Minkowski: 4-Dimensional Space Time	1927: Planck/Heisenberg : Zero Point Energy Field
1915: Einstein: General Relativity Theorie	1928: Dirac: Quantum-Electrodynamics/Quantum field theory
1913: Bohr: Structure of the Atom	1928: Artur Eddington : Q M determinism of brain function
1919: Kaluaza: Fifth dimension Gen. relativity /Electromagn.	1930: Fritz London/Edmond Bayer: Consciousness creates reality
1923: De Broglie: Wave/Particle duality, hidden variables	1932: John von Neuman: Relation between Qm and consciousness
1924: Alfred Lotka: Quantum brain in mind/brain relations	1934: J B S Haldane: Quantum wave character and life
1925: Pauli: Bosons and Fermions and Elementary particles	1934: Niels Bohr: The Mind and QM are connected

- 1940: Wheeler/Feynman: Absorber theorie
- 1942: Casimir: Experimental proof of Zero Point Energy
- 1948: Gabor: Holography
- 1951: Bohm: Hidden variables, Pilot waves and Implicate order
- 1955: Pauli/Jung: Synchronicity
- 1957: Everett: Many-worlds hypothesis
- 1961: Wigner: Consciousness collapses quantum state
- 1964: Bell: Quantum entanglement is non-local
- 1967: Wheeler: Quantum flavour dynamics of elem. particles
- 1966: John Eccles/F. Beck: Quantum effects in synaptic transmission
- 1967: L M Riccardi/H Umezawa: Quantum Neurophysics
- 1970: Prigogine: Nonequilibrium dynamics, unilateral time
- 1971: Pribham: The Holographic brain
- 1972: Clauser: Experimental proof of quantum entanglement
- 1974: Schwartz: Superstring theory
- 1974: Ewan Walker: Quantum tunnelling in brain processes
- 1976: Sperry: the Self in Mind/Brain concepts
- 1978: Stuart/Takahashi/Umezawa: Quantum brain dynamics
- 1982: Aspect: Experimental proof quantum correlated particles
- 1980: John Cramer: Transactional interpretation of quantum physics
- 1986: Barrow/Tipler: Anthropic cosmological principle
- 1986: Herbert Frohlich: Bose-Einstein condensates in biology
- 1986: Penrose; Quantum gravity induced reduction of wave function
- 1988: Steven Hawkins/: Multiverse concepts
- 1989: Ian Marshall/Zohar: Consciousness and Bose-Einstein condensates
- 1989: Puthoff: Particle inertia and Zero Point Energy
- 1989: Michael Lockwood: Mind, Brain and Quantum
- 1991: Zurek: Decoherence of quantum function by environment
- 1992: Schlempp: The quantum principle of MRI in brain scanning
- 1992: Smolin: Loop quantum gravity and Black holes/ multiverse
- 1992: Hamerhoff/Penrose: Microtubuli/Consciousness theory
- 1992: Pylkkänen: Mind /matter interaction and active information
- 1993: Goswami: the Self-aware Universe
- 1993: Herbert: Elemental mind
- 1994: Henry Stapp: Ca-ions, neuron coherence and free will
- 1995: Edward Witten: M (string) theory
- 1995: Mari Jibu/ K.Yasue: Ordered water and superradiance
- 1995: Gordon Globus: Quantum Cognition
- 1996: Price: Backward causation
- 1996: Chalmers: The hard problem/Panpsychism
- 1998: Scott Hagan: Microtubuli biophoton emission
- 2000: Wheeler: The Participatory Universe:
- 2001: Wolf: Mind into Matter and the Soul
- 2000: Vitiello: Dissipative Quantum model of the Brain
- 2002: Huping Wu/ m Wu: Spin mediated consciousness
- 2003: Zeilinger: Information and quantum teleportation
- 2004: Laszlo: The informed universe, non-local Akashi field
- 2003: Primas: Tensed time in Matter and Mind
- 2005: Yasue/Umezawa: Bioplasm in Quantum brain dynamics
- 2006: Scaruffi: Consciousness in elementary particles
- 2006: Deutch: Fabric of reality, quantum computing and multiverse
- 2012: King: Cosmology of consciousness
- 2013: Hameroff and Penrose: Modified the Orch Or brain model

because in this argument copying the mind would create the paradox of two identical selves. However if copying of minds is impossible this paradox will not arise.

QM approaches in neurobiology: the state of art

The following section, taken from **Meijer and Korf, 2013**, discusses the idea that the physical quantum concepts do physically apply to the mind: the mental domain is considered as an aspect of wave information. A special position takes the feature of *superposition*: quantum particles can be present in multiple spatial locations or states and be described by one or more pure state wave functions simultaneously of which a single state can finally be selected. **Penrose, (1989)** suggested that the underlying space /time geometry in fact bifurcates during the superposition process and wave collapse occurs in a non-computable manner. It was suggested the conditions found in the microtubule could allow coherent quantum particles to form a unity that can be described by a single wave function. These concepts are considered the "hard quantum theories", as opposed to the "soft" or formal theories of the previous section. QM adherents refer often to Wolfgang Pauli (**Pauli, 1994**), the eminent quantum scientist who suggested that the mental and the material domain are governed by common ordering principles, and should be understood as "complementary aspects of the same reality" (see **Atmanspacher and Primas, 1977; Primas 2003**). The "hard" mental QM theories apply either to specific brain structures/molecules (this section) or to quantum fields and dimensions or both.

Vannini and Di Corpo, 2008, Hu and Wu, 2010, and Tarlaci, 2010 listed and attempted to categorize the various published quantum brain models, without a detailed treatment of the individual models. Vannini and Di Corpo distinguish models based on consciousness creating reality, models based on probability aspects of QM and models based on already established QM order principles. Hu and Wu differentiate in models based on QM elements of entanglement and coherence and models on the relation of QM with consciousness that can include materialistic modes (consciousness emerges from material brain), dualistic mind/matter models and panpsychistic modes. The first two papers emphasize the potential testability of the various models. More detailed reviews can be found in **Pereira, 2003** and **Tuszynsky and Woolf, 2010**, the latter as an introductory chapter of the instructive book: "Emerging Physics of Consciousness", while an excellent and critical overview of the field is provided by **Atmanspacher, 2011**.

A number of, more or less specific, scientific journals are currently, or were, devoted to this subject: NeuroQuantology, Quantum Biosystems, Mind and Matter, and AntiMatters. Stanford Encyclopedia of Philosophy (see quantum mechanics and quantum theory) *also* provides an excellent reference. Additional publications on the topic can be found in: J Consciousness Exploration& Research, J New Dualism, Dualism Review, Journal of

Cosmology, J Scientific Exploration, Biosystems, , Cognitive Neurodynamics, Science and Consciousness Review, Journal of Mathematical Psychology, Chaos, Solitons and Fractals, Open Systems and Information Dynamics, International Journal of Quantum Chemistry, The Noetic Journal, Neuroscience and Biobehavioral Reviews, Experimental Neurology, J. of Mind and Behavior Physics of Life Reviews, Syntropy Journal, Biological Cybernetics and Kybernetik. The Journal of Consciousness Studies is an excellent source for various models for consciousness (see for example Fig. 6).

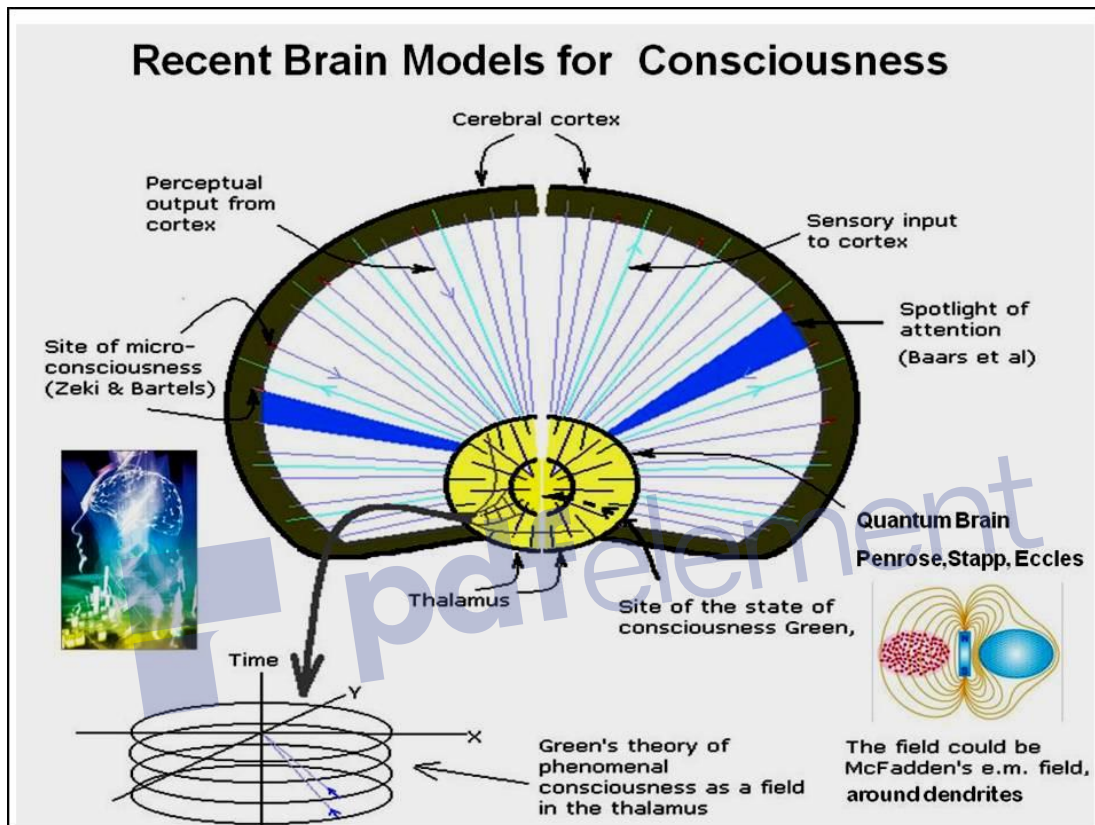


Fig. 6: Some models that have been proposed for human consciousness

Before we delve into the physical aspects of the quantum brain, a number of common misunderstandings on QM modeling should be dealt with:

- There is no *single* theory on quantum mechanical aspects of brain function. In fact a spectrum of more or less independent models have been proposed, that all have their intrinsic potential and problems (see **table 2**, for references see the above mentioned reviews and **Meijer, 2012, Meijer and Korf, 2013**).
- In spite of the introduction, already in the first part of the 20th century and the spectacular successes of the theory ever since, some still see quantum physics as a sort of esoteric part of science. However it rather represents a revolutionary refinement of classical

physics, for example taking into account that the theory was required in order to build an adequate atomic model and more recently to explain experimentally demonstrated teleportation of particles (see **Zeilinger, 2000**) as well as principles of downward causation (**Wheeler, 2002**) and time symmetry (see **Aharonov et al, 2010**). It is also the basis for laser, semi- and super- conductance, and microchip technology as well as MRI brain scanning (**Marcer and Schempp, 1997**). It should also be kept in mind that classical physics can be fully derived from quantum physics, not the other way around.

– Quantum physics is, by some rejected, since so many interpretations of the theory are at stake (Copenhagen, Many worlds, Implicate order, Interactional theory, Micro- macro- scale definition, Environmental de-coherence, Relational quantum mechanics etc.). Yet a number of common elements such as the true particle/wave aspect, instead of only a probability function, (**Pusey et al., 2012**), superposition, entanglement/non-locality and coherence/de-coherence phenomena are experimentally established and remain very usable in practice, although the related semantics should be carefully defined.

– It is often stated that quantum wave information coherence cannot be maintained long enough in the brain due to interaction with the macro-environment of the brain components. Yet, on this point major differences in decoherence-time calculations exist, as based on various models and their intrinsic assumptions (see **Hagan et al., 2002 and Tegmark, 2000, Lloyd, 2011**). A central point here is that sub-compartments could be present at the molecular or sub-molecular level, that by their special arrangements are quantum noise protected or coherence stabilized. Examples are internal parts of channel proteins (**Bernroider, 2004**), and stabilization by clustered (gel/sol) arrangements of cytoplasmic water clusters (see **Hameroff and Penrose, 1996, Penrose and Hameroff, 2011**). The latter authors proposed a hierarchic model encompassing nerve cell depolarization, gel/sol transitions of resulting in disconnection of microtubuli, shape/volume pulsation of dendrites including reorganization of synaptic contacts and finally sol/gel transition stabilizing a new state. Through coherence and macroscopic entanglement, life time of wave information can be much longer than in the classical phase, as a consequence of coherence/decoherence dynamic equilibria, allowing nonlocal remote interaction in large numbers of entangled neurons. Such gel/sol oscillations could even be a primary to excitation/depolarization triggered by normal sensory stimuli and are supposed to interact with zero-point vacuum dipole vibrations (the bi-vacuum matrix model of **Kaivairanen, 2006**).

– It should be realized that decoherence, does not, per definition imply *destruction* of information since, firstly, it is not compatible with the quantum principles of non-cloning and non-deletion, secondly a cyclic process of decoherence and re-coherence processes cannot be excluded (see **Hartmann, et al 2006; Li and Paraoano (2009); Atmanspacher, 2011**) while thirdly, even if such decoherence does occur, it may result in mixture of possibilities that may be accommodated by the collection of perceivable worlds in the brain (**Stapp, 2012**). It has been proposed by **Vattay and Kauffman, 2012**, that a decoherent state can be converted back

to a coherent state by the input of adequate phase and amplitude information. The resulting coherent states can last long enough in warm biological systems in order to, for example, enable coherent search processes for antenna-mediated transport of photon energy in photosynthesis. The author postulates that similar “poised realm” or micro-domains, on the edge of chaos, could also be instrumental in the human brain as sites where a dynamic interplay of decoherence and re-coherence takes place.

– It is often assumed that QM is only valid for a description of nature on the micro-scale (elementary particles etc.). Yet convincing evidence was more recently presented that quantum physics can be applied to macromolecules (**Zeilinger, 2000**), and to the surprise of many, even can occur in warm and wet biological systems (photosynthesis: **Engel et al., 2010**) and brains of birds in relation to magnetic sensing and navigation (for references see **Arndt et al., 2009, Lloyd, 2011**), see Fig. 7.

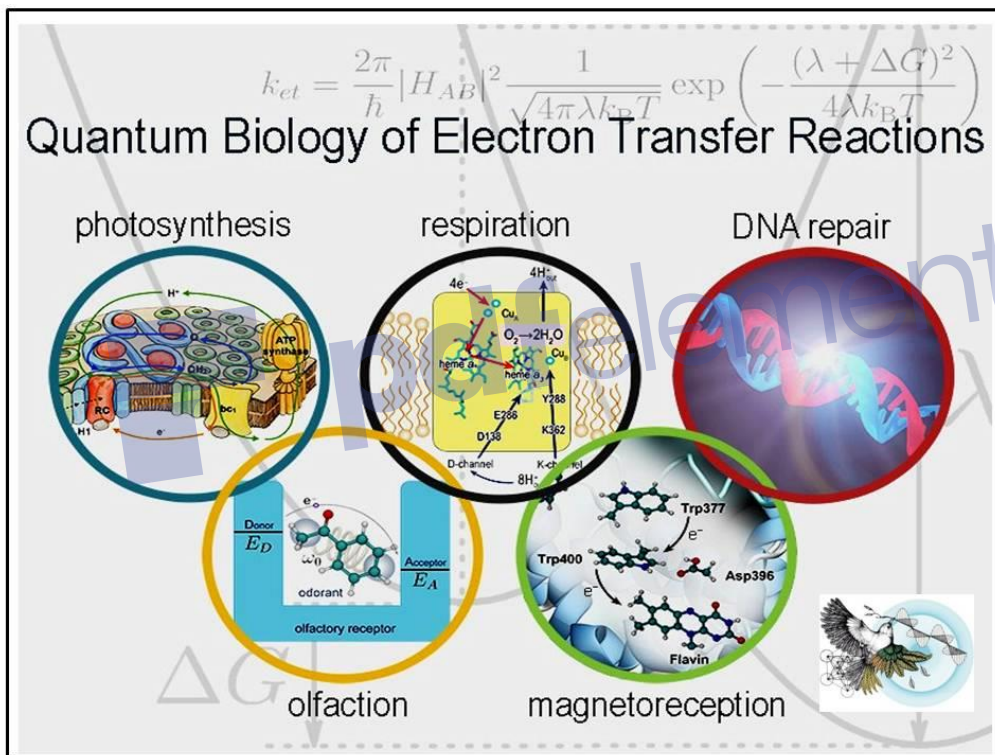


Fig 7: Quantum phenomena that have been detected at the life macro-scale

– Lloyd concluded: “Quantum coherence plays a strong role in photosynthetic energy transport, and may also play a role in the avian compass and sense of smell. In retrospect, it should come as no surprise that quantum coherence enters into biology. Biological processes are based on chemistry, and chemistry is based on quantum mechanics. If an organism can attain an advantage in reproduction, however slight, by putting quantum coherence to use, then over time natural selection has a chance to engineer the necessary biochemical mechanisms to exploit that coherence. Different types of quantum processes that operate at the

same time scale can interact strongly either to assist or to impede one another. In photosynthetic energy transfer, the convergence of quantum time scales gives rise to more efficient and robust transport. Evolved biological systems exhibit the quantum Goldilocks effect: natural selection pushes together time scales to allow quantum processes to help each other out”.

- A spectrum of atoms/molecules has been suggested to operate in a quantum manner: Ca²⁺- and K⁺- ions, H₂O, enzymes, membrane receptor and channel proteins, membrane lipids, neurotransmitter molecules, in addition to macromolecular structures such as DNA/RNA, gap junctions, pre-synaptic vesicles, microtubules and micro-filaments (**Tuszinsky and Woolf, 2010, Meijer, 2014**)

- Since our integral universe can be described by the current laws of QM and relativity, it does not seem warranted to place the human brain outside nature: some see even cosmic architecture mirrored in our complex brain (**Kak, 2009; Amoroso, 2003**)

- The discussion around higher brain functions is frequently obscured by modalities of promissory materialism: “at present we do not understand consciousness but within 20 years the problem will be resolved !” Not only is such an extrapolation scientifically unwarranted but certainly cannot be falsified. Even more damaging is the assumption that one will find the solution by further using current technology, instead of postulating new (for example quantum) models and innovative experimental approaches.

- Some QM models are based on the interaction of brain components with experimentally detected quantum fields (**Yasue and Jibu 1995, Vitiello, 1995, Pessa and Vitiello, 2003**). The central aspects of realistic quantum field theory hold that the essence of material reality is a set of fields. These fields obey the principles of special relativity and quantum theory and the intensity of a field at a point gives the probability for finding its associated quanta as the fundamental particles that are observed by experimentalists. These fields may holographically project into each other, implying interactions/interpenetrations of their associated quantum waves. Vitiello proposes a virtual shadow brain working in a time-reversed mode that stabilizes coherence and neural memory structures.

- It could be worthwhile to project neo-darwinism and its biological evolution theories against the canvas of potential QM mechanisms, in the sense that parallel quantum superpositions and backward causation mechanisms can provide explanations and/or alternatives for evolution jumps and so-called emergent phenomena (see **Davies, 2004; Murphy, 2011; Auletta et al., 2008 Davies and Gregersen, 2010; Ellis, 2005; Vattay et al 2012**). Recently, models were proposed for the transfer of information in biological evolution on the basis of quantum formalisms (**Bianconi and Rahmede, 2012, Djordjevic, 2012**).

- On the basis of QM concepts one should be prepared to envision uncommon and even utterly strange manifestations of quantum entanglement: certain transpersonal human experiences (**Kak, 2009; Radin and Nelson 2006; Di Biase, 2009 a, b, Jahn and Dunne, 2007**) should *not* be seen as potentially be *explained* by QM, but rather *required* (**Radin and Nelson,**

2006) by the concept that our world is part of a quantum universe (Vedral, 2010; Lloyd, 2006; Barrow and Tipler, 1986).

QM and Higher Brain Functions

Here we discuss current QM theories as possible theories bridging the classical neuronal and mental concepts. QM theories does indeed apply to the same brain physiological phenomena, but introduce also typical features such as particle/wave duality, entanglement and non-locality, as well as wave interference and superposition. In addition processes such as quantum coherence and resonance of wave interactions are at stake.

Quantum Brain models proposed

<i>Author</i>	<i>Year</i>	<i>Author</i>	<i>Year</i>
Amaroso	2009	Lockwood	1989
Baaquie and Martine	2005	Marshall	1989
Beck and Eccles	2000	Mender	2007
Bernroider	2000	Hameroff and Penrose	2012
Bohm	1980	Pereira	2003
Culbertson	1963	Pitkänen	1990
Di Biase	2009	Pribram	1971
Flanagan	2003	Romijn	2000
Fröhlich	1968	Santinover	2002
Goswami	1993	Sarfatti	2011
Georgiev	2003	Stapp	1993
Herbert	1987	Talbot	1991
Hu and Wu	2005	Umezawa and Ricciardi	1967
Järvilehto	2004	Vannini and DiCorpo	2009
Josephson	1991	Vitiello	1995
Kaivarainen	2006	Walker	1970
King	1989	Wolf	1995
		Yasue	1995

Table 2: Quantum Brain Models proposed from 1960 and further (see for references Meijer, 2012; Meijer and Korf, 2013; Meijer, 2014; Vannini and Di Corpo, 2008; Hu and Wu, 2010, and Tarlaci, 2010).

It is not our purpose to assess the various QM theories in detail, rather we intend to discuss some of their major implications regarding the concept of a “quantum brain”. The key position of proteins in the quantum-mediated initiation and execution of mental activities was already emphasized. Several QM theories are based on specific properties of proteins, as for instance micro-tubular proteins, (Penrose, 1989; Hameroff, 2007), proteins involved in facilitating

synaptic transmission (e.g. **Beck and Eccles 1992; Beck 2001**), including Ca^{2+} - channels, see **Stapp, 2009**), as well as specific channel proteins, instrumental in the initiation and propagation of action potentials (K^{+} - channels), **Bernroider and Roy, 2004**), see **Fig 8**.

QM theories also extends the mind to different spaces and time dimensions and some consider the individual mind (partly) as an expression of a universal mind through holonomic communication with quantum fields. In the latter approach, the human brain is conceived as an interfacing organ that not only produces mind and consciousness but also receives information necessary for full deployment of these mental phenomena (see next session). The central question here is whether neuronal cells are the sole units for information processing in the brain rather than sub-cellular organelles or molecules (**Schwarz et al., 2004**).

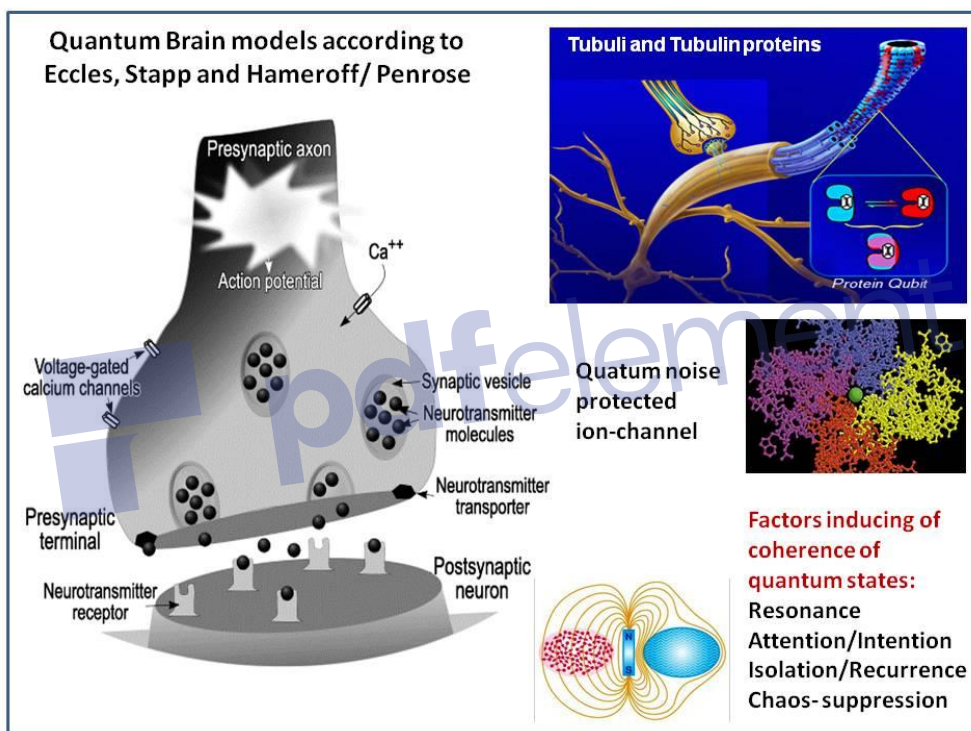


Fig 8. Some aspects of quantum brain models: Synaptic transmission by vesicular exocytosis of neurotransmitter molecules, Ca^{2+} -influx via Ca^{2+} - channel protein in the neuronal membrane facilitates fusion of synaptic vesicles in the presynaptic terminal. The fusion of sufficient vesicles leads to transmitter release and depolarization of the postsynaptic membrane, this fusion process bears a quantum probability character.

A major debate about these theories concerns the possibility of coherent quantum states in the "warm" and wet internal milieu of the brain. (see e.g. **Atmanspacher, 2011**). The defenders of the quantum brain models have argued that *in vivo* molecular configurations exist that enable the modulation of quantum states through efficient protection and shielding of the wave interaction compartments in the cells (**Hagan et al., 2002**).

The particular local collapse of the wave function, in this manner, produces new information. As originally proposed by Eccles, this is realized by membrane protein induced fluxes of Ca^{2+} or K^{+} ions, that than increase the probability of fusion of neurotransmitter-filled vesicles in the synapses, leading to the firing of the particular neuron or even groups of neurons. The central hypothesis here is that synaptic transmission represents a typical (quantum) probability state in which the total number of vesicles available for exocytosis is critical for an all or none response of neuronal firing (**Beck and Eccles, 1992; Beck, 2001**). Coherent neuronal perturbations and especially their entangled state are supposed to provide non-local "binding" of sensory and cognitive brain centers, and may also enable perception of qualia and the unitary sense of "conscious self" (**Hameroff, 2007**). As the "mesoscopic" scale of brain activity where the "binding" process is expected to occur is in the vicinity of the quantum domain, the binding principle is likely to be a quantum non-local effect, probably the only known physical mechanism able of performing such a task. One possibility is the formation of a quantum photonic field (**Flanagan, 2006**); another possibility is the formation of coherent states on the level of trans-membrane ion fluxes such as that of Ca^{2+} as suggested by **Pereira, 2003, 2007**, see section 8, **Fig. 8**).

Hameroff and Penrose (2011, see later) argue against mechanisms of all-or-none firing of axonal potentials as suggested by Beck and Eccles, since such binary states do not include non-linear and not computable characteristics of consciousness. They rather prefer the model of **Davia, 2010** (see the chapter in the book edited by **Tuszinski and Woolf, 2010**), proposing that consciousness is related to traveling waves in the brain as a uniting life principle on multiple scales. The latter is based on energy dissipation, enzyme catalysis, protein folding that maintains energy balance in an excitable system such as the brain, conditions that are also compatible with the isoenergetic brain model treated in **Meijer and Korf, 2013**. Non-linearity in brain processes is modeled using the well-known Schrödinger equation, adjusted with a non-linear term, as proposed earlier by **Walker** (see **Behera, 2010** in the same book), by which robustness of a classical approach is combined with the more flexible elements of quantum theory.

The originators of this hypothesis (**Penrose, 1989; Hameroff, 2007**) have discussed that microtubule, in principle, can maintain quantum states (i.e. superposition) lasting at least 10^{-6} seconds, long enough to be instrumental in the transfer of quantum wave information. Such lasting quantum states are possible because of the shielding of hydrophobic pockets in the particular proteins, as well as the formation of coherent clusters of these molecules that thereby share a common quantum wave function (so called Bose-Einstein Condensates). There is indirect evidence that microtubules may be relevant for neurocognition: increased synthesis in relation to postnatal development with regard to synaptogenesis and visual learning and as counterpart aging deficits in memory as well as interactions with general anesthetics (**Penrose**

and Hameroff, 2011, 2012; Tuszynski and Woolf, 2010; Kalvairainen, 2005). Yet such correlative studies should not only be further substantiated with experiments that show quantum states in isolated tubules, as reported by (Bandyopadhyay, 2011), but rather and most importantly, directly demonstrate tubular involvement in higher brain functions in situ. More recently in 2013 Bandyopadhyay's group demonstrated that in microtubules the energy level of up to 40,000 individual tubulin proteins and the energy level of the microtubule are the same. The water core and the individual tubulin proteins are suggested to control the properties of the microtubule by means of delocalised electromagnetic oscillations. The properties of the microtubule might be taken to suggest that the system can support a macroscopic quantum state. The authors say that prior to this 2013 paper the properties of tubulin and microtubules were not extensively studied using the up-to-date technologies mentioned here. Theories that apply to metals, insulators and semi-conductors are not relevant to microtubules.

In conclusion: tubular and synaptic channel proteins exhibit conformational transitions within 10^{-9} seconds that may last for 10^{-6} seconds or even longer, (Beck and Eccles 1992; Beck 2001; Bernroider and Roy, 2004, Kaivairainen, 2005). These perturbations may last long enough to be finally detected as miniature neuronal potentials (Hamill et al., 1981, Hagan et al., 2002). The particular mechanisms also imply a manifestation of non-local quantum effects due to distant coherence, a phenomenon that was even recorded in laser stimulated neuronal cell cultures in which classical physical explanations were excluded (Pizzi et al., 2004).

The coherence of such quantum states among brain proteins has been suggested to lead to *material* changes in brain physiology through orchestrated collapse of quantum coherent clusters of tubulin proteins, triggered by quantum gravity expressed at the spin (Planck scale) level. On the basis of a recent theory on the nature of gravity (Verlinde, 2011), postulating that gravity is not a force but rather an entropic compensation for the movement of mass/information, it was speculated that consciousness may arise from a gravity-mediated reaction on the entropic displacement of information as it occurs in high density in the human brain (Meijer, 2012).

Anyhow, there should be a mechanism to integrate signal processing within a single neuron with other, even distant, neurons and consequently non-local effects due to quantum entanglement should play a role also in this case. These quantum processes may explain phenomena such as qualia, meaning, sensation of unity, intentionality as well as conflict solving, reliability in the sense of correspondence with the outer world and the sense of self. The latter is related to the feeling of causal power that could result from a quantum/classical interface in which classical synaptic processes create a quantum coherent state that enables quantum computation that exert a back-influence on the original synaptic process (Pereira, 2003, 2007). The existence of nonlocality in brain function, being a basic property of the

universe strongly argues for an underlying deep reality out of space/time as originally proposed by **Bohm (1990)** in the form of an implicate order. Bohm claimed that these mechanisms also play a role in different forms of transpersonal and extrasensory perception by wave resonance with an universal quantum field (**Kak, 2009, Jahn and Dunne, 2007, Kafatos and Draganescu, 2000, Kafatos, 2009**).

The main issue of the present essay is that wave information provides a potential coupling to mental processes. For instance, wave information could be transmitted from and into the brain by wave resonance and may locally collapse to matter entities through conscious observation, including sufficient individual attention and intention (**Stapp, 2009**). **Stapp (2012)** argued recently that this does not represent an interference effect between superposed states, as assumed by **Hameroff and Penrose (1996)**, but that through environmental de-coherence, superpositions will be converted to multiple mixtures of information. Since our brain contains a large collection of perceivable worlds, it is able by supercausal free choice and subsequent common random choice to make a fit with one or more of the abovementioned mixed information modalities. The particular waves than spread out and rapid sequence repetitions (the so called Zeno effect) may sufficiently maintain coherence in parts of the brain. Of note, Stapp does not see free will as based on quantum probability aspects. He states: "In the original Copenhagen formulation this extra process is initiated by what is called "A free choice on the part of the experimenter." The phrase "free choice" emphasizes the fact that, while a definite particular choice is needed, this choice is not determined by any known law or rule: The purely physical aspects of the theory have, therefore a significant causal gap, which opens the door to a possible causal input from the mentally side of reality".

Quantum information may exert physical effects via a bottom-up flow of information starting at spin networks (**Penrose, 1994; Hu and Wu, 2010**), that can be passed on as wave forms of elementary particles/atoms, to be ultimately expressed at the level of neuronal molecules. **Meijer and Korf, 2013**, consider the latter flow of information more feasible than being directly transferred through vibratory interference at the molecular level. According to this integral quantum model, perturbations at the various spatiotemporal domains allow both time-symmetric forward and backward causation and therefore top-down influence of quantum fields).

The basic question is: how are quantum waves or quantum fields finally perceived by the human brain and how they influence or even induce phenomena as (self)consciousness? Organisms do indeed visually perceive photons that exhibit wave/particle duality; humans even sense less than ten photons, whereas insects may even detect a single photon (**Baylor et al., 1979; Menini et al., 1995**). Sensitive detection is possible with dedicated cellular structures as for instance in the mammalian retina that amplify the energy of a single photon by a cascade of processes, based on changes of protein conformations and cellular potential energy,

leading to the electrochemical stimulation of neurons projecting to the brain. Recently, photosensitive proteins have been coupled to ion-channel proteins with biotechnical techniques, so that the neural activity can be modified or inhibited *in vivo* by light introduced via optic microfibers (**Lima and Miesenböck, 2005; Boyden et al., 2005; Tsai et al., 2009**). These experimental approaches demonstrate that quantum effects may directly affect neural function, but it remains to be shown more definitely, that this also does occur directly inside the *human* brain as it was demonstrated in the brain of *birds* (see the reviews of **Arndt et al., 2009, Lloyd, 2011**).

Quantum information mechanisms were recently used to model human consciousness as well as the unconscious in relation to conscious perception (**Martin et al, 2013**) in which various modalities of non-locality were discussed. Of note, entanglement and non-locality may not only apply to spatial separation but also a temporal one (**Megidish et al, 2012**). It was proposed by Martin that archetypes can be stored as quantum systems and that consciousness may be controlled by quantum entanglement from *outside* space-time. Although this cannot be easily envisioned, **Nicolescu (1992, 2011)** made clear that the relation between different levels of reality have to be interpreted in the framework of Gödel's incompleteness theorems, and that it may be intrinsically impossible to construct a complete theory for describing the unity of all levels of reality. Interestingly, recently a 5-dimensional space-time brane model was proposed in order to adequately position consciousness and universal consciousness in the cosmos (**Carter, 2014a, 2014b**), an item that was discussed earlier by **Smythies, 2003** suggesting that consciousness may be in a brane rather than in the brain. **Atmanspacher (2003)** explained that mind/matter correlations may require new science, in the sense that the use of emergence and reductionistic schemes may not be adequate and should be replaced by possible symmetry breaking within a domain in which matter and mind are unseparated. He cites d'Espagnat postulating an independent "Ultimate Reality" that is neither mental nor material.

Another issue is whether, more or less, random quantum events can be orchestrated in such way that the information becomes meaningful for the brain. Thus the major challenge is to *directly* demonstrate that proteins such as in microtubules, K⁺-channels or synaptic vesicles and associated proteins become informative to the organism. It has been put forward that a combination of quantum mechanisms and non-linear (chaos) theory have to be considered in the amplification of subtle external information necessary for immediate action (**King, 2003, 2011**). Future information (feeling of future events) may be realized by time-reversed sensing of such an event on the basis of an attractor state. According to the "supercausal" model of consciousness of Chris King, the constant interaction between information coming from the past and information coming from the future leads to that quantum entities that are always confronted with bifurcations between past and future causes. This involves fractal structures and chaotic dynamics that enable free choices to be performed. Consequently consciousness

should be a property of all living structures in which each biological process is forced to choose between information coming from the past and information coming from the future (King, 2003). Such models (including that of Vannini and Di Corpo, 2008) attribute consciousness to principles of relativity, quantum physics, and fractal geometry and on the basis of established physical applications of these theory's, would, in principle, allow experimental testing to falsify them. It is of interest that top-down recurrent connections in higher order in the associative cortex was shown to be indispensable conscious perception (Boly et al., 2011).

In more general terms: processing and amplification of quanta/wave information in the brain may underlie the presumed higher brain or mental functions. If one assumes that such detection mechanisms does indeed operate in the brain, than the next question is whether the information to be processed is *exclusively* associated with quantum waves or quantum states or, alternatively, with the specific proteins that carry them. Apart from discussing the inherent mechanisms such as forward and backward causation, superposition and entanglement in the mental space, we shortly treat the idea that that individual mind may, at least partly, be an expression of universal consciousness as opposed to the concept the mind is merely an attribute of matter.

David Bohm: Wholeness and the Implicate Order



David Bohm en Louis de Broglie

David Bohm, 1980, 1990, took the view that quantum theory and relativity contradicted one another, and that this contradiction implied that there existed a more fundamental level in the physical universe. He claimed that both quantum theory and relativity pointed towards this deeper theory. This more fundamental level was supposed to represent an undivided wholeness and an implicate order, from which arose the explicate order of the universe as we actually experience it. The explicate order is seen as a particular case of the implicate order. (Fig. 9).

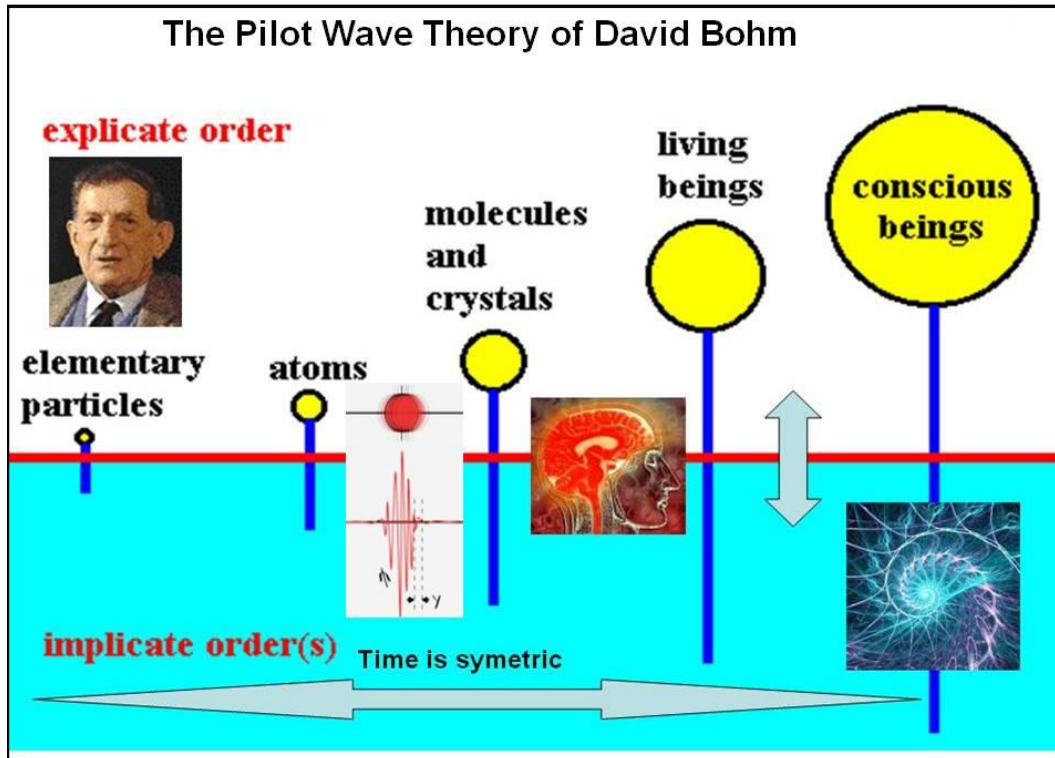


Fig. 9: The Implicate Order concept of David Bohm in which particles and their more complex forms in our classical world are steered by, so called, pilot waves that operate from a 4-dimensional hidden domain, in a mode of active information.

The implicate order applies both to matter and consciousness, and it can therefore explain the relationship between these two apparently different things. Mind and matter are here seen as related projections into our explicate order from the underlying reality of the implicate order. Bohm claims that when we look at the extension of matter and separation of its parts in space, we can see nothing in these concepts that helps us with understanding consciousness.

Bohm compares this problem to Descartes discussion of the difference between mind and matter. Descartes to some extent relied on God to resolve the gap. Bohm says that since Descartes time the idea of introducing God into the equation has been let drop, but he argues that as a result conventional modern thinking has no way left to it for bridging the gap between matter and consciousness. In Bohm's scheme there is an unbroken wholeness at the fundamental level of the universe, in which consciousness is not separated from matter.

Bohm's view of consciousness is closely connected to Karl **Pribram's**, 1991 holographic conception of the brain. Pribram sees sight and the other senses as lenses, without which the universe would appear as a hologram. Pribram thinks that information is recorded all over the brain, and that this information is enfolded into a whole, also in the manner of a hologram, although it is suggested that the physical function involved is more complicated than a

hologram. In Pribram's scheme, it is suggested that the different memories are connected by association and manipulated by logical thought. If the brain is also attending to sensory data, all of these facets are proposed to fuse together in an overall experience or unanalysable whole. This is suggested to be closer to the essence of consciousness than the mere excitation of neurons. In trying to arrive at a description of consciousness.

Bohm discusses the experience of listening to music. He thinks that the sense of movement and change that constitutes the experience of the music relies on notes both from the immediate past and the present being held in the brain at the same time. Bohm does not view the notes from the immediate past as memories but as active transformations of what came earlier. He proposes that a given moment can cover an extended duration, as opposed to the more conventional 'now' concept of something instantaneous. The moment is proposed to have extension in time and space, but the amount of this extension is not precisely defined. One moment gives rise to the next, with content that was implicate in the immediate past becoming explicate in the present. The sense of movement in music is the result of the intermingling of transformations.

Bohm likens these transformations to the emergence of consciousness from the implicate order. He thinks that in listening to music people are directly perceiving the implicate order. The order is thought to be active and to flow into emotional and physical responses. Bohm also discusses the problem of time, the concept of 'now' and the difficulty of distinguishing 'now' from the immediate past, which no longer exists. In classical physics this problem is overcome via the calculus, with its concept of 'the limit', which is effectively a zero change in time or space. This is successful for calculating the movement of material objects in classical physics, which comprises the explicate order. However, it is not applicable to quantum theory in which movement is not seen as continuous. In the implicate order intermingled elements are present together, and processes are the outcome of what is enfolded in the implicate order. In this structure, there is a flow between experience and logical thought that is considered by Bohm to hold out the possibility of a bridge between matter and consciousness.

Bohm also advances the idea of overall necessity driving short-term brain processes. Thus it is proposed that an ensemble of elements enfolded in the brain will constitute the next development of thought, and that these elements are bound by an overall necessity that brings them together, and also determines the next moment in consciousness. Bohm relates movement to the implicate order; for movement, we can also read change or flow or the coherence of our perception of a piece of music over a short period of time. Evidence for this is claimed to derive from studies of infants (**Piaget, 1956**), who have to learn about space and time, which are seen as part of the explicate order, but appear to have a hard-wired understanding of movement that is implicate. Bohm's view is that the movement and flow of the implicate order are hard-wired into human brains, in the same way that Chomsky asserts

that grammar is hard-wired into the human brain, but that by way of contrast, the classical space and time of the explicate order are something that has to be learnt by experience. -

Basil Hiley was the long-term associate of David Bohm, and is a continuing exponent of many of his ideas (**Bohm and Hiley, 1987, 1993**). Hiley argues that the Bohmian notion of active information introduced in relation to quantum phenomena can also be applied to classical signalling. This is suggested to have relevance to concept of meaning as opposed to mere information. Hiley queries whether the word 'information' that is widely used in science including neuroscience always carries the same meaning. Bohm and Hiley were interested in so-called active information that drives physical processes and leaves no choice as to whether they are implemented or not. This is distinct from a mere list of data or instructions or a way of viewing entropy. Active information has been used in a number of papers relative to the mind/matter relationship (**Hiley, 2001 and Hiley & Pylkkänen, 2005**)

The colloquial understanding of information is that it is data from which meaning can be extracted by an intelligent entity. Hiley regards it as a fundamental question as to whether information has objective significance devoid of the subjective involvement. Verbal communication is seen as a particular problem, where meaning is translated into sound waves and then back into meaning. Hiley relates this meaning to the agency of the speaker and the agency of the listener. He relates this inseparable link to Bohr's notion of the indivisibility of the quantum action, which cannot distinguish between the system under observation and the means of observation.

Bohm believed that a quantum potential could be extracted from Schrödinger's equation and that this quantum potential could act as an information potential. In transmitting a signal there is a trade off between the duration of the pulse and the frequency. There is an ambiguity in the signal that is similar to the uncertainty in quantum mechanics. The two concepts are said to employ different aspects of the same mathematical structure. Hiley refers to the two-slit experiment, where the potential is claimed to cover the whole experimental arrangement. The quantum information changes in relation to any change in the experimental arrangement, and this is related to information entering the brain and changing the arrangement of its parts.

Within the brain Bohm thought that meaning was in the process itself. Bohm proposed that there were two sides or two poles to the brain, the manifest and relatively stable material side and the subtle mind-like side. The manifest side is classical physics, while the subtle side is the quantum level that produces the classical level. Thus the mind cannot be separated from matter. The ambiguity or uncertainty of the quantum comes through in the ambiguity attached to meaning. The quantum is seen as a pool of information shared by entangled particles. When the potential or pool vanishes, the classical world emerges. Hiley also agrees that this system could operate in terms of quantum fields. The main weakness of this

description seems to be the lack of detail as to how the quantum mechanism would operate in the brain, and the lack of distinction between information which does not by itself imply consciousness and consciousness itself. The emergence of meaning could be thought to imply consciousness but this important point is not at all developed.

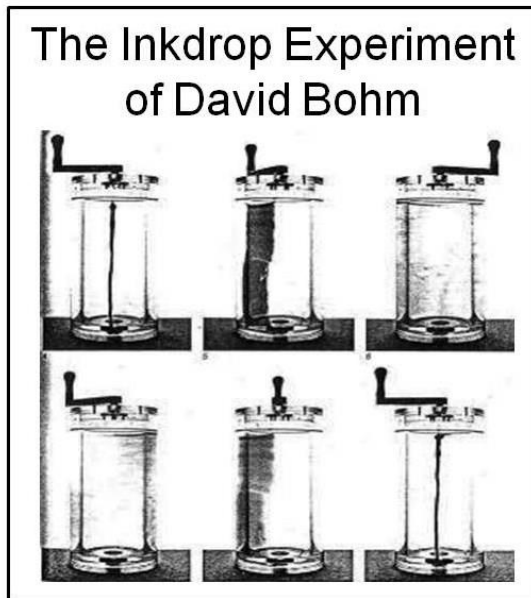


Fig. 10: *The reversible ink drop /cylinder-experiment, as an allegory for the unfolding of "implicate order" with hidden variables*

In the 1960s Bohm began to take a closer look at the notion of order. One day he saw a device on a television program that immediately fired his imagination. It consisted of two concentric glass cylinders, the space between them being filled with glycerin, a highly viscous fluid. If a droplet of ink is placed in the fluid and the outer cylinder is turned, the droplet is drawn out into a thread that eventually becomes so thin that it disappears from view; the ink particles are enfolded into the glycerin, (see Fig. 10) .

But if the cylinder is then turned in the opposite direction, the thread-form reappears and re-becomes a droplet; the droplet is unfolded again. Bohm realized that when the ink was diffused through the glycerin it was not in a state of 'disorder' but possessed a hidden, or non-manifest, order. In Bohm's view, all the separate objects, entities, structures, and events in the visible or explicate world around us are relatively autonomous, stable, and temporary 'subtotalities' derived from a deeper, implicate order of unbroken wholeness.

Bohm gives the analogy of a flowing stream: On this stream, one may see an ever-changing pattern of vortices, ripples, waves, splashes, etc., which evidently have no independent existence as such. Rather, they are abstracted from the flowing movement, arising and vanishing in the total process of the flow. Such transitory subsistence as may be possessed by

these abstracted forms implies only a relative independence or autonomy of behavior, rather than absolutely independent existence as ultimate substances.

Anthony Valentini



Valentini, 2002 consistently defends the pilot wave mechanism of David Bohm. Bohm, he says, had an interesting trajectory. There are really three Bohms. There's the very early Bohm who was interested in Niels Bohr's ideas about complementarity. Then there's the Bohm of the 1950s who worked on the pilot wave theory of hidden variables. Then in the 1960s he changed again. He met Krishnamurti and got very interested in Indian philosophy and started trying to tag some mystical ideas onto the pilot-wave theory. If you look at the yoga sutras of Patanjali you can see this idea that material objects are somehow illusions and projections from something deeper, that things emerge from this deeper level and disappear into this deeper level again. So, indeed, Bohm tried to adopt an interpretation of the wave as a manifestation of a deeper level, perhaps associated with consciousness.

Why does Valentini like the pilot-wave theory ?:

- It preserves a realist ontology wherein particles possess determinate values of space-time location and momentum.
- They continue to possess such values between various acts of observation/measurement, rather than acquiring them only in consequence of being measured with respect to this or that parameter.
- This allows for greater continuity with certain components of classical (prequantum) physics such as the conservation laws respecting matter-energy and angular momentum.
- The pilot-wave hypothesis produces results in perfect accordance with those obtained in standard QM by means of the Schrödinger-derived wave probability function.
- While avoiding any recourse to mysterious ideas of the wave packet collapse as somehow brought about by observer intervention or only on the instant - in Schrödinger's parable - when the box is opened up for inspection and the cat thus release from its supposed 'superposed' (dead-and-alive) state.
- Pilot-wave theory also seeks to explain quantum effects such as photon deflection or

multipath interference without proposing a massively expanded ontology of parallel worlds, shadow universes, multiple intersecting realities, etc.

Pilot-wave theory has three axioms. The first is de Broglie's law of motion, which specifies exactly how particles are guided by the wave. The second is Schrödinger's wave equation, telling us how the wave itself changes over time. The third is that particles have to start off with a certain probability distribution. "In any given experiment, each particle is accompanied by a wave". The particle starts off somewhere inside the wave. In order to give results that can be verified with an experiment, all three axioms have to be used. In classical physics there is an interplay between particle and field, each generates the dynamics of the other. In the original pilot wave theory the steering wave acts on positions of particles, but it is not acted upon by the particles. However **Holland, (2001)** has explored some deeper ideas related to this question in his work on a possible Hamiltonian formulation of pilot-wave and proposed a particle to wave back-reaction. This implies that, through the pilot wave mechanism, particles, just like waves, carry information regarding their future states. It also means that particle trajectories may exert a back reaction on the wave function, implying symmetric interaction between implicate and explicate orders.

What is so unusual about Antony Valentini? He, in fact, resurrected a theory that undoes the central tenet of quantum mechanics, and gives relativity theory a support as well. The theory follows quantum math, but at the same time allows for new possibilities beyond conventional quantum mechanics. It's a theory that says there is indeed an objective reality behind the things we observe, that quantum uncertainty is not fundamental, and that somewhere, somehow, time is universal – not relative. This implies goodbye to ghostly probabilities, with their strange propensity for collapsing into real things and hello to hidden variables that are objective.

This seems related to the American physicist **John Archibald Wheeler (1990, 2002)**, who suspected that reality exists not because of physical particles, but rather because of the act of observing the universe. "Information may not be just what we *learn* about the world. It may be what *makes* the world." In other words: when humans ask questions about nature, there is an active transfer of information in the domain of quantum waves where, in principle, backward causation from the future is possible. The second arrow (from future to past) remains hidden (unnoticed) for us, because life is trapped in the momentum of time. Entanglement means that particles separated at any distance, under certain conditions, can have mutually determined properties (are correlated). In this block universe multiple path's or life lines are laid out of which the individual chooses a single one. Consequently this concept allows free choice and therefore is not deterministic. Such non-locality becomes manifest by observation (or collapse of the wave aspect), as has been shown by electron spin orientation or polarized light. This might also be viewed as backward causation.

According to **Wheeler's (1990)** and Feynman's electrodynamics, emitters coincide with retarded fields, which propagate into the future, while absorbers coincide with advanced fields, which propagate backward in time. This time-symmetric model leads to predictions identical with those of conventional electrodynamics. For this reason it is impossible to distinguish between time symmetric results and conventional results.

In his "Transactional Interpretations of Quantum Mechanics, **John Cramer (1988)** stated that "Nature, in a very subtle way, may be engaging in backwards-in-time handshaking: The transaction between retarded waves, coming from the past, and advanced waves, coming from the future, gives birth to a quantum entity with dual properties of the wave/particle. Thus the wave property is a consequence of the interference between retarded and advanced waves, and the particle property is a consequence of the point in space where the transaction takes place". The transactional interpretation requires that waves can really travel backwards in time. This assertion seems counterintuitive, as we are accustomed to the fact that causes precede effects. It is important to underline, however, that, unlike other interpretations of QM, the transactional interpretation takes into account special relativity theory which describes time as a dimension of space, as mentioned earlier. Of note, the completed transaction erases all advanced effects, so that no direct advanced wave signaling is possible: "The future can affect the past only very indirectly, by offering possibilities for transactions" (**Cramer, 1988, see Fig. 11**).

King, 2003 (see later) stated: "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 implicate order, although in a different manner from Bohm's pilot wave theory. Because transactions connect past and future in a time-symmetric way, they cannot be reduced to predictive determinism, because the initial conditions are insufficient to describe the transaction, which also includes quantum boundary conditions coming from the future absorbers. However this future is also unformed in real terms at the early point in time emission takes place".

The principle of backward causation has been experimentally demonstrated recently. Aharonov's team and various collaborating groups (see **Aharonov, 2010**), studied whether the future may influence the past by sophisticated quantum physics technology. Aharonov concluded that a particle's past does not contain enough information to fully predict its fate, but he wondered, if the information is not in its past, where could it be? Clearly, something else must also regulate the particle's behavior. Aharonov and coworkers proposed a new framework called *time-symmetric quantum mechanics*. Recent series of quantum experiments in

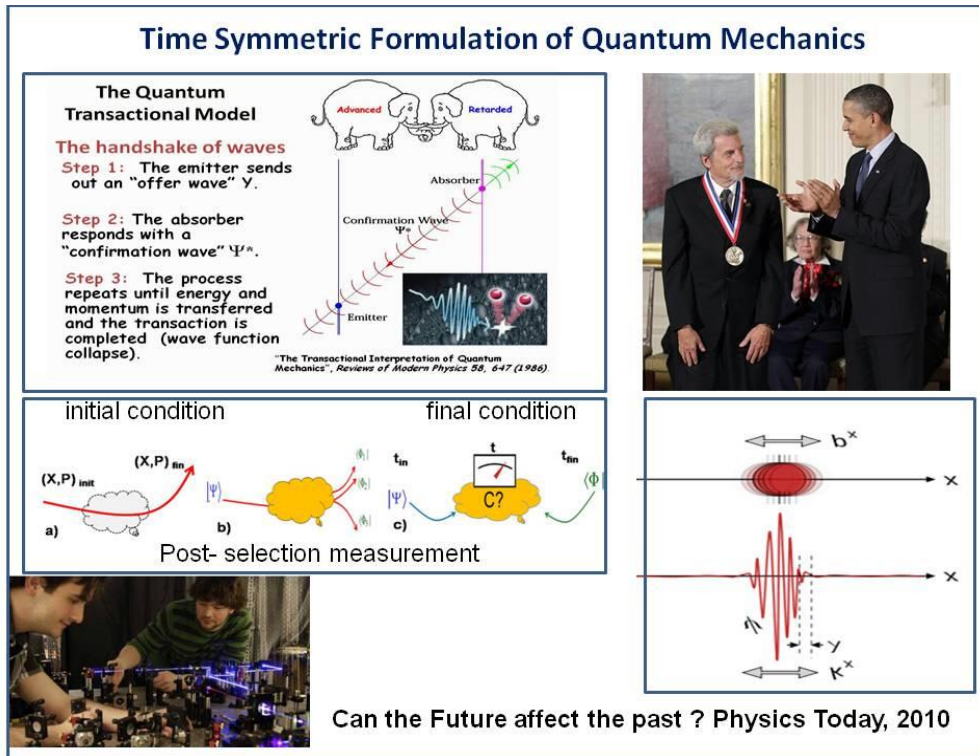


Fig. 11: The transactional interpretation of QM of Cramer of retarded and advanced waves from past and future that produce the present (up left) and the time-symmetric concept of the prize winning Aharonov (upper right inset) arising from post-selection (soft) measurement of a quantum state, that prevents wave collapse and also shows that the future may affect the past. This shows that through the wave aspect the "wavicle"(inset right below), intrinsically contains an aspect of the future.

about 15 different laboratories around the world seem to actually confirm the notion that the future can influence results that happened before those measurements were even made, see **Fig. 11**.

Generally the protocol included three steps: a "pre-selection" measurement carried out on a group of particles; an intermediate measurement; and a final, "post-selection" step in which researchers picked out a subset of those particles on which to perform a third, related measurement. To find evidence of backward causality, meaning information flowing from the future to the past, the effects of, so called, weak measurements were studied. Weak measurements involve the same equipment and techniques as traditional ones but do not disturb the quantum properties in play. Usual (strong) measurements would immediately collapse the wave functions in superposition to a definite state. The results in the various groups were amazing: repeated post-selection measurement of the weak type changed the pre-selection state, revealing an aspect of non-locality. Thus it appears that the universe might have a destiny that reaches back and "collaborates" with the past to bring the present into view. On a cosmic scale, this idea could also help explain how life arose in the universe against

tremendous odds and confirms the idea that knowledge was inherited from a common information pool (Meijer 2012, Kak, 2009, Jahn and Dunne, 2007).

Henry Stapp: attention, intention and quantum coherence

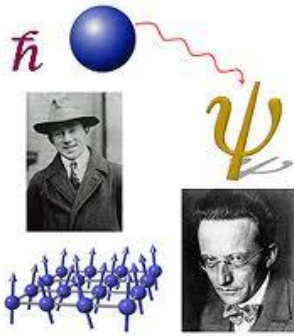


Henry Stapp

Stapp starts by asking what sort of brain action corresponds to a conscious thought. He criticizes the mainstream for assuming that Newtonian physics can be applied directly to the brain, and claims that a quantum framework is needed to understand the brain. The Copenhagen interpretation of quantum theory was the first mainstream version, and was pragmatic in recommending the theory as a system of rules that allowed the calculation of empirically verifiable relationships between observations. **Stapp, 2009, 2012**, favors Heisenberg's refinement of the original Copenhagen position. Heisenberg thought that the probability distribution of quantum theory really existed in nature, and that the evolution of this probability was punctuated by uncontrolled events, which are the events that actually occur in nature, and which at the same time eliminate the other probabilities.

The development of computing during the second half of the 20th century demonstrated that thought-like or cognitive processes required internal representations not allowed for in the then prevailing behaviourist concept. However, this still did not account for conscious experience, and in this period thinking or cognition came to be seen as something separate from consciousness.

Both Bohr and Heisenberg viewed quantum theory as a set of rules for making predictions about observations under experimental conditions. These predictions are incompatible with classical physics in respect of the prediction of non-locality. Heisenberg did not view the quanta as actual things, but as tendencies for certain types of events to occur. The orderly evolution of the system is deterministic, but this controls only the tendencies for things or propensity for events, and not the actual things or events themselves. The things are controlled by quantum jumps that do not individually conform to any natural law, but collectively conform to statistical rules.



Heisenberg and Schödinger

Stapp, 2009, 2012, bases his proposal for quantum consciousness on three observations.

- 1.) The brain's representation of the body or body schema must be represented by some form of physical structure in the brain. 2.) Some brain processes such as the behavior of calcium ions involved in synaptic transmission need to be treated quantum mechanically. Stapp also thinks that the sensitivity and non-linearity of the synaptic system, the involvement of calcium ions and the large number of meta-stable states into which the brain could evolve all point to a quantum mechanical system. 3.) Stapp suggests that the brain could evolve into a state analogous to the deterministic evolution of the quantum state from which an actual state must be selected.

Although Stapp pays a lot of attention to the synapses his is not actually a neuron based theory. Rather the event could be selected from the large scale excitation of the brain. The selection of events from a wide range of probabilities is seen as being particular adaptive where an organism needs to select from a range of future probabilities. Stapp wishes to establish the relationship between mind and matter, the relationship between reality and quantum theory, and also how relativity is reconciled with both experience and non-locality. The solution is suggested to be a series of creative events bringing into being one of a range of possibilities created by prior events. He suggests that consciousness exercises top-level control over neural excitations in the brain. The neural excitations are regarded as a code, and each human experience is regarded as a selection from this code. He sees the physical world as a structure of tendencies in the world of the mind. He finds it as unacceptable that there is an irreducible element of chance in nature as described by quantum theory, which is the most usual conclusion to be drawn from the randomness of the wave function collapse. The element of conscious choice is seen as removing chance from nature. He distinguishes between systems where an external representation and knowledge of the laws of physics can accurately predict how the system develops, and his own idea of a system that is internally determined in a way that cannot be represented outside the system.

The brain is viewed as a self-programming computer with self-sustaining neural patterns as the codes. It is necessary to integrate the code from sensory input, with the code from previous experience. This creates a number of probabilities, from which consciousness has to select. The conscious act is the selection of a piece of top-level code, which then exercises control over the flow of neural excitation. The unity of conscious thought comes from a unifying force in the conscious act itself. It selects a single code from amongst a multitude on offer in the brain. Raising an arm involves a conscious act selecting the top-level code that raises the arm. This is suggested to close the traditional explanatory gap between thought and classical physics, because here the conscious thought is the selection of the code that allows the physical act. Stapp goes on to discuss the conscious process of looking at pictures. According to him top-level codes instruct lower-level codes to produce new top level codes and to initiate their storage in memory. The experience of noticing something is deemed to be the process of initiation into memory. There are close connections between the top-level code and the memory structure. The lower level codes have to be functioning correctly i.e. not damaged, and to be focused on the incoming stimuli in order for it to be put into higher level code and to be registered in memory.

Stapp discusses what neural research would need to reveal if it were to support his theory. It would need to reveal the neural connections needed to support self-sustaining patterns of neural excitation. It is necessary to find the neurons providing the top level coding, then the mechanism for storing memory traces of this, and finally the mechanism by which these memories are involved in the production of new top-level codes. Each conscious experience is seen as a creative act represented in the physical world by the selection of a top level code from among the many generated by the laws of quantum theory. The conscious experiences are the initiation of processes that produce changes in the body schema and the external and internal reality schema. The conscious act is functionally equivalent to changes in the physical world as represented in quantum theory. In the Heisenberg version of quantum theory physical things are events and quantum theory gives the propensity for particular events to occur. This is seen as providing a link between conscious processes and brain processes. In the Heisenberg version it is the act of observation which leads to the selection of a particular propensity.

Stapp attaches great importance to the idea of the formation of a record. This is seen as analogous to the Geiger counter that registers a record of a quantum event. Every conscious experience is seen as recordable, because it is evidence of some form of brain process. The later retrievability of the experience is evidence of a record in the brain. A key process in brain dynamics is seen as persisting patterns of neural excitation producing physical changes in

neurons that enable a particular pattern to be re-excited, and allow re-excited pattern to connect with new stimuli. This is seen as the basis of the brain's associative memory.

The top-level brain process is viewed as a process of actualizing symbols, composed of earlier symbols connected into a whole by neural links. The top-level process is seen as directing information gathering, planning and choice of particular plans, monitoring the execution of plans. This can be understood in terms of top-level direction of multiple neural processes. Because of the top-level directive role, its connection to associative memory and the multiple structure of the symbols involved it is suggested that each top-level event corresponds to a psychological event, and this in turn connects psychological events to the quantum level. Both the top-level brain event and the psychological event act as choosers of a possibility, or converters of potentialities into actualities. Each human conscious experience is seen as the feel of an event in the top-level of processing in the human brain, a sequence of Heisenberg actual events, actualizing a quasi-stable pattern of neural activity. Activation of particular symbols creates a tendency for the activation of other related symbols. The body schema is the product of actualized events accumulated over the life of the body. The top-level symbols have compositional structure formed from other symbols. The Heisenberg events are seen as being capable of grasping a whole a pattern of activity, and this is seen as accounting for the unity of consciousness. The continuity or flow of time is explained by an overlap of symbols with the preceding mental event.

Stapp drawing on studies of infants assumes that humans have a hard-wired body-world schema. Consciously directed action is seen as a projection of this body-world schema into the future, with a corresponding representation in the brain. This body-world schema is seen as directing the unconscious brain, issuing commands for motor action and instructions for mental processing. Ongoing questions to nature continue to be posed by the observer. This equates to the 'Heisenberg choice', where the human observer has to decide what question to put to nature. In this case it is the conscious processing in the brain that does this. Each experience leads to further updating of the system.

When an action is initiated by a thought, this usually includes some monitoring of the subsequent action, to check it against the intended action. So something experienced as an intention becomes an action, the attention to which is also experienced. Stapp views the deterministic unfolding of matter according to the Schrödinger equation as running parallel to the movement from intention to attention, as two poles of the same quantum event that prolong the coherent state and thereby protect against potential decoherence. He also sees a tripartite structure being the Schrödinger equation, the Heisenberg choice of question to ask and the (Dirac) choice of answer from nature.

Stapp's point is that only a conscious observer within the brain can ask the question, and drive the quantum process. This also allows the experiential process to enter into the causal structure of the body/brain. Stapp feels that some additional process is needed and the conscious observer is a perfect candidate. He sees quantum theory as informational in nature and thus linked to increments in knowledge occurring in the brain. The increment in knowledge is seen as linked to a reduction in the quantum state, thus linking mind to the physical world. Mind is thus seen as entering into the physical world through the Heisenberg choice.

When the quantum state is reduced a wave that extends over an indefinite amount of space is instantaneously reduced to a tiny local region. Stapp feels that this constitutes a representation of knowledge rather than a representation of matter. The wave before collapse is seen as a matter of potentiality or probabilities, which are themselves often conceived as ideas rather than realities. However, the quantum state pre-collapse evolves in line with the deterministic Schrödinger equation, giving the state some of the properties of the physical, thus and creating in fact a sort of hybrid.

Stapp does not suggest that our conscious thoughts are completely unconstrained, but he does see our thoughts as a part of the causal structure of the mind-brain that is not dominated by the actions of the smallest components of the brain, but is also not a random effect. Our thoughts are seen not as linked to external objects, but instead linked to patterns of brain activity. Stapp points out that his theory has a place for an efficacious conscious mind linked to the physical processes of the brain. He suggests that the dynamic of the Schrödinger evolution, which is to produce an event that replicates the event that produced, it could somehow stand in for the later action of conscious minds. The identity theory of mind claims that each mental state is identical to some process in the brain. However, classical physics says that the entire causal structure of a physical system is determined by the microscopic level of the physical structure, so that larger scale effects such as consciousness cannot have any influence.

A potential problem with the whole Copenhagen influenced interpretation of quantum theory is its possible dualism. Mathematics can be seen as a mental process instantiated in protein, which, in principle, cannot directly influence the external world. Somehow the mathematical description of the quantum waves is sitting out there in space, and then as a result of a measurement becomes a physical particle. In Copenhagen, a mental concept external to the body seems to become physical with no explanation as to how the two could interact. The Copenhagen system has the additional problem of what was happening before human minds emerged to perform measurements, for which Stapp's explanation appears rather sketchy. Consequently, a more detailed model is required to picture the inherent interaction between a more general form of consciousness as a measuring device in evolution (see later).

Roger Penrose: Consciousness and the Spacetime Geometry of Universe



Roger Penrose, 1989, 1994, 2004, is one of the very few thinkers to consider how consciousness could arise from first principles rather than merely trying to shoe horn it into nineteenth century physics, and his ideas appear to be a good starting point from which to try to understand consciousness as a fundamental.

Penrose's approach was a counter attack on the functionalism of the late 20th century, which claimed that computers and robots could be conscious. He approached the question of consciousness from the direction of mathematics. The centre piece of his argument is a discussion of Gödel's theorem. Gödel demonstrated that any formal system or any significant system of axioms, such as elementary arithmetic, cannot be both consistent and complete. There will be statements that are undecidable, because although they are seen to be true, but are not provable in terms of the axioms.

Penrose's controversial claim: The Gödel theorem as such is not controversial in relation to modern logic and mathematics, but the argument that Penrose derived from it has proved to be highly controversial. Penrose claimed that the fact that human mathematicians can see the truth of a statement that is not demonstrated by the axioms means that the human mind contains some function that is not based on algorithms, and therefore could not be replicated by a computer. This is because the functioning of computers is based solely on algorithms (a system of calculations). Penrose therefore claimed that Gödel had demonstrated that human brains could do something that no computer was able to do.

Arguments against Penrose's position: Some critics of Penrose have suggested that while mathematicians could go beyond the axioms, they were in fact using a knowable algorithm present in their brains. Penrose contests this, arguing that all possible algorithms are defeated by the Gödel problem. In respect to arguments as to whether computers could be programmed to deal with Gödel propositions, Penrose accepts that a computer could be instructed as to the non-stopping property of Turing's halting problem. Here, a proposition that goes beyond the original axioms of the system is put into a computation. However, this proposition is not part of the original formal system, but instead relies on the computer being fed with human insights, so as to break out of the difficulty. So the apparently non-algorithmic insights are required to supplement the functioning of the computer in this instance.

An unknowable algorithm: Penrose further discusses the suggestion of an unknowable algorithm that enables mathematicians to perceive the truth of statements. He argues that there is no escape from the knowability of algorithms. An unknowable algorithm means an algorithm, whose specification could not be achieved. But any algorithm is in principle knowable, because it depends on the natural numbers, which are knowable. Further, it is possible to specify natural numbers that are larger than any number needed to specify the algorithmic action of an organism, such as a human or a human brain.

Mathematical robots: Penrose says that with a mathematical robot, it would not be practical to encode all the possible insights of mathematicians. The robot would have to learn certain truths by studying the environment, which in its turn is assumed to be based on algorithms. But to be a creative mathematician, the robot will need a concept of unassailable truth, that is a concept that some things are obviously true.

This involves the mathematical robot having to perceive that a formal system 'H' implies the truth of its Gödel proposition, and at the same time perceiving that the Gödel proposition cannot be proved by the formal system 'H'. It would perceive that the truth of the proposition follows from the soundness of the formal system, but the fact that the proposition cannot be proved by the axioms also derives from the formal system. This would involve a contradiction for the robot, since it would have to believe something outside the formal system that encapsulated its beliefs.

Amongst experts in this area who do not entirely reject Penrose's argument, **Feferman, 1996** has criticized Penrose's detailed argument, but is much closer to his position than to that of mainstream consciousness studies. Feferman makes common cause with Penrose in opposing the computational model of the mind, and considering that human thought, and in particular mathematical thought, is not achieved by the mechanical application of algorithms, but rather by trial-and-error, insight and inspiration, in a process that machines will never share with humans. Feferman finds numerous flaws in Penrose's work, but at the end he informs his readers that Penrose's case would not be altered by putting right the logical flaws that Feferman has spent much time discovering.

Feferman's own position is that the computational-mind argument is misleading in terms of the weight that it places on the equivalence between Turing machines and formal systems. The model of mathematical thought in terms of formal systems is considered to be closer to the nature of human thought, and particularly mathematical thought, than to the functioning of Turing machines. The Turing machine model would assume that given a problem, human reason would plug away, applying the same algorithm indefinitely, in the hope of finding an

answer. Feferman says that it is ridiculous to think that mathematics is performed in this way. Trial-and-error reasoning, insight and inspiration, based on prior experience, but not on general rules, are seen as the basis of mathematical success. A more mechanical approach is only appropriate, after an initial proof has been arrived at. Then this approach can be used for mechanical checking of something initially arrived at by trial-and-error and insight. He views mathematical thought as being non-mechanical. He says that he agrees with Penrose that understanding is essential to mathematical thought, and that it is just this area of mathematical thought that machines cannot share with us.

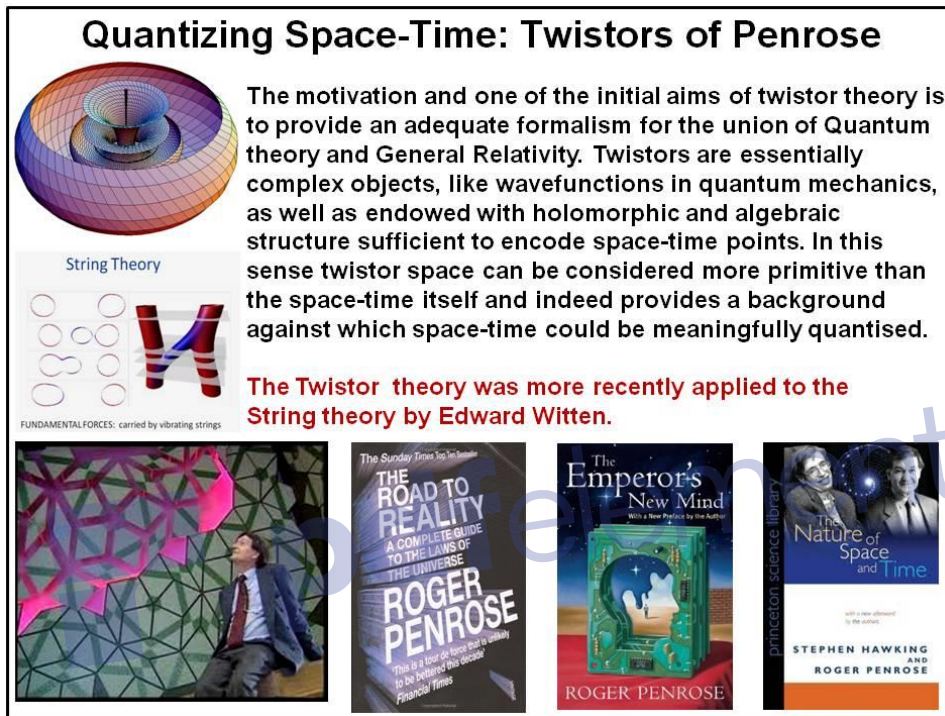


Fig. 12: The Twistor theory as proposed by Penrose to find a basic structure for spacetime geometry, as is also attempted by String theories. Twistor theory was later on applied by Witten in the universal string M-theory, to diminish the total number of required extra dimensions

Penrose's own take on the wave function collapse suggests that it is a real event. He sees superposition as a separation in the underlying space-time geometry. Each quanta is embedded in a bit of space, and as the superpositions grow further apart, a blister or separation appears in space-time. This can be viewed as the same thing as the beginning of the multiple world view, but instead of going on to generate separate universes, if the separation between superpositions grows to more than the Planck length, the wave collapses and chooses one of the superposed alternatives.

Twistor theory (**Fig. 12**) in the context of space-time has been pioneered by Roger Penrose and others since the 1960s and is based on the association of a complex twistor space CP^3 to the space of light rays in space-time. The name derives from the Robinson congruence which is the

natural realization of a (non-null) twistor. Penrose thereby attempted to encode spacetime points, affording a quantized spacetime. Some appealing aspects of the theory are:

- twistor space becomes the basic space so that light rays are the fundamental objects from which space-time is derived;
- discrete quantities such as spin are represented in the discrete values obtained by contour integration;
- its evident elegance and simplicity

The normal quantum wave collapse is seen as an entirely random choice of the state of a quantum particle, from amongst the various superpositions of states. However, these collapses involve interaction with the environment. Penrose suggests that a quanta, which does not interact with the environment will undergo objective reduction (OR) when the separation between superpositions begins to exceed the Planck length. He also suggests that while the normal collapse is totally random OR is not totally random but involves a non-computable process. This is suggested because Penrose thinks that the brain manifests a non-computational aspect, and that the wave function collapse is the only place in the universe where such a thing can exist. Penrose also proposes that OR based quantum computation occurs in the brain.

Penrose's search for a non-algorithmic feature: Penrose went on to ask, what it was in the human brain that was not based on algorithms. The physical law is described by mathematics, so it is not easy to come up with a process that is not governed by algorithms. The only plausible candidate that Penrose could find was the collapse of the quantum wave function, where the choice of the position of a particle is random, and therefore not the product of an algorithm. However, he considered that the very randomness of the wave collapse disqualifies it as a useful basis for the mathematical judgement or understanding in which he was initially interested.

The wave function: In respect of consciousness, it is Penrose's attitude to the reality of the quantum wave function collapse that is the important area. In particular, he disagrees with the traditional Copenhagen interpretation, which says that the theory is just an abstract calculational procedure, and that the quanta only achieve objective reality when a measurement has been made. Thus in the Copenhagen approach reality somehow arises from the unreal or from abstraction, giving a dualist quality to the theory.

The discussion of quantum theory repeatedly comes back to the theme that Penrose regards the quantum world and the uncollapsed wave function as having objective existence. In Penrose's view, the objective reality of the quantum world allows it to play a role in consciousness. Penrose emphasizes that the evolution of the wave function portrayed by the

Schrödinger equation is both deterministic and linear. This aspect of quantum theory is not random. Randomness only emerges when the wave function collapses, and gives the choice of a particular position or other properties for a particle. Penrose discusses the various takes made on wave function collapse by physicists. Some would like everything to depend on the Schrödinger equation, but Penrose rejects this idea, because it is impossible to see how the mechanism of this equation could produce the transformation from the superposition of alternatives, as found in the quantum wave, to the random choice of a single alternative.

He also discusses the suggestion that the probabilities of the quantum wave that emerges into macroscopic existence arise from uncertainties in the initial conditions and that the system is analogous to chaos in macroscopic physics. This does not satisfy Penrose, who points out that chaos is based on non-linear developments, whereas the Schrödinger equation is linear.

Important distinction between Penrose and Wigner

Penrose also disagrees with **Eugene Wigner's (see Wigner, 1992)** suggestion that it is consciousness that collapses the wave function, on the basis that consciousness is only manifest in special corners of spacetime. Penrose himself advances the exact opposite proposal that the collapse of a special (objective) type of wave function produces consciousness. It is important to stress this difference between the Penrose and the Wigner position, as some commentators mix up Wigner's idea with Penrose's propositions on quantum consciousness, and then advance a refutation of Wigner, wrongly believing it to be a refutation of Penrose.

Penrose is also dismissive of the 'many worlds' version of quantum theory, which would have an endless splitting into different universes with, for instance, Schrödinger's cat alive in one universe and dead in another universe. Penrose objects to the lack of economy and the multitude of problems that might arise from attempting such a solution, and in addition argues that the theory does not explain why the splitting has to take place, and why it is not possible to be conscious of superpositions.

Objective reduction, Consciousness, Spacetime and the Second law & Gravity

Penrose instead argues for some new physics, and in particular an additional form of wave function collapse. If the superpositions described by the quantum wave extended into the

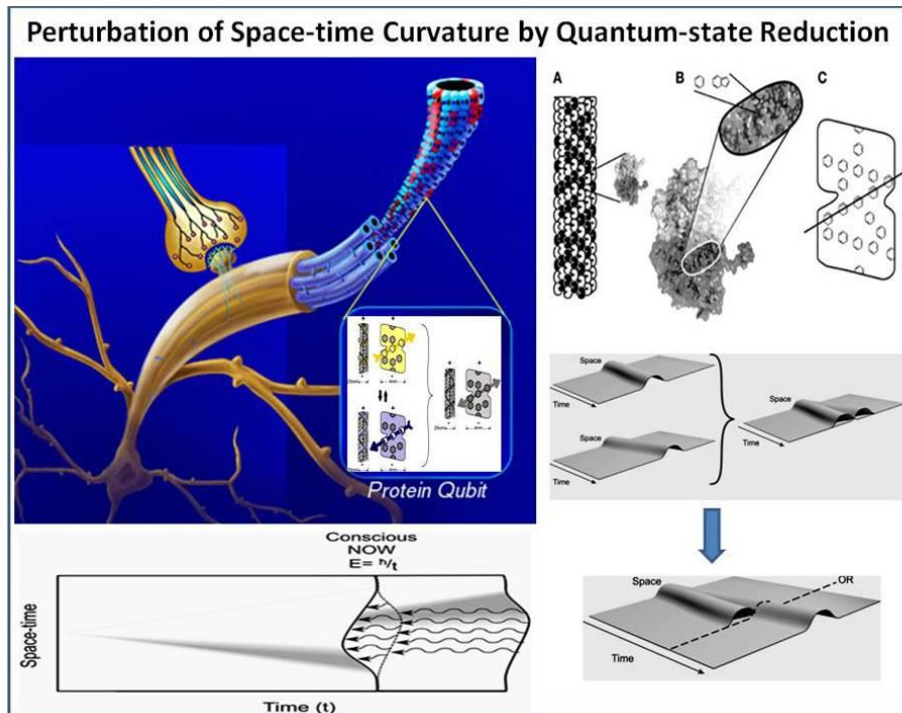


Fig. 13: Neuronal tubulus as the potential site for quantum mediated effects in brain. Each tubulin is shown to have 9 rings representing 32 actual phenyl or indole rings per tubulin, with coupled, oscillating London force dipole orientations among rings traversing 'quantum channels', aligning with rings in adjacent tubulins in helical pathways through microtubule lattices. On the right, superposition of alternative tubulin and helical pathway dipole states.

macroscopic world, we would in fact see superpositions of large-scale objects. As this does not happen, it is argued that something that is part of objective reality must take place to produce the reality that we actually see. This requirement for new physics is often criticized as unjustified. However, these criticisms tend to ignore the fact that while quantum theory provides many accurate predictions, there has never been satisfactory agreement about its interpretation, nor has its conflict with relativity been resolved.

Penrose sees consciousness as not only related to the quantum level but also to spacetime. He discusses the spacetime curvature described in general relativity. He looks at the effect of singularities relative to two spacetime curvature tensors, Weyl and Ricci. Weyl represents the tidal effect of gravity, by which the part of a body nearest to the gravitational source falls fastest creating a tidal distortion in the body. Ricci represents the inward pull on a sphere surrounding the gravitational force. In a black hole singularity, the tidal distortion of Weyl would predominate over Ricci, and Weyl goes to infinity at the singularity.

However, in the early universe expanding from the Big Bang, the inward tidal distortion is absent, so $Weyl=0$, while it is the inward pressure of Ricci that predominates. So the early universe is seen to have had low entropy with Weyl close to zero. Weyl is related to

gravitational distortions, and Weyl close to zero indicates a lack of gravitational clumping, just as Weyl at infinity indicated the gravitational collapse into a black hole. Weyl close to zero and low gravitational clumping therefore indicate low entropy at the beginning of the universe.

The fact the Weyl is constrained to zero is seen by Penrose as a function of quantum gravity. The whole theory is referred to as the Weyl curvature hypothesis. The question that Penrose now asks is as to why initial spacetime singularities have this structure. He thinks that quantum theory has to help with the problem of the infinity of singularities. This would be a quantum theory of the structure of spacetime, or in other words a theory of quantum gravity.

Penrose regards the problems of quantum theory in respect of the disjuncture between the Schrödinger equations deterministic evolution and the randomness in wave function collapse as fundamental. He thinks in terms of a time-asymmetrical quantum gravity, because the universe is time-asymmetric from low to high entropy. He argues that the conventional process of collapse of the wave function is time-asymmetric. He describes an experiment where light is emitted from a source and strikes a half-silvered mirror with a resulting 50% probability that the light reaches a detector and 50% that it hits a darkened wall. This experiment cannot be time reversed, because if the original emitter now detects an incoming photon, there is not a 50% probability that it was emitted by the wall, but instead 100% probability that it was emitted by the other detecting/emitting device.

Penrose relates the loss of information that occurs in black holes to the quantum mechanical effects of the black hole radiation described by Stephen Hawking. This relates the Weyl curvature that is seen to apply in black holes and the quantum wave collapse. As Weyl curvature is related to the second law of thermodynamics, this is taken to show that the quantum wave reduction is related to the second law and to gravity. He proposes that in certain circumstances there could be an alternative form of wave function collapse. He called this objective reduction (OR). He suggests that as a result of the evolution of the Schrodinger wave, the superpositions of the quanta grow further apart. According to Penrose's interpretation of general relativity, each superposition of the quanta is conceived to have its own spacetime geometry. The separation of the superpositions, each with its own spacetime geometry constitutes a form of blister in space-time. However once the blister or separation grows to more than the Planck length of 10^{-35} meters, the separations begin to be affected by the gravitational force, the superposition becomes unstable, and it soon collapses under the pressure of its gravitational self-energy. As it does so, it chooses one of the possible spacetime geometries for the particle. This form of wave function collapse is proposed to exist in addition to the more conventional forms of collapse (see also **Fig.13**).

Evidence for non-computational spacetime

In support of this, he points out that when the physicists, **Geroch and Hartle, 1986** studied quantum gravity, they ran up against a problem in deciding whether two spacetimes were the same. The problem was solvable in two dimensions, but intractable in the four dimensions that accord with the four dimensional spacetime, in which the superposition of quantum particles needs to be modeled. It has been shown that there is no algorithm for solving this problem in four dimensions.

Earlier the mathematician, A. Markov, had shown there was no algorithm for such a problem, and that if such an algorithm did exist, it could solve the Turing halting, for which it had already been shown that there was no algorithm. The possibly non-computable nature of the structure of four-dimensional space-time is deemed to open up the possibility that wave function collapses could give access to this non-computable feature of fundamental space-time.

A long-term experiment is underway to test Penrose's hypothesis of objective reduction. This experiment is currently being run by Bouwmeester at the University of California, Santa Barbara and involves mirrors only ten micrometres across and weighing only a few trillionths of a kilo, and the measurement of their deflection by a photon. The experiment is expected to take ten years to complete. This means that theories of consciousness based on objective reduction are likely to remain speculative for at least that length of time. However, the ability to run an experiment that could look to falsify objective reduction, at least qualifies it as a scientific theory.

Significance for consciousness

The significance of this for the study of consciousness is that, in contrast to the conventional idea of wave function collapse, this form of collapse is suggested to be non-random, and instead driven by a non-computable function at the most fundamental level of spacetime. Penrose argues that, in contrast to the conventional wave function form of collapse, there are indications that in this case, there is a decision process that is neither random nor computationally/algorithmically based, but is more akin to the 'understanding' by which Penrose claims the human brain goes beyond what can be achieved by a computer.

The road from physics to mental phenomena has already been frequented, notoriously by Pauli and Jung and, under the influence of Pauli, by Heisenberg. The interaction is not limited to a three decades-long Jung–Pauli epistolary and the reciprocal influences have been profound. The founding role of Pauli's work in quantum physics does not need to be recalled (**Pauli, 1994**) and the effects of his quantum vision in the development of Jung's vision of the

human mind (archetypes included) have been well explored. The title of the essay by Jung in their co-authored volume “Synchronizität als ein Prinzip akausaler Zusammenhänge” (Synchronicity as a Principle of Acausal Connections) could not indicate more clearly the influence of Pauli’s quantism on Jung’s perception of reality (**Jung and Pauli, 1955**), and the interplay of the two great minds. Before them, the self-referentiality of the Euclidean approach to human consciousness has been narrated by Lewis Carroll in his “Through the looking-glass”.

Philosophically, Orch OR perhaps aligns most closely with **Alfred North Whitehead**, (see [link Wikipedia](#)) and who viewed mental activity as a process of ‘occasions’, spatio-temporal quanta, each endowed—usually on a very low level, with mentalistic characteristics which were ‘dull, monotonous, and repetitious’. These seem analogous, in the Orch OR context, to ‘proto-conscious’ non-orchestrated OR events. Whitehead viewed high level mentality, consciousness, as being extrapolated from temporal chains of such occasions. In his view highly organized societies of occasions permit primitive mentality to become intense, coherent and fully conscious. These seem analogous to Orch OR conscious events. **Abner Shimony, 2005, Henry Stapp, 2007 and Hameroff, 1998** recognized that Whitehead’s approach was potentially compatible with modern physics, specifically quantum theory, with quantum state reductions—actual events—appearing to represent ‘occasions’, namely Whitehead’s high level mentality, composed of ‘temporal chains ... of intense, coherent and fully conscious occasions’ (**Fig. 14**), these being tantamount to sequences of Orch OR events.

These might possibly coincide with gamma synchrony, but with our current ‘beat frequency’ ideas gamma synchrony might more likely to be a beat effect than directly related to the OR reduction time τ . As Orch OR events are indeed quantum state reductions, Orch OR and Whitehead’s process philosophy appear to be quite closely compatible. Whitehead’s low-level ‘dull’ occasions of experience would seem to correspond to our non orchestrated ‘proto-conscious’ OR events. According to this scheme, OR processes would be taking place all the time everywhere and, normally involving the random environment, would be providing the effective randomness that is characteristic of quantum measurement. Quantum superpositions will continually be reaching a threshold for OR in non-biological settings as well as in biological ones, and OR would usually take place in the purely random environment such as in a quantum system under measurement. Nonetheless, in the Orch OR scheme, these events are taken to have a rudimentary subjective experience, which is undifferentiated and lacking in cognition, perhaps providing the constitutive ingredients of what philosophers call *qualia*. We term such un-orchestrated, ubiquitous OR events, lacking information and cognition, ‘proto-conscious’. See **Fig 14**.

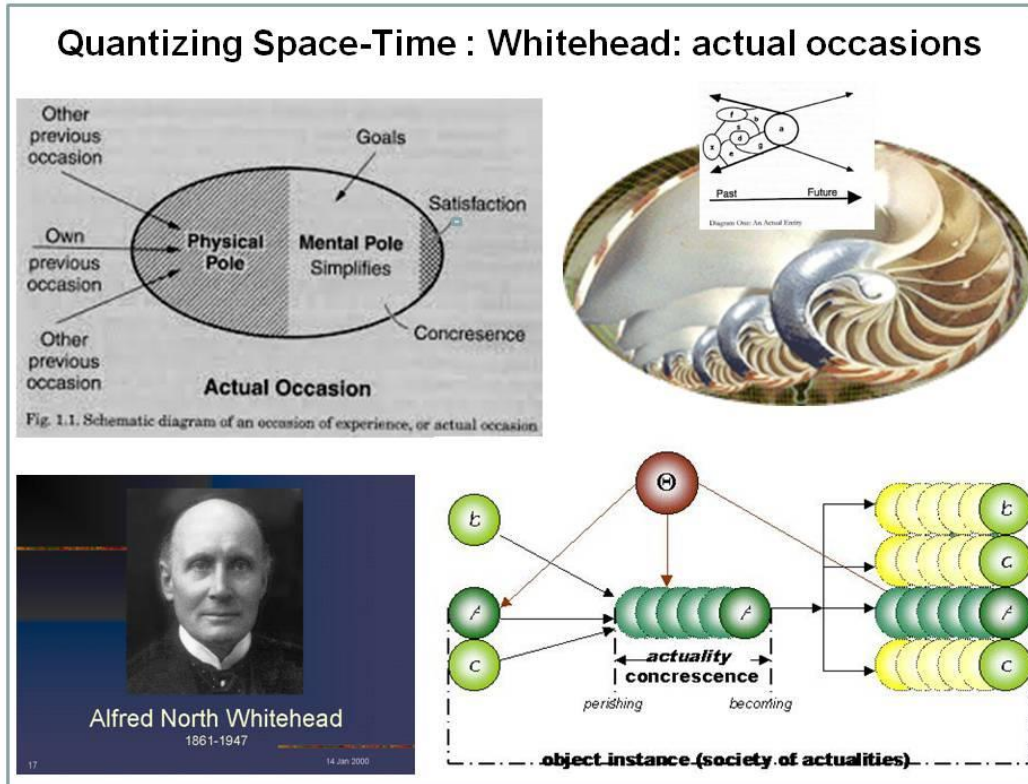


Fig. 14 : Quantizing space time of Whitehead by postulating units of experience and actual occasions that have a mental and physical pole and carry elements of goals, satisfaction and beauty. They are build up from previous occasions from societies of occasions(right insets).

In this regard, Orch OR has some points in common with the viewpoint, which incorporates spiritualist, idealist and panpsychist elements, these being argued to be essential precursors of consciousness that are intrinsic to the universe. It should be stressed, however, that Orch OR is strongly supportive of the *scientific* attitude, and it incorporates the viewpoint's picture of neural electrochemical activity, accepting that non-quantum neural network membrane-level functions might provide an adequate explanation of much of the brain's *unconscious* activity. Orch OR in microtubules inside neuronal dendrites and soma adds a deeper level for conscious processes.

Stuart Hameroff: Quantum coherence in brain tubules



Stuart Hameroff and Roger Penrose

Hameroff and Penrose, 2011 2013, classify all the mainstream approaches to consciousness as 'classical functionalism'. Functionalism takes no account of what the brain is made of or of anything finer grained than the level of neuron-to-neuron connections. It believes that these connections could be copied in another material such as silicon, and that the resulting construct would be conscious. However, Hameroff argues that although axonal spikes and synaptic connections clearly play a key role in information processing in the brain, they may not be the main currency of consciousness. Hameroff argues that quantum processing in microtubules within the dendrites and gap junctions between dendrites are the main currency of consciousness.

The main case against quantum processing in the brain has always been that any quantum coherence in the brain would decohere faster than the time taken for any useful biological process. Hameroff accepts that this is in principle a valid argument. However, Hameroff claims that the microtubules may be screened from their environment by a gelatinous non-liquid ordered state that arises in the neuronal interior.

A further objection to quantum processing is that even if it arose in one neuron, it would be difficult for it to communicate across the brain. This is countered by the suggestion that there could be quantum tunneling at gap junctions between neurons. In recent years, gap junctions have been discovered to be more widespread in the brain than was previously thought. They are also correlated with the 40Hz gamma synchrony. This oscillation was at one time promoted by Crick and Koch as the most promising correlate of consciousness. However, the idea fell from favour with mainstream neuroscience, when it was discovered that the gamma synchrony correlated with dendritic activity rather than axonal spiking.

In general, Hameroff argues that the emerging evidence of neurobiology has moved in favour of the Orch OR model over the last decade, notwithstanding the continued unpopularity of the theory. Hameroff summarizes his proposals in the early part of the chapter. He thinks that consciousness arises in the dendrites of neurons that are connected by gap junctions to form

'hyperneurons', and that these are related to the gamma synchrony. Axonal spikes and synapses are seen as making inputs to and receiving outputs from the microtubular process as part of an interactive systems.

Hameroff touches on the famous **Libet, 2006** experiments that demonstrated a 500ms timelag between a stimulus and the perception of it entering consciousness, although the subject is not aware of this time lag, as a result of a so-called backward referral in time. The mainstream has tended to favour an interpretation resembling the Dennett 'multiple drafts' concept, which would involve an after the event reconstruction of what had happened. Hameroff, however, thinks that the backward referral in time should be taken seriously. This was also the view of Roger Penrose, who suggested that backward referral (**Fig. 15**) might be indicative of quantum activity.

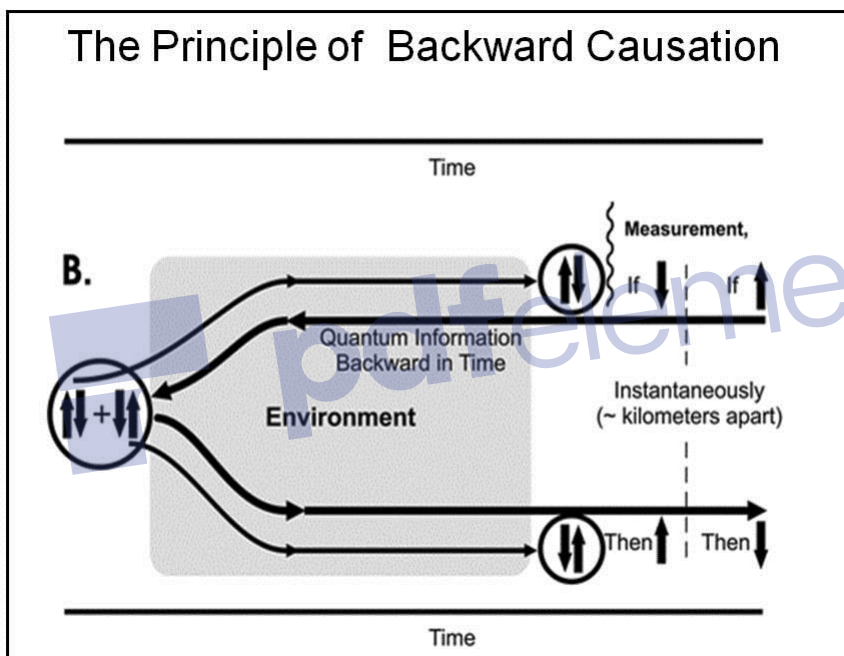


Fig.15 : Backward referral of time as proposed by Libet et al.

Hameroff points out that changes in dendrites can lead to increased synaptic activity. This is basic to ideas about learning, memory and neural correlates of consciousness. The changes in dendrites involve the number and arrangement of receptors and the arrangement of dendritic spines and dendrite-to-dendrite connections. Axon potentials or spikes have been assumed to be the main basis of consciousness, but Hammerof suggests that there could be other candidates. Electrodes implanted into the brain detect mainly the activity of dendritic gap junctions plus inhibitory chemical synapses. Thus the detected synchrony derives from dendrites rather than axonal spikes.

The main function of dendrites is seen to be the handling of input signal into the neuron, which may eventually result in an axon spike. However, this is not the whole story, since many cortical neurons have dendrites but no axons. Here dendrites interact with other dendrites. Also there can be extensive dendritic activity with no spikes. The evidence suggests that there are complex logic functions in the dendrites, and these may oscillate over a wide area, while remaining below the axon spiking threshold. Many post-synaptic receptors send signals into the dendrite cytoskeleton

Gamma synchronies, in the 30-70 Hz range, have aroused interest as possible correlates of consciousness. **Gray and Singer, 1989**, found coherent gamma oscillations in the brain that were dependent on visual stimulation. It was suggested that this synchrony could solve the binding problem, which is the problem of how the different inputs into the brain are bound together into a single conscious experience. It was suggested that the synchrony selected the activity of a relevant assembly of neurons. **Varela, 1995** noted that synchrony operated whenever the processing of spatially separated parts of the brain were brought together in consciousness. Gamma synchrony has been demonstrated across cortical areas, hemispheres and the sensory/motor modalities. The synchrony is involved in a range of brain activities including perception of sound, REM dream sleep, attention, working memory, face recognition and somatic perception. Also gamma decreases during general anesthesia and returns on waking from this. Hameroff regards gamma synchrony as the best overall correlate of consciousness.

He further addresses the question of how the gamma synchrony is mediated. There is coherence over large areas of the brain, sometimes including multiple cortical areas and both hemispheres of the brain, with zero or near zero phase lag. If the synchrony was based on the axon/synapse system a considerable lag would be expected. In fact, the lack of coherence between the synchrony and axonal spike activity has led to a reduction in the amount of mainstream attention paid to the gamma synchrony.

Hameroff points to gap junctions as an alternative to synapses for connections between neurons. Neurons that are connected by gap junctions depolarize synchronously. Gap junctions play a more important role in the adult brain than was previously supposed. Numerous studies show that gap junctions mediate the gamma synchrony. A neuron may have many gap junction connections but not all of them are necessarily open at the same time. The opening and closing of the junctions may be regulated by the microtubules.

Hameroff suggests that cells connected by gap junctions may in fact constitute a cell assembly, with the added advantage of synchronous excitation. Cortical inhibitory neurons are heavily studded with gap junctions, possibly connecting each cell to 20 to 50 others (4). The axons of

these neurons tend to form inhibitory GABA chemical synapses on the dendrites of other interneurons.

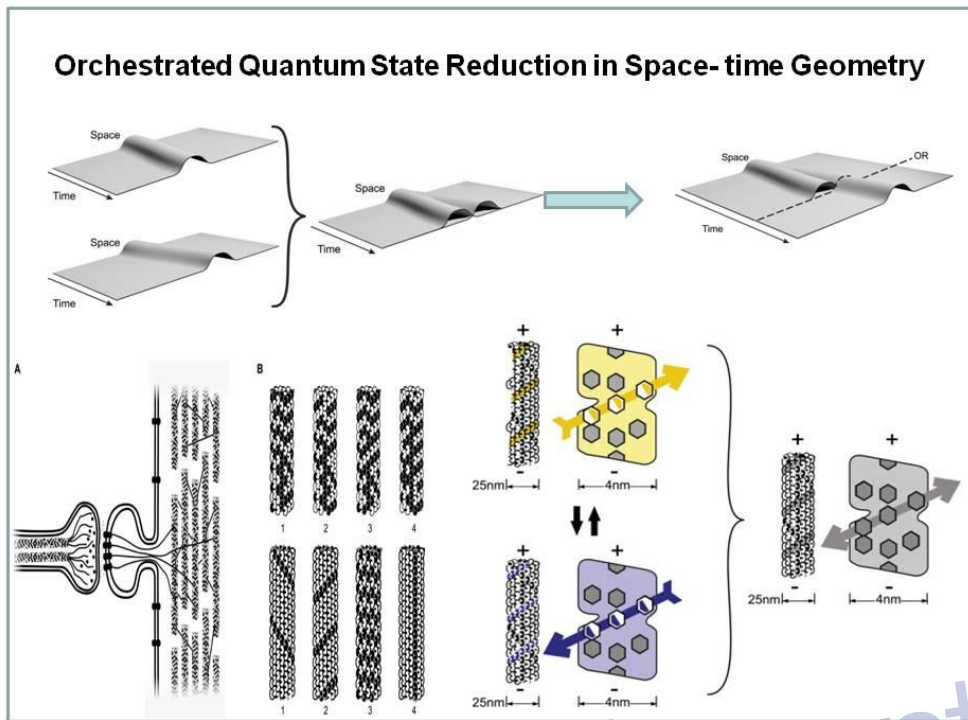


Fig. 16: Schematic representation of a brain microtubule, build up from tubulin proteins that can undergo rapid fluctuations in three dimensional configuration, enabling the sensing and transmission of quantum information (Qbits), see also Fig. 13.

Hameroff moves on to discuss the role of the cytoskeleton, which is seen to determine the structure, growth and function of neurons. Actin is the main constituent of dendritic spines and is present throughout the neuronal interior. Actin can de-polymerize into a dense meswork, and when this happens the interior of the cell is converted from an aqueous solution into a gelatinous state. Furthermore, when this happens the whole of the cytoskeleton forms a negatively charged matrix around which water molecules are bound into an ordered state. It is noted that the neurotransmitter glutamate binding to NMDA and AMPA receptors cause gel states in actin spines.

The cytoskeleton of the dendrites is distinct both from that found in cells outside the brain and from the cytoskeleton found in the axons of neurons. The microtubules in dendrites are shorter than those in axons and have mixed as opposed uniform polarity. This appears a sub-optimal arrangement from a normal structural point of view, and it is suggested that in conjunction with microtubule associated proteins (MAPs), this arrangement may be optimal for information processing rather than supportive structural functions. These microtubule/MAP arrangements are connected to synaptic receptors on the dendrite

membrane by a variety of calcium and sodium influxes, actin and other inputs. Alterations in the microtubule/MAPs network in the dendrites correlate with the arrangement of dendrite synaptic receptors. Studies demonstrate that the cytoskeleton is also involved in signal transmission. It is suggested that the microtubule lattice is well designed to represent and process information (**Fig. 17**).

Tubulin was supposed to switch between two conformations (see **Fig. 18**). It is suggested that tubulin conformational states could interact with neighboring tubulin by means of dipole interactions. The dipole-coupled conformation for each tubulin could be determined by the six surrounding tubulins. Hameroff describes protein conformation as a delicate balance between countervailing forces. Proteins are chains of amino-acids that fold into three dimensional conformations. Folding is driven by van der Waals forces between hydrophobic amino-acid groups. These groups can form hydrophobic pockets in some proteins. These pockets are critical to the folding and regulation of protein. Amino acid side groups in these pockets interact by van der Waals forces. Non-polar atoms and molecules can have instantaneous dipoles.

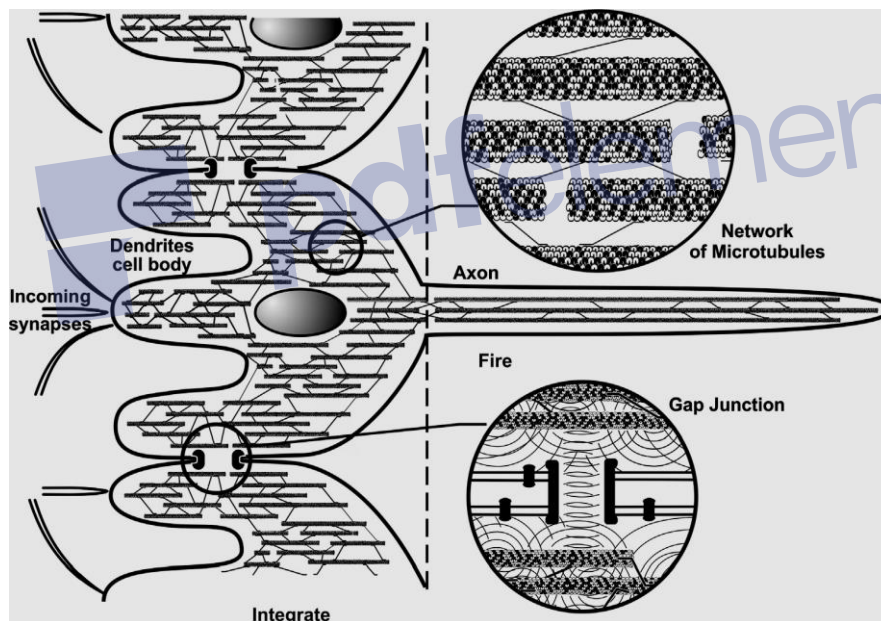


Fig.17 : An 'integrate-and-fire' brain neuron, and portions of other such neurons are shown schematically with internal microtubules. In dendrites and cell body/soma (left) involved in integration, microtubules are interrupted and of mixed polarity, interconnected by microtubule-associated proteins (MAPs) in recursive networks (upper circle, right). Dendritic-somatic integration (with contribution from microtubule processes) can trigger axonal firings to the next synapse. Microtubules in axons are unipolar and continuous. Gap junctions synchronize dendritic membranes, and may enable entanglement and collective integration among microtubules in adjacent neurons (lower circle right). In Orch OR, microtubule quantum computations occur during dendritic/somatic integration, and the selected results regulate axonal firings which control behavior

Hameroff discusses the process of anesthesia which erases consciousness, but leaves many non-conscious functions intact. Anesthetic gas molecules are soluble in a lipid-like hydrophobic environment. Such areas are present in the brain in the lipid regions of cell membranes and in hydrophobic pockets within proteins. It is suggested that anesthetic gas molecules interact with amino-acid groups via London forces, altering the normal action of London forces on the conformation of protein.

Hameroff discusses quantum information processing. Quantum superpositions where the quantum waves represent multiple possibilities for the state of a particle, are known to persist until quanta are either measured or naturally interact with the rest of the environment. Hameroff takes the view that the original mainstream interpretation, Copenhagen Interpretation, puts not only consciousness but the concept of reality itself outside physics. Alternatives interpretations include the 'many worlds' view, where there is no collapse but the superpositions continue in multiple worlds and David Bohm's idea in which the quanta are guided by active information.

It is important to stress that quantum computing as such is not expected to generate consciousness. In quantum computers, which many researchers, are now trying to develop quantum collapse will occur as a result of measurement or interaction with the environment. It is only in the event of OR that non-computability and consciousness could be brought into play.

Hameroff goes on to look at some of the detail of the theory that he and Penrose developed as to how consciousness could be based in microtubules in the brain. It is suggested that quantum computations take place in microtubules orchestrated by the inputs of synapse via MAPs. Hence the theory is often known as Orch OR for orchestrated objective reduction. The computations are suggested to persist for 25 ms, which would link them to the 40Hz gamma synchrony, viewed as a correlate of consciousness even in more mainstream theories. The computations are terminated by objective reduction. It is proposed that in dendrites, the tubulin sub-units of the microtubules interact by dipole coupling so as process information. The tubulin conformation is governed by quantum London forces, so that the tubulins can exist as quantum superpositions of different conformations. In superposition the tubulins would be qbits in a quantum computer, computing by means of non-local entanglement with other tubulin qbits. This entanglement would not just be with tubulins in the same microtubule, but other microtubules in the same dendrite, and in other dendrites connected by gap junctions. Neurons connected by gap junctions can be viewed as a single hyperneuron, and the hyperneuron can be seen as a conventional neuron assembly.

The dendritic interiors alternate between two states as a result of the polymerisation of actin protein. In the depolymerised form the interior of the neuron is aqueous and microtubules

signal and process information classically. There are synaptic inputs to the microtubules during this phase. When actin polymerises the interior of the dendrite becomes quasi-solid of gelatinous, and water near to the proteins becomes ordered as a result of the actin gelation. Debye layers of counterions may also shield the microtubules, due to the charged C-termini tails on the tubulins. This is suggested to make the microtubules sufficiently isolated from the environment for quantum superposition to occur in the tubulins. The geometry of a quantum computer lattice could be formed so as to be resistant to decoherence. Microtubules are suggested to have a structure which is particularly suitable for error correction. Coherent pumping of energy and quantum error correction may thus help to prevent decoherence. Quantum error correction involves a code that can detect and correct decoherence in a quantum system.

Hameroff claims to refute Tegmark's attempt to disprove the Penrose/Hameroff model, **(Hagan, et al, 2002)**. This is significant as Tegmark's criticism of Orch OR has been widely accepted as a completely satisfactory dismissal of the theory, and responses to Tegmark are habitually ignored. Tegmark calculated microtubule decoherence time as being 10^{-13} seconds, which would certainly be much too short for any neural activity. However, he worked on the basis of his own model for quantum activity in microtubules, which was never proposed by Hameroff or anyone else, basing his calculation on a 24nm separation of solitons from themselves along the microtubules, whereas Orch OR proposes a superposition separation distance six orders of magnitude smaller. For some reason, Tegmark did not choose to address the Penrose/Hameroff model. This invalidates his particular approach, whatever the truth is about decoherence, but somehow it has not prevented his work from being quoted as an absolutely reliable refutation of Orch OR **(Hagan, et al, 2002)**.

A recent update of the Orch OR model

A recent review and update of this 20-year-old theory of consciousness published in *Physics of Life Reviews*, 2013, persists to claim that consciousness derives from deeper level, finer scale activities inside brain neurons. The recent discovery of quantum vibrations in "microtubules" inside brain neurons corroborates this theory, according to review authors Stuart Hameroff and Sir Roger Penrose. This groundbreaking article, and some of the accompanying comments, are partly cited and summarized in the following:

“ Hameroff and Penrose suggest that EEG rhythms (brain waves) also derive from deeper level microtubule vibrations, and that from a practical standpoint, treating brain microtubule vibrations could benefit a host of mental, neurological, and cognitive conditions. Orch OR was harshly criticized from its inception, as the brain was considered too "warm, wet, and noisy" for seemingly delicate quantum processes. However, evidence has now shown warm quantum coherence in plant photosynthesis, bird brain navigation, our sense of smell,

and brain microtubules. The recent discovery of warm temperature quantum vibrations in microtubules inside brain neurons by the research group led by **Anirban Bandyopadhyay, 2011** at the National Institute of Material Sciences in Tsukuba, Japan (and now at MIT), corroborates the pair's theory and suggests that EEG rhythms also derive from deeper level microtubule vibrations. In addition, work from the laboratory of **Emerson and Eckenhoff et al, 2013**, at the University of Pennsylvania, suggests that anesthesia, which selectively erases consciousness while sparing non-conscious brain activities, acts via microtubules in brain neurons.

"The origin of consciousness reflects our place in the universe, the nature of our existence. Did consciousness evolve from complex computations among brain neurons, as most scientists assert? Or has consciousness, in some sense, been here all along, as spiritual approaches maintain?" ask Hameroff and Penrose in their current review. "This opens a potential Pandora's Box, but our theory accommodates both these views, suggesting consciousness derives from quantum vibrations in microtubules, protein polymers inside brain neurons, which both govern neuronal and synaptic function, and connect brain processes to self-organizing processes in the fine scale, 'proto-conscious' quantum structure of reality

After 20 years of skeptical criticism, "the evidence now clearly supports Orch OR," continue Hameroff and Penrose. " Our new paper updates the evidence, clarifies Orch OR quantum bits, or "qubits," as helical pathways in microtubule lattices, rebuts critics, and reviews 20 testable predictions of Orch OR published in 1998 - of these, six are confirmed and none refuted." An important new facet of the theory is introduced. Microtubule quantum vibrations (e.g. in megahertz) appear to interfere and produce much slower EEG "beat frequencies." Despite a century of clinical use, the underlying origins of EEG rhythms have remained a mystery. Clinical trials of brief brain stimulation aimed at microtubule resonances with megahertz mechanical vibrations using transcranial ultrasound have shown reported improvements in mood, and may prove useful against Alzheimer's disease and brain injury in the future.

Lead author Stuart Hameroff concludes, "Orch OR is the most rigorous, comprehensive and successfully-tested theory of consciousness ever put forth. From a practical standpoint, treating brain microtubule vibrations could benefit a host of mental, neurological, and cognitive conditions."

The review is accompanied by eight commentaries from outside authorities, including an Australian group of Orch OR arch-skeptics. To all, Hameroff and Penrose respond robustly. They will engage skeptics in a debate on the nature of consciousness, and Bandyopadhyay and his team will couple microtubule vibrations from active neurons to play Indian musical instruments. "Consciousness depends on an anharmonic vibrations of microtubules inside

neurons, similar to certain kinds of Indian music, but unlike Western music which is harmonic".

Hameroff explained that consciousness depends on biologically 'orchestrated' coherent quantum processes in collections of microtubules within brain neurons, that these quantum processes correlate with, and regulate, neuronal synaptic and membrane activity. The continuous Schrödinger evolution of each such process is supposed to terminate in accordance with the specific Diósi–Penrose (DP) scheme of 'objective reduction' ('OR') of the quantum state. This orchestrated OR activity ('Orch OR') is taken to result in moments of conscious awareness and/or choice. The DP form of OR is related to the fundamentals of quantum mechanics and space–time geometry, so Orch OR suggests that there is a connection between the brain's biomolecular processes and the basic structure of the universe. The authors recently reviewed the Orch OR in light of criticisms and developments in quantum biology, neuroscience, physics and cosmology (**Hameroff and Penrose, 2012**).

The authors introduce a novel suggestion of 'beat frequencies' of faster microtubule vibrations as a possible source of the observed electro-encephalographic ('EEG') correlates of consciousness. They conclude that consciousness plays an intrinsic role in the universe. The group of **Bandyopadhyay, 2011** has indeed discovered conductive resonances in single microtubules that are observed when there is an applied alternating current at specific frequencies in gigahertz, megahertz and kilohertz ranges. Electron dipole shifts do have some tiny effect on nuclear positions via charge movements and Mossbauer recoil. A shift of one nanometer in electron position might move a nearby carbon nucleus a few femtometers ('Fermi lengths', i.e. 10^{-15} m), roughly its diameter. The effect of electron spin/magnetic dipoles on nuclear location is less clear. (**Fig.18**)

Recent Orch OR publications have cast tubulin bits (and quantum bits, or qubits) as coherent entangled dipole states acting collectively among electron clouds of aromatic amino acid rings, with only femtometer conformational change due to nuclear displacement (**Fig.13**). As it turns out, femtometer displacement might be sufficient for Orch OR/ Diósi–Penrose objective reduction (DP) is a particular proposal for an extension of current quantum mechanics, taking the bridge between quantum- and classical-level physics as a 'quantum-gravitational' phenomenon. This is in contrast with the various conventional viewpoints, whereby this bridge is claimed to result, somehow, from 'environmental decoherence', or from 'observation by a conscious observer', or from a 'choice between alternative worlds', or some other interpretation of how the classical world of one actual alternative may be taken to arise out of fundamentally quantum-superposed ingredients.

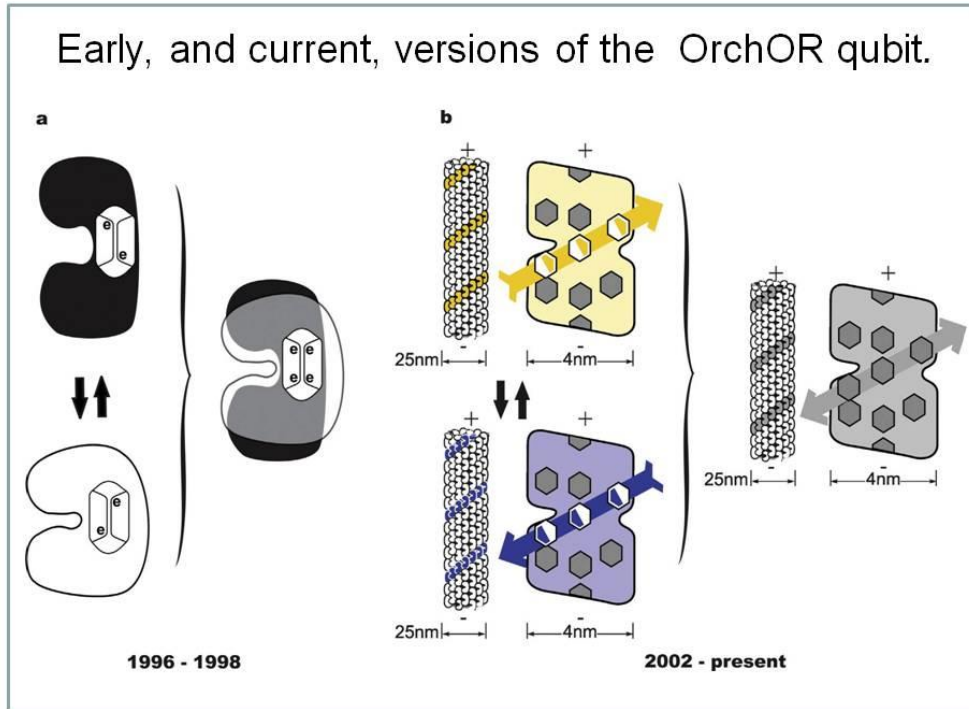


Fig.18 : Early, and current, versions of the OrchOR qubit. (a) Schematic cartoon version of OrchOR tubulin protein qubit used in OrchOR publications mainly from 1996 to 1998. On left, tubulin oscillates between 2 states with 1 nanometer conformational flexing (10% tubulin diameter). On right, both states exist in quantum superposition. (Irrespective of the schematic cartoon the 1 nanometer displacement has never been implemented in OrchOR calculations). The states are shown to correlate with electron locations (dipole orientations) in two adjacent phenyl (or indole) resonance rings in a non-polar 'hydrophobic pocket'. **(b)** Schematic cartoon version of the OrchOR qubit developed since 2002 (following identification of tubulin structure by electron crystallography). Each tubulin is shown to have 9 rings representing 32 actual phenyl or indole rings per tubulin, with coupled, oscillating London force dipole orientations among rings traversing 'quantum channels', aligning with rings in adjacent tubulins in helical pathways through microtubule lattices. On the right, superposition of alternative tubulin and helical pathway dipole states. There is no conformational flexing. Mechanical displacement occurs at the femtometer level of tubulin atomic nuclei (not shown). Reimers et al. continually, and exclusively, criticize the obsolete, non-implemented version on left (a), and ignore the actual OrchOR dipole pathway qubit version on right (b).

The DP version of OR involves a different interpretation of the term 'quantum gravity' from what is usual. Current ideas of quantum gravity (see, for example, **Smolin, 2004**, normally refer, instead, to some sort of physical scheme that is to be formulated within the bounds of standard quantum field theory – although no particular such theory, among the multitude that has so far been put forward, has gained anything approaching universal acceptance, nor has any of them found a fully consistent, satisfactory formulation. 'OR' here refers to the alternative viewpoint that standard quantum (field) theory is not the final answer, and that the reduction R of the quantum state ('collapse of the wave function') that is adopted in standard quantum mechanics is an *actual* physical process which is not part of the conventional unitary

formalism U of quantum theory (or quantum field theory). In the DP version of OR, the reduction R of the quantum state does not arise as some kind of convenience or effective consequence of environmental decoherence, etc., as the conventional U formalism would seem to demand, but is instead taken to be one of the consequences of melding together the principles of Einstein's general relativity with those of the conventional unitary quantum formalism U, and this demands a departure from the strict rules of U. According to this OR viewpoint, any quantum measurement—whereby the quantum-superposed alternatives produced in accordance with the U formalism becomes reduced to a single actual occurrence—is a *real* objective physical process, and it is taken to result from the mass displacement between the alternatives being sufficient, in gravitational terms, for the superposition to become unstable.

It is helpful to have a conceptual picture of quantum superposition in a gravitational context. According to modern accepted physical theories, reality is rooted in 3-dimensional space and a 1-dimensional time, combined together into a 4-dimensional *space-time*. This space-time is slightly curved, in accordance with Einstein's general theory of relativity, in a way which encodes the gravitational fields of all distributions of mass density. Each different choice of mass density effects a space-time curvature in a different, albeit a very tiny, way. This is the standard picture according to *classical* physics. On the other hand, when *quantum* systems have been considered by physicists, this mass-induced tiny curvature in the structure of space-time has been almost invariably ignored, gravitational effects having been assumed to be totally insignificant for normal problems in which quantum theory is important. Surprising as it may seem, however, such tiny differences in space-time structure *can* have large effects, for they entail subtle but fundamental influences on the very rules of quantum mechanics'.

The initial part of each space-time is at the upper left of each individual space-time diagram, and so the bifurcating space-time diagram on right moving downward and rightward illustrates two alternative mass distributions evolving in time, their space-time curvature separation increasing. mechanically (so long as OR has not taken place), the 'physical reality' of this situation, as provided by the evolving wavefunction, is being illustrated as an actual superposition of these two slightly differing space-time manifolds, The OR process is considered to occur when quantum superpositions between such slightly differing space-times take place differing from one another by an integrated space-time measure which compares with the fundamental and extremely tiny Planck (4-volume) scale of space-time geometry. As remarked above, this is a 4-volume Planck measure, involving both time and space, so we find that the time measure would be particularly tiny when the space-difference measure is relatively large (as with Schrödinger's hypothetical cat), but for extremely tiny space-difference measures, the time measure might be fairly long. For example, an isolated single electron in a superposed state (very low EGEG) might reach OR threshold only after

thousands of years or more, whereas if Schrödinger's (~10 kg) cat were to be put into a superposition, of life and death, this threshold could be reached in far less than even the Planck time of 10^{-43} s (Fig.19)

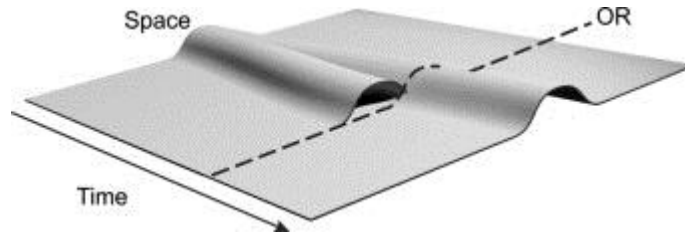


Fig. 19: As superposition curvature E reaches threshold, OR occurs and one particle location/curvature is selected, and becomes classical. The other ceases to exist.

In the situations under consideration here, where we expect a conscious brain to be at far from zero temperature, and because technological quantum computers require zero temperature, it is very reasonable to question quantum brain activities. Nevertheless, it is now well known that superconductivity and other large-scale quantum effects can actually occur at temperatures very far from absolute zero. Indeed, biology appears to have evolved thermal mechanisms to *promote* quantum coherence. **Ouyang and Awschalom, 2003** showed that quantum spin transfer through phenyl ring π orbital resonance clouds (the same as those in protein hydrophobic regions, as illustrated in **Fig.14**, are enhanced at increasingly warm temperatures. Spin flip currents through microtubule pathways, , may be directly analogous.)

In the past 6 years, evidence has accumulated that plants routinely use quantum coherent electron transport at ambient temperatures in photosynthesis **Engel et al, 2007 and Hildner, 2013**. Photons are absorbed in one region of a photosynthetic protein complex, and their energy is conveyed by electronic excitations through the protein to another region to be converted to chemical energy to make food. In this transfer, electrons utilize multiple pathways simultaneously, through π electron clouds in a series of chromophores (analogous to hydrophobic regions) spaced nanometers apart, maximizing efficiency (e.g. via so-called 'exciton hopping'). Chromophores in photosynthesis proteins appear to enable electron quantum conductance precisely like aromatic rings are proposed in Orch OR to function in tubulin and microtubules.

Quantum conductance through photosynthesis protein is enhanced by mechanical vibration, and microtubules appear to have their own set of mechanical vibrations (e.g. in megahertz as suggested by **Sahu et al., 2013**. Megahertz mechanical vibrations is ultrasound, and brief, low intensity (sub-thermal) ultrasound administered through the skull to the brain modulates electrophysiology, behavior and affect, e.g. improved mood in patients suffering from chronic pain, perhaps by direct excitation of brain microtubules

Further research has shown warm quantum effects in bird-brain navigation, **Gaucher et al, 2011**, ion channels **Benroider and Roy, 2005**, sense of smell **Turin, 1996**, DNA, **Rieper, 2011**, protein folding, **Luo and Lu, 2011**, and biological water, **Reiter, 2013** (see also the reviews of **Arndt, 2009** and **Lloyd, 2011 on these aspects**). What about quantum effects in microtubules? In the 1980s and 1990s, theoretical models predicted 'Fröhlich' gigahertz coherence and ferroelectric effects in microtubules. In 2001 and 2004, coherent megahertz emissions were detected from living cells and ascribed to microtubule dynamics (powered by mitochondrial electromagnetic fields) by the group of Jiri Pokorný in Prague .

Beginning in 2009, **Anirban Bandyopadhyay** and colleagues at the National Institute of Material Sciences in Tsukuba, Japan, were able to use nanotechnology to address electronic and optical properties of individual microtubules (**Sahu et al, 2013 a,b**). The group has made a series of remarkable discoveries suggesting that quantum effects do occur in microtubules at biological temperatures. First, they found that electronic conductance along microtubules, normally extremely good insulators, becomes exceedingly high, approaching quantum conductance, at certain specific resonance frequencies of applied alternating current (AC) stimulation. These resonances occur in gigahertz, megahertz and kilohertz ranges, and are particularly prominent in low megahertz (e.g. 8.9 MHz). Conductances induced by specific (e.g. megahertz) AC frequencies appear to follow several types of pathways through the microtubule – helical, linear along the microtubule axis, and 'blanket-like' along/around the entire microtubule surface. Second, using various techniques, the Bandyopadhyay group also determined AC conductance through 25-nm-wide microtubules is greater than through single 4-nm-wide tubulins, indicating cooperative, possibly quantum coherent effects throughout the microtubule, and that the electronic properties of microtubules are programmed within each tubulin. Their results also showed that conductance increased with microtubule length, indicative of quantum mechanisms (**Fig. 20**).

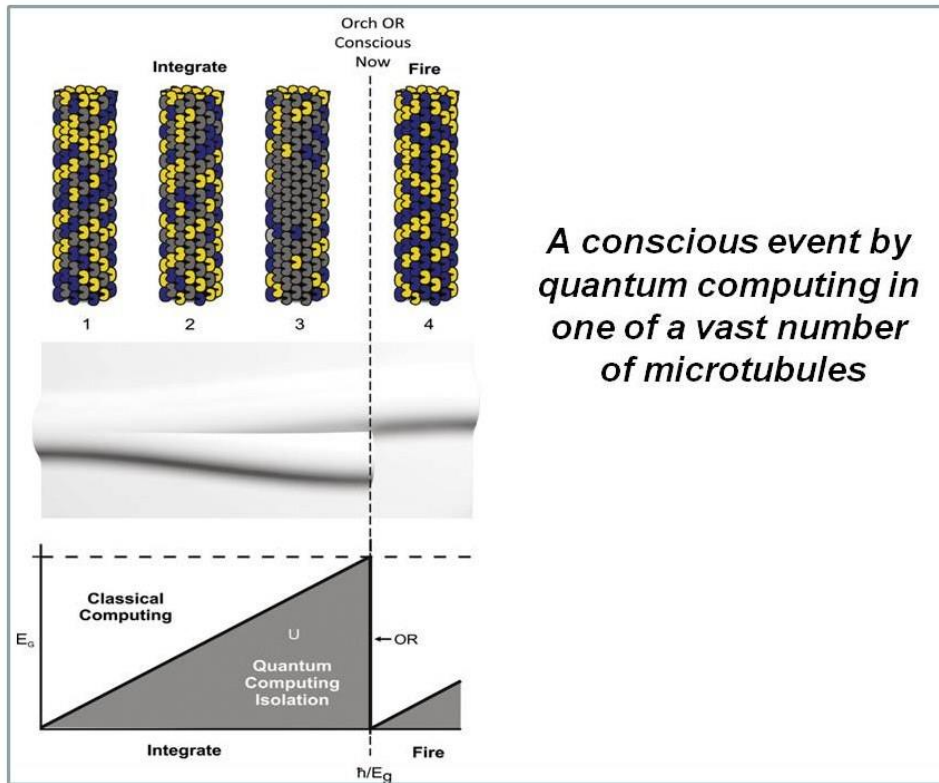


Fig.20: Top: Tentatively proposed picture of a conscious event by quantum computing in one of a vast number of microtubules all acting coherently so that there is sufficient mass displacement for Orch OR to take place. Tubulins are in classical dipole states (yellow or blue), or quantum superposition of both dipole states (gray). Quantum superposition/computation evolves during integration phases (1-3) in integrate-and-fire brain neurons, increasing quantum superposition E G E G (gray tubulins) until threshold is met, at which time a conscious moment occurs, and tubulin states are selected which regulate firing and control conscious behavior. **Middle:** Corresponding alternative superposed space-time curvatures reaching threshold at the moment of OR and selecting one space-time curvature. **Bottom:** Schematic of a conscious Orch OR event showing U-like evolution of quantum superposition and increasing E G E G until OR threshold is met, and a conscious moment occurs .

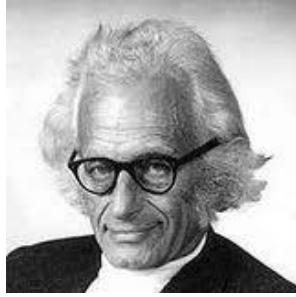
The resonance conductance ('Bandyopadhyay coherence' - 'BC') through tubulins and microtubules is consistent with the intra-tubulin aromatic ring pathways (**Fig. 13**), which can support Orch OR quantum dipoles, and in which anesthetics bind, apparently to selectively erase consciousness. Bandyopadhyay's experiments do seem to provide clear evidence for coherent microtubule quantum states at brain temperature. This said, solid scientific evidence (microtubules and the rest) is not yet completely convincing and one is left with the desire to contribute to the whole intellectual construction in order, not to leave it in its present state. Anyhow, certain parts of the mosaic are particularly appealing: the fact for instance that anesthetic gas exert their effects on consciousness, and that actual evidence from genomics and proteomics point to anesthetic action in microtubules. As Faraday said, it is always better to have a partial vision of the facts rather than having none.

Some could, on the contrary, be fully convinced of the existence and function of objective reductions of the quantum states occurring in and orchestrated by biological structures. Of these, microtubules would represent the most efficient and evolutionary winning example, consciousness being the most visible of its non-epiphenomenal phenotypes. As a novel suggestion relative to their previous studies, “beat frequencies” are introduced by Hameroff and Penrose as a possible source of the observed electro-encephalographic (EEG) correlates of consciousness.

Introducing quantum physics into the realm of biology entails another major positive aspect: room is made for Darwinism and Chance-and-Necessity reasoning. Biological structures as microtubules evolved (well within Darwinian logics) which occurred to cause objective reduction of the quantum state. Once Darwin enters the scene, everything becomes possible. Our mind provides the a posteriori verification. For a deeper look at this concept, the reader is referred to the elaboration of the terms “Ereignis” and “Ereignen” by Martin Heidegger. The basic Hameroff and Penrose assumption would in this case objectively become of paramount importance. The Hameroff-Penrose form of orchestrated objective reduction(**Hameroff and Penrose, 2011, 2013**) is related to the fundamentals of quantum mechanics and space-time geometry. Hence the connection between the basic structure of the Universe and biomolecular processes. Relating these effects to neurons might appear an unjustified self-inflicted limitation and, in this perspective, the general conclusion should not be avoided: consciousness is a property and a manifestation of life, life is universal in principle. Thus, consciousness is in principle universal”.

A note of caution: Roger Penrose himself recently said: “I don’t see why we should take quantum mechanics as sacrosanct. I think there’s going to be something else which replaces it”. These words, if they can be considered as not being out-of-context, find their explanation in the incompleteness of quantum theory. The awareness of this incompleteness is at the very basis of the Orch OR Theory and is reappearing throughout this important essay.

Hiroomi Umezawa and Herbert Frohlich: Quantum Brain Dynamics



Hiroomi Umezawa Herbert Fröhlich

The basic concept in quantum brain dynamics (QBD) is that the electrical dipoles of the water molecules in the brain constitute a cortical field. The quanta of this field are described as corticons. The field interacts with quantum coherent waves propagating along the neuronal network. There is more than one view within QBD as to how this system supports or instantiates consciousness.

The ideas behind quantum brain dynamics (QBD) derived originally from the physicists, Hiroomi Umezawa and Herbert Fröhlich in the 1960s. In the last 20 years, these ideas have been elaborated and given greater prominence by the combined efforts of Japanese physicists, **Mari Jibu and Kunio Yasue, 1992, 1993** and the Italian physicist, **Giuseppe Vitiello, 1995, 2001**.

Iain Stuart, Umezawa and Yasushi Takahashi (1978) proposed the idea of a cortical field in the brain. Water comprises 70% of the brain, and QBD proposes that rather than providing a passive background, water could be an active player in brain processes. Water molecules have a constant electric dipole, and are considered in QBD to be capable of interacting with waves generated by biomolecules that are also electrical dipoles.

In QBD, the totality of the water molecules in the brain is viewed as the best candidate for a cortical field, with the water's electrical dipoles binding both to one another and to the biomolecules of the neuronal network. There are also suggested to be long-range waves within the cortical field. The quanta of the cortical field are given the name of corticons, and in Jibu and Yasue's version of the theory, the interaction between the cortical field and the neuronal network, particularly the dendritic part of that network, is the basis of consciousness.

The other half of the theory refers to biomolecules propagating through the neuronal network, an idea deriving from the work of **Frohlich, 1968**. Frohlich argued that it was not clear how order was sustained in living systems, given the likely disrupting effect of the fluctuations in

biochemical processes (**Frohlich, 1985**). His ideas relate mainly to the ordering of the neuronal network, on which the proposed cortical network of Umezawa is proposed to act.

Frohlich saw the electric potential across the cell membrane as the macroscopic observable of an underlying quantum order. Frohlich's studies claim to show that with oscillating electrical charges in a thermal bath, a large number of quanta may become condensed into a single state, known as a Bose condensate, allowing long-range correlations amongst the dipoles involved. He also proposed that biomolecules with a high electric dipole moment line up along the actin filaments, and that electric dipole oscillations propagate along these filaments in the form of quantum coherent waves. There is some support for these ideas, in the form of experimental confirmation that biomolecules with high electric dipole moment have a periodic oscillation (**Gray and Singer, 1989**).

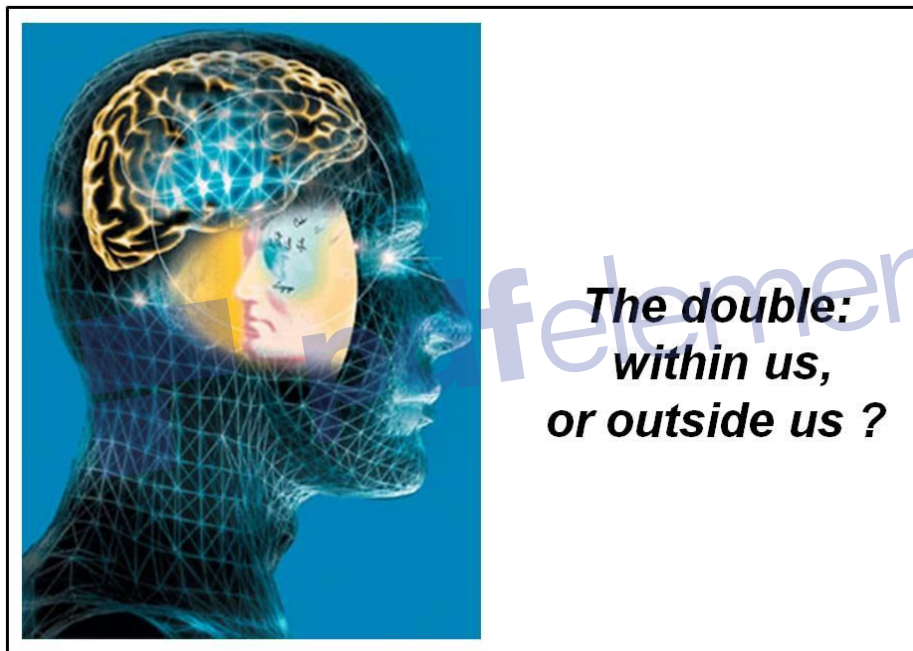


Fig.21: The hypothesis of an individual double as created by our mind

Vitiello agrees with Frohlich in arguing that living systems constitute ordered chains of chemical reactions, which could normally be expected to collapse in the random chemical environment of biological tissue. In Vitiello's view stable ordering comes from the quantum level, but this is described by quantum field theory rather than quantum mechanics. He also claims that the folding of protein, which is fundamental to the activity of cells, cannot be described by classical physics, but could be quantum ordered. **Vitiello, 1995, 2001** provides citations, which he feels support a quantum dynamical view of biological tissue, notably studies of radiation effects on cell growth, on electromagnetic fields and stress, on dynamical response to external stimuli, on non-linear tunnelling, on coherent nuclear motion in

membrane proteins, on optical coherence in biological systems, on weak radiation fields and biological systems by (Popp, 1986) and on energy transfer via solitons and coherent excitations. QBD proposes that the cortical field not only interacts with, but also to a good extent controls the neuronal network. It suggests that biomolecular waves propagate along the actin filaments, an important part of the cytoskeleton, particularly in the vicinity of the cell membrane and dendritic spines. The waves derive energy from ATP molecules stored in the membrane, and these in turn are controlled by calcium ions. These waves are also suggested to control the action of ion channels, which are crucial in the transmission of signals to the synapses. The neurons membrane is further suggested to act as a Josephson junction providing insulation between two layers of superconductivity. The superconductivity current across the membrane can be controlled by the electrical potentials across the same membrane.

Vitiello also discusses the question of quantum decoherence. He claims that QBD only requires quantum oscillations to last 10-14 picoseconds, which should be much shorter than the period required for decoherence (Del Giudice, 1988, 2002). In common with Stuart Hameroff, he additionally argues that ordered water around protein molecules may shield them from the surrounding thermal bath.

A decisive further step in developing the approach has been achieved by taking *dissipation* into account. Dissipation is possible when the interaction of a system with its environment is considered. Vitiello (1995) describes how the system-environment interaction causes a doubling of the collective modes of the system in its environment (Fig.21). This yields infinitely many differently coded vacuum states, offering the possibility of many memory contents without overprinting. Finally, dissipation generates a genuine arrow of time for the system, and its interaction with the environment induces entanglement. In a recent contribution, Pessa and Vitiello (2003) have addressed additional effects of chaos and quantum noise.

Mari Jibu & Kunio Yasue: Quantum field concepts



Mari Jibu,



Kunio Yasue



Giuseppe Vitiello

Jibu and Yasue (1992, 1993) appear to see consciousness as simply a function of the interaction of the corticons, the energy quanta which are proposed to arise in the cortical field, with the biomolecular waves of the neuronal network. Vitiello, while thinking in terms of much the same quantum systems as Jibu and Yasue, proposes that these quantum states produce two poles, first a subjective representation of the external world and secondly a self, which opens itself to this representation of the external world. According to Vitiello's version of the theory, consciousness is not strictly speaking in either the self or the external representation but between the two, in the opening of one to the other.

The concepts derive from the Japanese physicist, **Hiroomi Umezawa, 1993** who speculated that understanding the processes of memory in the brain would involve quantum field theory. This led onto the idea that understanding consciousness would also involve quantum field theory. The first four chapters of their book in 1993 provide a standard background to quantum theory and neuroscience. Those without some grounding would be better advised to look at more standard text books or popularizations, as the style of the book is generally difficult and unnecessarily repetitive. The first four chapters of the book deal with quantum theory. For those not familiar with this, there are many much more comprehensible descriptions. This is followed by some descriptive passages on the brain, which is again better described elsewhere.

Getting beyond these introductory stages, the authors make the same point as others in stressing the estrangement between physics, where fundamental new views of nature emerged during the last hundred years and neuroscience which has remained largely wedded to 19th century physics. In particular physics has tended to think dynamically, in terms of controlled changes. Physics deals primarily with the inanimate, but the concepts of dynamics can be applied to living organisms, as they also undergo controlled changes. The authors suggest that the functions of the cortex might be better understood through the dendritic network, by which information enters cells. They stress that many neurons in the cortex do not have axons but only dendrites. They think that the conventional processing system described in the axon-neurotransmitter-dendrite system may overlook other networks in the brain. Neurons without axons are the majority in the cortex and the authors see these as the likely basis of consciousness.

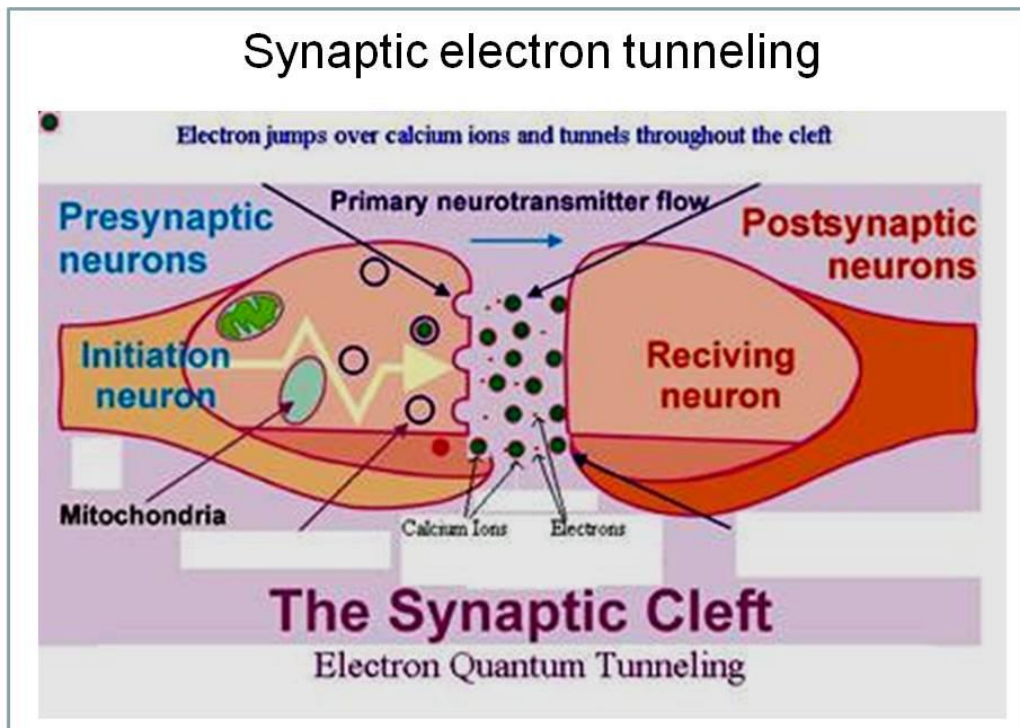


Fig.22: Schematic representation of the synapse and synaptic cleft with the element of quantum tunneling of electrons(a) and dendritic network (b)

The authors discuss the dendritic network at length. They point out that it is much more sophisticated than the axonal network (Fig. 18). The dendritic membrane comprises biomolecules with electric dipoles, the positive poles of the membrane are aligned on the inner surface and the negative poles on the outer surface. The negative poles on the outer surface attract positive ions, while the positive poles on the inner surface attract negative ions. The regions where these interactions occur are called Debye layers. The dendrites of several neurons are often entangled in a network. Chemical synapses are located on the tips of dendritic spines and there are emphases on the dendritic membranes. In such processes even quantum tunneling may play a significant role (Fig.22).

Since the 1970s, Evan Harris Walker has proposed that quantum tunneling of electrons would take place across junctions between Neurons. Stuart Hameroff says that "... Gap junctions enable quantum tunneling among dendrites ...". According to principles of modern physics: if a particle such as an electron encounters a barrier such as the synaptic junction, there is a finite probability that the particle will ... be found on the other side ... From the point of view of Bohm's pilot wave quantum theory, Peter R. Holland says that quantum tunneling is explained because the effective barrier potential is not the classical barrier potential, but is the quantum potential. From the many-worlds point of view, quantum tunneling means that the electron is in a superposition of position states, some of which are

on one side of the junction and some of which are on the other side. Therefore quantum tunneling can also allow quantum superposition states to extend from neuron to neuron across gap junctions.

There is experimental confirmation that biomolecules of high electric dipole moment have a periodic oscillation (**Fröhlich, 1968**). The authors suggest that these oscillations are crucial to the functioning of the brain. This can be called wave cybernetics, because the wave or biomolecule oscillation is seen as the controlling factor in the brain.

Fröhlich proposed a theory where biomolecules with high electric dipole moment line up along the actin filaments immediately below the cell membrane, while electric dipole oscillations propagate along each filament as coherent waves. These are maintained by electrons trapped in and moving along the protein molecules. This is now known as a Fröhlich wave. These waves exchange energy with the electromagnetic field. **Stuart, Umezawa, and Takahashi, 1978** proposed the idea of a cortical field. This interacts with the macroscopic dynamics of the main neural network, which in turn transmits signals to the body tissues. The filamentous strings found in the cells also extend outside the cells forming an extracellular matrix that is also linked to the cell membrane. So the membrane proteins are linked both to the cytoskeleton and the extracellular matrix.

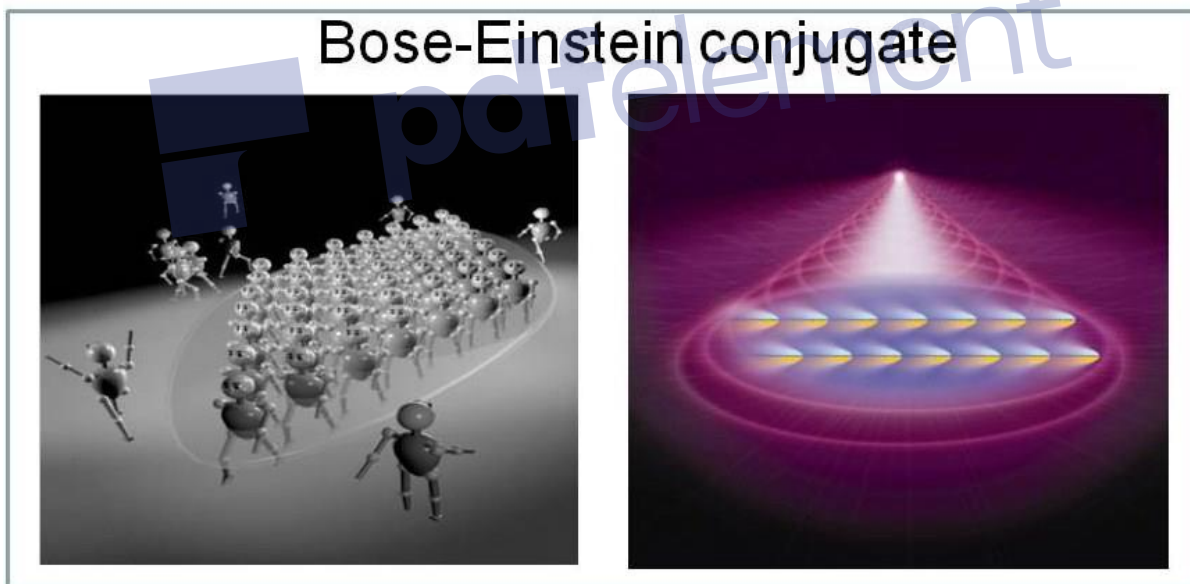


Fig.23: Cartoons of, so called, Bose -Einstein conjugates

The authors propose that Fröhlich waves propagate along the filamentous strings. The waves are produced by energy stored in ATP molecules at membrane protein sites, which are in turn controlled by calcium ions. The waves also effect the operation of ion channels, which control neural impulses. The authors suggest that this structure can give rise to a macroscopic quantum phenomena, similar to superconductivity. They also regard the cell membrane as an

insulating layer between two areas of superconductivity, otherwise known as a Josephson junction. This means that superconductivity current across the Josephson Junction can be controlled by electric potential differences in the insulating layer.

The authors suggest that this quantum activity may facilitate the functioning of the brain and in particular an interface between the proposed cortical field and the neurons network. The cortical field is proposed to contain energy quanta behaving as particles, which the authors call corticons. Corticons are suggested to exist everywhere in the cerebral cortex. The interface between the cortical field and the neuron network takes place in the waves propagating along the filamentous strings in the cytoskeleton and the extracellular matrix.

The authors emphasize the nature and importance of water within the brain. They suggest that water is not just a background substance, but is an active component in cell assemblies. This idea lies behind the original concept of the cortical field and corticons. The water molecule has a constant electrical dipole. It also has a symmetrical form that is invariant under reflection. The molecule rotates around its symmetry axis, which is the electrical dipole. Thus the molecule is a quantum mechanical spinning top, which interacts with the fields generated by biomolecules.

The totality of water molecules in the brain is seen as the best candidate for the sought for cortical field. In water, one side of the molecule becomes negatively charged, and one side positively charged creating an electric dipole. This is an attraction between molecules known as hydrogen bonding. The attraction is both between water molecules and between water molecules and other molecules with electrical dipoles. Biomolecules such as proteins have constant electric dipoles and connect to water molecules.

The cortical field is identified with the water rotational field, created by the spinning dipoles of the water molecules. The field on the cytoskeleton and extracellular matrix is proposed to be a Bose field (**Fig. 23**), and the interaction between this Bose field and the corticons of the cortical field is seen as the basis of consciousness. Corticons are identified with the energy quanta of the water rotational field of the brain. The corticons interact with each other by emitting and absorbing the exchange bosons of the Bose field, and are themselves the energy quanta of the water rotational field. The water rotational field is a dipole field and therefore interacts with an electromagnetic field. There are also suggested to be long-range correlation waves in the water rotational field of the brain.

The brain structures described here are thought to be sensitive to and to modify themselves in responses to information coming into the brain. The combined dynamics of the cortical field and the electromagnetic field comprise what the authors describe as quantum brain dynamics (QBD). The dynamics of the corticons is thought to be capable of controlling the dendritic and

neural networks. The authors think that the creation and annihilation of corticons in the QBD is what is called consciousness.

Unfortunately the authors do not explain why they think this, and therefore like more mainstream theories of consciousness, the actual consciousness seems to be created by fiat. There is no more apparent reason why consciousness should arise from this physical interaction than from the physical interaction of electrical potentials and chemical in the synapses. The authors could have suggested that consciousness was a fundamental property of photons or of the proposed corticons or of particular fields but they do not do this.

Johnjoe McFadden: Electromagnetic fields in brain



McFadden starts by stating that synchronous firing in the brain correlates with awareness and perception indicating that disturbances in the brain's electromagnetic field also correlate with these. This field is a representation of neuronal information and its dynamics could be seen as a correlate of consciousness. **McFadden, 2001** views this field as the physical substrata of consciousness. **Popper, 1997 and Libet, 2006** have both suggested that consciousness might derive from an overarching field that could integrate the processing of neurons, but they did not think that this could be any known physical field. At the same time, there has been considerable interest in synchronous firing of neurons. Awareness has been shown to correlate with the synchrony of firing in the 40-80Hz range, and this may bind together neurons involved in different aspects of the same visual perception, thus creating the unity of consciousness (**Fig.24**).

The brain's electromagnetic field is induced by neuron firing, and also the movement of ions involved in the fluctuation of electrical potential along the cell membrane. The structure of the cortex tends to amplify the induced field. Experiments in the olfactory bulb have demonstrated EEG activity in response to sensory stimuli. Information about the stimuli related to the spatial pattern of the EEG amplitude.

The author concludes that the brain contains a highly structured extracellular electromagnetic field. The field is weak with the trans membrane fields being about 3,000 times stronger. It is suggested that neurotransmission through gap junctions may be voltage dependent and therefore sensitive to local fields. However, McFadden prefers to concentrate on the voltage-gated ion channels in the cell membranes, because their role is better understood. Synchronous firing is thought to be due to a large number of spatially distributed neurons. It is thought that many millions of neurons could be influenced by such firing. McFadden claims evidence for neuron communication via the electromagnetic field.

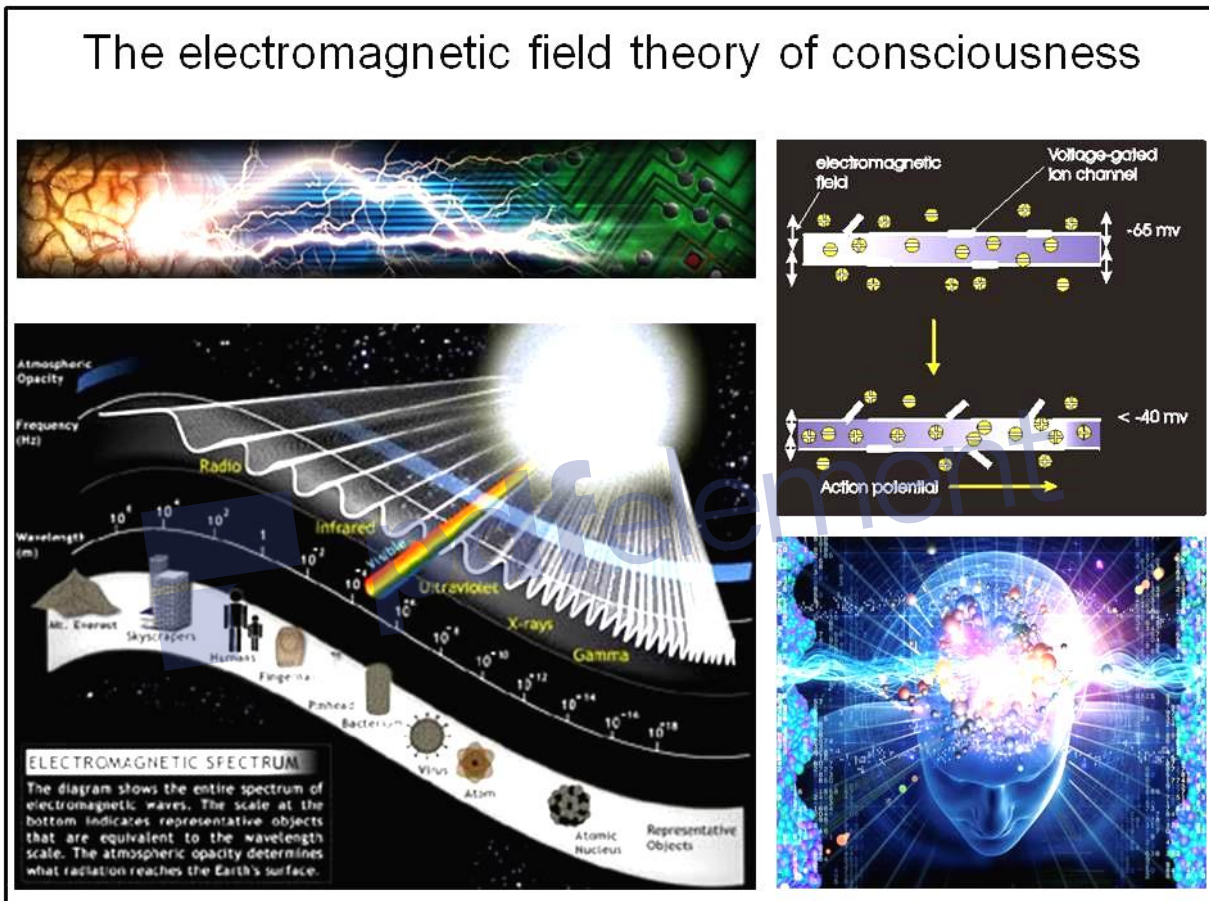


Fig. 24: The electromagnetic field theory of consciousness as part of an integral electromagnetic spectrum

The medical use of trans cranial magnetic stimulation (TMS) is taken to indicate the sensitivity of the brain to weak electromagnetic fields, and as this has impacts on behavior, it is argued to impact neuronal computation and neuronal function. Even when fields are weaker than the surrounding noise, they can modulate neurons. The brain's electromagnetic field is argued to hold the same information as the neuron firing patterns. The widespread of the electromagnetic field would help to explain the unity of consciousness.

Clusters of neurons in the visual cortex have been shown to fire in synchrony in response to particular stimuli. With insects, destruction of synchronous firing has been shown to reduce the ability to discriminate between stimuli. There is indirect evidence for the correlation between synchronous firing and attention and awareness in humans. The olfactory system of rabbits shows that the sensory information is encoded in the spatial pattern of the EEG, and therefore of the electromagnetic field. This correlation also reflected what a particular smell meant to the rabbit, when it had been trained to associate particular things with a smell. This suggested that the shape of the electromagnetic field could be related to perception and meaning. This is taken to suggest that consciousness is related to the electromagnetic field. Where there is habituation with a process and therefore less conscious activity there is a reduction in synchronous firing, so loss of awareness correlates with reduced disturbance in the brain's electromagnetic field. The theory predicts that only activity that acts on the motor neurons is conscious. This is testable, although there is no direct evidence. The EEG shows that activity increases during creative thinking, declines with sleep but revives with REM dreaming, so the amount of conscious activity correlates with the amount of electromagnetic activity.

The high conductivity of the cerebral fluid in the brain ventricles makes the brain into a kind of Faraday's cage, insulating it from external electrical fields. However, it is much easier for magnetic fields to penetrate the brain and other tissues. Moving magnetic fields, such as those used in TMS do produce effects in the brain.

Mc Fadden and the function of consciousness

McFadden sides with those who argue that consciousness must have a function or evolution would not have selected for it. Field effects that had an advantageous effect on the performance of ion channels would have been selected for. McFadden thinks that there is information transfer between neurons during synchronous firing. He proposes that the neural circuits involved in conscious and unconscious activity differ in their sensitivity to the electromagnetic field. The conscious will is claimed to be our experience of the electromagnetic field. He thinks that consciousness is not actually the electromagnetic field, but its ability to transmit information to neurons. He also points out the difficulty of trying to perform two conscious tasks or a conscious and unconscious task at the same time. The two interfere with each other, while unconscious multi-tasking is possible.

Consciousness is required for the laying down of long-term memories and for most learning. The Cemi field theory conceives that the electromagnetic field in the brain fine tunes the probabilities of neuron firings. The affected neurons may be part of large connected assemblies, and this leads to memory and learning. In simulated networks non-synaptic neuronal interactions via the electromagnetic field and also gap junctions enhance learning.

Modulation of long term potentiation by electromagnetic fields has also been demonstrated in vitro in rat hippocampal slices.

McFadden and Free will

The author claims that free will is the subjective experience of the influence of the cemi field on neurons. However, the influence of the cemi field is seen as entirely deterministic. The fluctuations in the field that are capable of modulating the firing of neurons would all be generated by changing patterns of electrical activity, while the neurons themselves induce the field. The author admits that there might be some element of random quantum fluctuations in the field, but this randomness is unsuitable for producing free will.

The author, in common with others in consciousness studies, tries to have it both ways at this point. The functioning of the brain is claimed to be entirely deterministic, but something called 'will' is active in driving our conscious actions. This appears to be a clear contradiction, since the whole idea of will is an agent which initiates something of its own accord.

The Cemi theory is trying to provide a plausible explanation of consciousness. The author could have said that consciousness was a fundamental property of electrical charge, or individual charged particles, or the photons that intermediate it, thus making it a primitive or a brute fact of the universe. But he does not do this. He says that our conscious will is our experience of the influence of the Cemi field. This seems to raise a host of questions and contradictions. If the Cemi field isn't conscious itself, who or what is experiencing it's influence. This suggests a dualistic non-physical entity that experiences the action of the field. Even if we are happy with this concept it is not clear why this particular set of electromagnetic fields should produce this experience for this entity.

Like many before him, McFadden suddenly declares by fiat that one particular part of the otherwise ordinary material of the brain produces consciousness. Again, it is reasonable to say that evolution selected for a particular type of field that could fine tune the neurons, but the additional production of a feeling of free will, which is false has no demonstrable value.

Gustav Bernroider: Ion channel coherence



Ion channels are a crucial component in the axonal spiking/synaptic firing model of neuronal signaling and information processing. The axonal signal starts from the body of the neuron and proceeds down an extension called the axon, by means of a fluctuation in the difference in electrical potential across the membrane that forms the exterior of the axon. The membrane is formed by a double layer of lipids. The ion channels consist of protein molecules inserted through the lipid bi-layer. The axon fires when sodium (Na^+) ions flow in through one set of ion channels, and subsequently returns to its resting state when potassium (K^+) ions flow out through another set of ion channels. This process continues down the length of the axon until it reaches the synapse, which it allows to fire, and thus communicate with other neurons. Ion channels are thus a key mechanism in the brain's signaling and information processing (see Fig. 25).

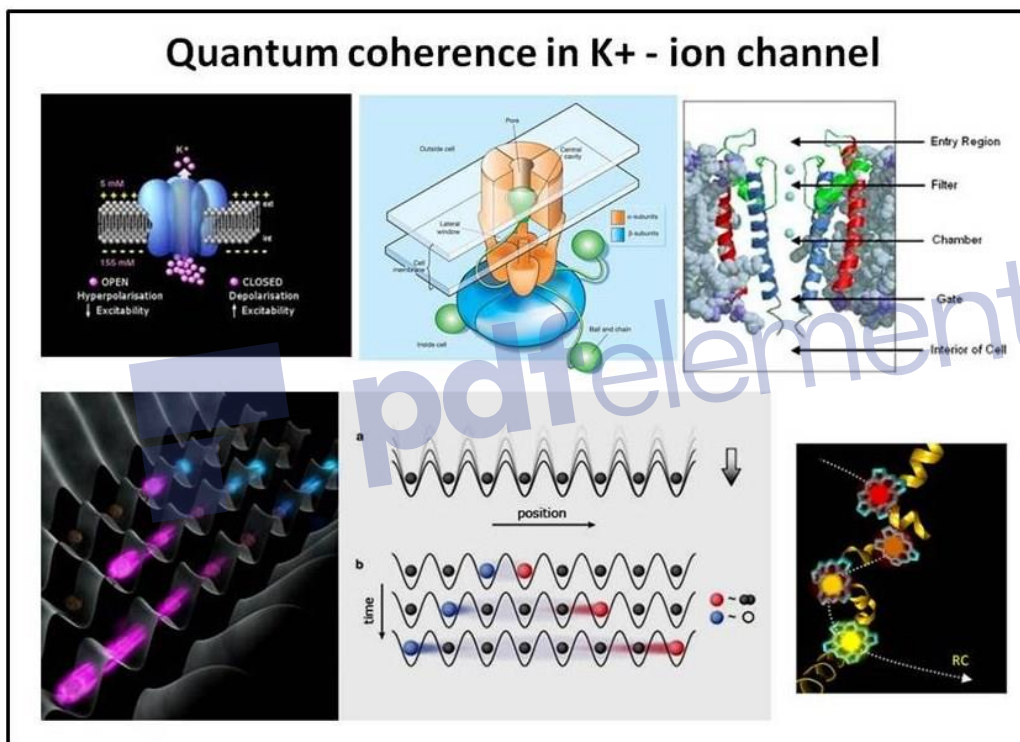


Fig. 25 : The potassium channel structure that protects the K^+ -ion from decoherence (above) and the flow of quantum information through entangled series of channels.

Bernroider and Roy, 2004, 2005 base this theory on recent studies of ion channels. These have been made possible by advances in high-resolution atomic-level spectroscopy and accompanying molecular dynamics simulations. In this work, they draw particularly on the work of the MacKinnon group, and on studies of the potassium (K^+) channel, especially the closed state of this channel. The functioning of the K^+ channel occurs in two stages, firstly, the selection of K^+ ions in preference to any other species of ion, and secondly voltage-gating that controls the flow of these favored K^+ ions. The authors say that the traditional understanding

of both functions has been altered by the recent studies. In its closed state, the channel is now seen to stabilise three K⁺ ions, two in the permeation filter of the ion channel and one in a water cavity to the intracellular side of this permeation path. In the case of the channel's voltage gating, the electrical charges involved which were previously thought to act independently of the surrounding proteins and lipids, are now seen to be coupled to these proteins and lipids, and are thus involved in the gating process.

Atomic-level spectroscopy has revealed the detailed structure of the K⁺ channel in its closed state. The filter region of the channel has a framework of five sets of four oxygen atoms, which are each part of the carboxyl group of an amino-acid molecule in the surrounding protein. These are referred to as binding pockets, involving eight oxygen atoms in total. Both ions in the channel oscillate between two configurations (**Fig. 21**).

Bernroider and Roy's calculations lead them to claim that ion permeation can only be understood at the quantum level. Taking this as an initial assumption, they go on to ask whether the resulting model of the ion channel can be related to logic states. Their calculations suggest that the K⁺ ions and the carboxyl atoms of the binding pockets are two quantum-entangled sub-systems, and they equate this to a quantum computational mapping. The K⁺ ions that are destined to be expelled from the channel could, in the authors hypothesis, encode information about the state of the oxygen atoms in the axon membrane.

In a later paper, presented at the Quantum Mind conference, **Bernroider, 2007**, proposed that different ion channels could be non-locally entangled, thus proposing a quantum process over an extended area of the axon. Given the importance of the ion channels in brain functioning, this model would give quantum coherence and non-locality in the axon membrane an integral role in the brain's signalling and information processing.

Further to this, **Bernroider and Roy** have pointed out a similarity between the structure of the K⁺ ion channel and some recent proposals for building quantum computers, in which ions are held in microscopic traps.

The authors argue that their model is well protected against decoherence, which has always been the most cogent criticism of quantum consciousness proposals. In particular, they claim that Tegmark's calculations do not apply to their model. The authors agree that for ions moving freely in water, Tegmark's coherence time of 10⁻²⁰ seconds would apply. However, they argue that the situation of the ions held in the permeation filter of the ion channel is markedly different, with a temperature about half the prevailing level for the brain, and the ions protected from decoherence by the binding pockets and the adjoining water cavity.

Bernroider and Roy propose a quantum information system in the brain that is driven by the entangled ion states in the voltage-gated ion channels. These ion channels, situated in the

neuron's membrane are a crucial component of the conventional neuroscience description of axon spiking leading to neural transmitter release at the synapses. The ion channels allow the influx and outflux of ions from the cell driving the fluctuation of electrical potential along the axon, which in turn provides the necessary signal to the synapse.

The authors concentrate their attention on the potassium (K^+) channel and in particular the configuration of this channel when it is in the closed state. This channel is traditionally seen as having the function of resetting the membrane potential from a firing to a resting state. This is achieved by positively charged potassium (K^+) ions flowing out of the neuron through the channel.

Recent progress in atomic-level spectroscopy of the membrane proteins that constitute the ion channels and the accompanying molecular dynamic simulations indicate that the organisation of the membrane proteins carries a logical coding potency, and also implies quantum entanglement within ion channels and possibly also between different ion channels. An increasing number of studies show that proteins surrounding membrane lipids are associated with the probabilistic nature of the gating of the ion channels (Fig.25 and 27).

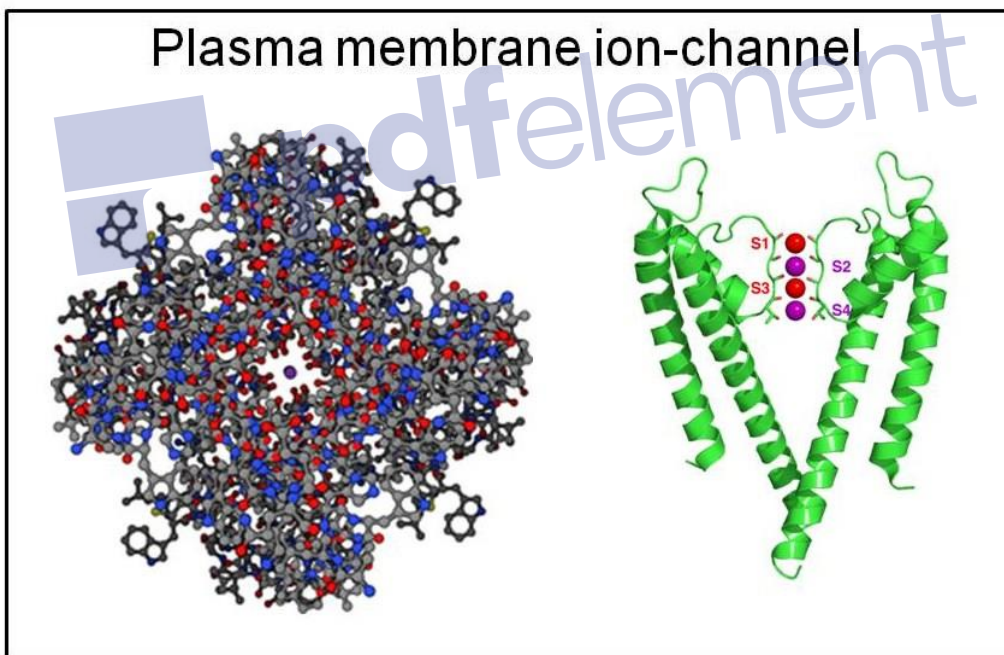


Fig. 26 : *Crystallographic X-ray determined structure of a potassium channel (a) and a schematic representation of it showing the polypeptide units (b)*

The authors draw particularly on the work of MacKinnon and his group, notably his crystallographic X-ray work, see Fig. 26. The study shows that ions are coordinated by carboxyl based oxygen atoms or by water molecules. An ion channel can be in either a closed or an open state, and in the closed state there are two ions in the permeation path that are

confined there. The authors regard this closed gate arrangement as the essential feature with regard to their research work. The open gate presents very little resistance to the flow of potassium ions, but the closed gate is a stable ion-protein configuration.

The ion channel serves two functions, selecting K^+ ions as the ones that will be given access through the membrane, and then voltage-gating the flow of the permitted K^+ ions. In the authors' view, recent studies also require a change in views both of the ion permeation and of the voltage-gating process. A charge transfer carried by amino acids is involved in the gating process. In the traditional model the charges were completely independent, whereas in the new model there is coupling with the lipids that lie next to the channel proteins. This view, which came originally from MacKinnon, is now supported by other more recent studies. The authors think that the new gating models are more likely to support computational activity, than were the traditional models.

As mentioned above, three potassium ions would be involved in the ion channel's closed configuration. Two of these are trapped in the permeation path of the protein, when the channel gate is closed. The filter region of the ion channel is indicated by the recent studies to have five binding pockets in the form of five sets of four carboxyl related oxygen atoms. Each of the two trapped potassium ion are bound to eight of the oxygen atoms, i.e. each of them are bound to two out of the five binding pockets. The author's calculations predict that the trapped ions will oscillate many times before the channel re-opens, and the calculations also suggest an entangled state between the potassium ions and the binding oxygen atoms. This structure is seen as being delicately balanced and sensitive to small fluctuations in the external field. This sensitivity is viewed as possibly being able to account for the observed variations in cortical responses.

Bernroider's theory might be seen to represent even more of a challenge to conventional neuroscience than the other quantum consciousness theories. This is because it recruits as its basis the axon membrane and ion channels which form a crucial part of the conventional neuroscience model, and then tries to remodel these core structures on a quantum-driven basis. It is hard to deny that if this theory were to become better substantiated, it would produce in neuroscience a revolution of the most profound kind.

The essential question was how selectivity could be maintained without compromising conductance. The interaction between ions, attracted water molecules and neighbouring oxygen atoms is considered to require a quantum description. This raises the question of whether quantum effects can propagate in the classical states of proteins. The access of ions to the pore gate is a relatively slow process not likely to require quantum processing.

However, the selectivity filter can change its conformation from permissive to non-permissive on a much shorter timescale. It appears that in the conditions of the selectivity filter the ion's wave function can become highly delocalized over a significant part of the filter region.

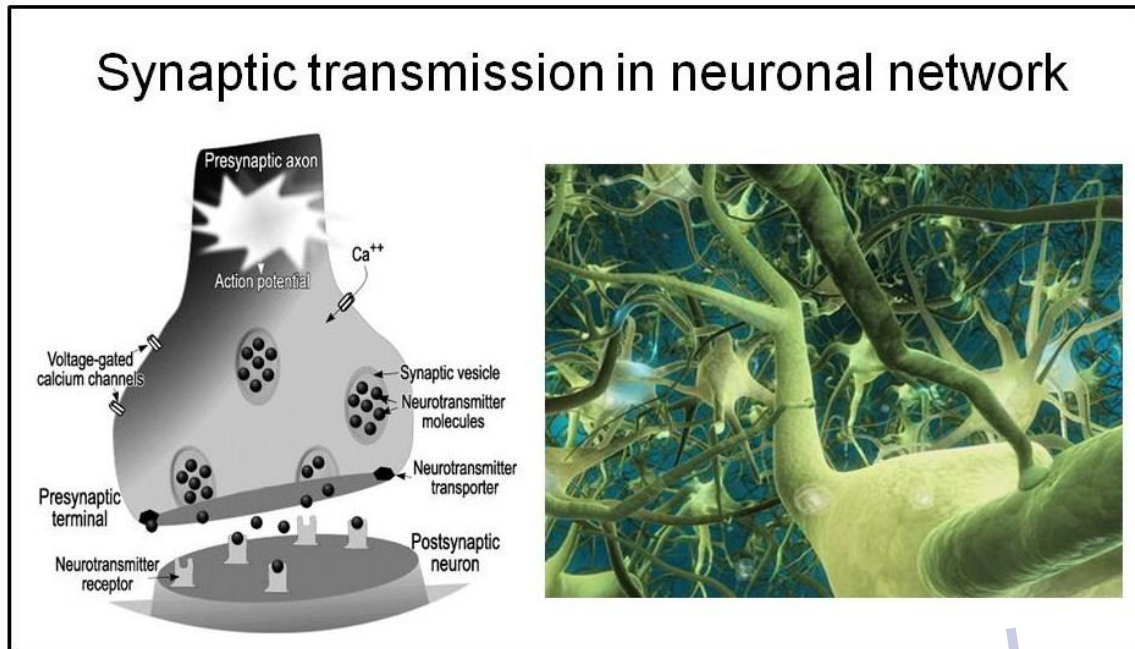


Fig. 27 : Neurotransmission via a neuronal synapse with ion channels (a) and a neuronal network (b)

A New Theory of Quantum Consciousness?

Bernroider's theory could potentially be a vehicle for transferring consciousness from the implicate into the explicate order of David Bohm. Bernroider differs from Penrose and Hameroff's Orch OR model in his emphasis of the axons and membranes, as opposed to the dendrites and the cytoskeleton. However, there are similarities between the two models in that both of them propose quantum coherence, non-locality and subsequent wave function collapse linked to the brain's macroscopic information processing activity. As it stands, Bernroider's proposals only deal with information processing in the brain rather than consciousness as such. However, it appears possible that wave function collapse in the ion channels might link to Penrose's proposed geometry of space time, just as readily as wave function collapse in the cytoskeleton (Fig. 27).

Bernroider's theory is distinct from all earlier quantum consciousness theories in locating its mechanism in structures that are central to mainstream theories of the brain's information processing and production of consciousness. If future experimentation were to substantiate kind the Bernroider proposals, this would involve a revolution in neuroscience of the most profound character.

Chris King: Cosmology, consciousness, chaos and fractal geometry



Chris King, 1989, 2003 2011, 2012, 2014, favors the approach of Chalmers over the approach of Dennett in looking at the problem of consciousness. He describes Dennett's 'multiple drafts' concept as a description of how verbal reports of internal states are produced, but as lacking in any explanation of how consciousness is achieved (Dennett, 2007). He reminds us of Chalmers comment that a theory of physics that does not explain consciousness is not a theory of everything. Furthermore, he argues that ultimately our knowledge of objective science is only available via our subjective conscious experience (Fig. 28).

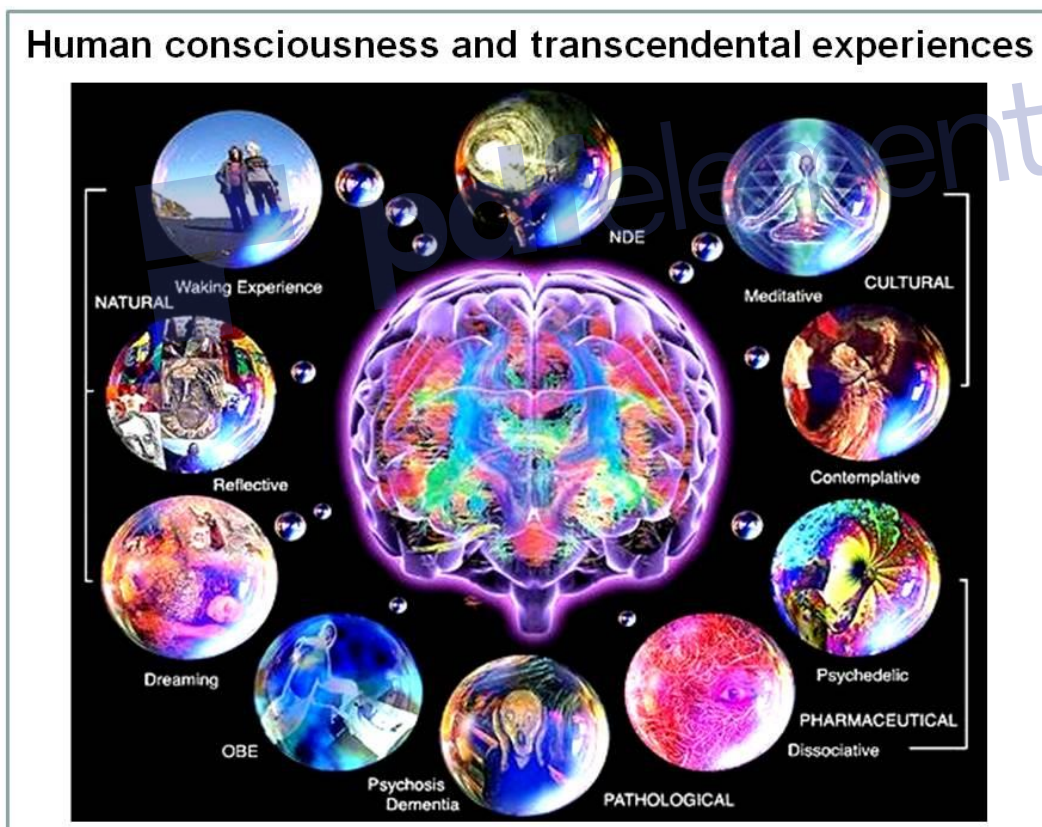


Fig. 28 : Human consciousness as a template for a spectrum of common and transcendental experiences (from King 2012).

He cautions against the common tendency to try and discount quantum uncertainty as something that will be averaged out as a result of the very large number of quanta involved in

any macroscopic state. In Chaos theory, which may well have a role in brain processes, small fluctuations may be inflated into important differences, and quantum uncertainties may be included in these small differences. King goes on to look at the possible uses of quantum computation. He mentions that classical computing has a problem with the potentially unlimited time needed to check a range of possibilities

King favors the transactional interpretation of EPR type non-local quantum correlations. In the transactional interpretation of non-local events, when a measurement is made on an entangled particle, it sends a photon back in time to when it and the other entangled particle were emitted, and then forward in time to the second entangled particle. Thus the net time taken to send the quantum information about the measurement of the first particle is zero, and the effect of measurement on the second particle appears to be instantaneous, despite the spatial gap between them. The backward travel in time, which looks like an exotic feature is allowed by the laws of physics as embodied in both the Maxwell and Schrodinger equations

King, 2014 thinks that the transactional interpretation of non-locality can be combined with quantum computing to give a spacetime anticipating system and that this may be basic to the way the brain works. He argues that the brain's performance is not particularly impressive in terms of what classical computers are good at, but it's impressive in terms of anticipating environmental and behavioral changes. Further citing this article: "The transactional interpretation visualizes an exchanged particle wave function as the interference of a retarded usual time direction offer wave and a time-reversed advanced confirmation wave. Time symmetric interactions also occur in quantum field theories where special relativity allows both advanced and retarded solutions because of the energy relation $E = \pm \mathbf{p}^2 + m^2$. Virtual photons and electron-positron pairs deflecting an electron in quantum electrodynamics. Since the photon is its own anti-particle, a negative energy photon traveling backwards in time is precisely a positive energy one traveling forwards. In quantum mechanics, not only are all probability paths traced in the wave function, but past and future are interconnected in a time-symmetric hand-shaking relationship, so that the final states of a wave-particle or entangled ensemble, on absorption, are boundary conditions for the interaction, just as the initial states that created them are. The transactional interpretation of quantum mechanics expresses this relationship neatly in terms of offer waves from the past emitter/s and confirmation waves from the future absorbers, whose wave interference becomes the single or entangled particles passing between. When an entangled pair are created, each knows instantaneously the state of the other and if one is found to be in a given state, e.g. of polarization or spin, the other is immediately in the complementary state, no matter how far away it is in space-time. This is the spooky action at a distance, which Einstein feared because it violates local Einsteinian causality in which particles not communicating faster than the speed of light.

However quantum entanglement cannot be used to make classical causal predictions, which would formally anticipate a future event, so the past-future handshaking lasts only as long as a particle or entangled ensemble persist in their wave function. Weak quantum measurement (WQM) is one way a form of quantum anticipation could arise. Weak quantum measurement (Aharonov et al. 2010) is a process where a quantum wave function is not irreversibly collapsed by absorbing the particle but a small deformation is made in the wave function whose effects become apparent later when the particle is eventually absorbed e.g. on a photographic plate in a strong quantum measurement. Weak quantum measurement changes the wave function slightly mid-flight between emission and absorption, and hence before the particle meets the future absorber involved in eventual detection. A small change is induced in the wave function, e.g. by slightly altering its polarization along a given axis (Kocsis et al. 2011). This cannot be used to deduce the state of a given wave-particle at the time of measurement because the wave function is only slightly perturbed, and is not collapsed or absorbed, as in strong measurement, but one can build up a prediction statistically over many repeated quanta of the conditions at the point of weak measurement, once post-selection data is assembled after absorption.

This suggests (Merali, 2010, Cho, 2011) that, in some sense, the future is determining the present, but in a way we can discover conclusively only by many repeats. Focus on any single instance and you are left with an effect with no apparent cause, which one has to put it down to a random experimental error. This has led some physicists to suggest that free-will exists only in the freedom to choose not to make the post-selection(s) revealing the future's pull on the present. Yakir Aharonov, the co-discoverer of weak quantum measurement (Aharonov et al. 2010) sees this occurring through an advanced wave travelling backwards in time from the future absorbing states to the time of weak measurement. What God gains by playing dice with the universe, in Einstein's words, in the quantum fuzziness of uncertainty, is just what is needed, so that the future can exert an effect on the present, without ever being caught in the act of doing it in any particular instance: "The future can only affect the present if there is room to write its influence off as a mistake.", neatly explaining why no subjective account of prescience can do so either. Weak quantum measurements have been used to elucidate the trajectories of the wave function during its passage through a two-slit interference apparatus (Kocsis et al. 2011), to determine all aspects of the complex waveform of the wave function (Hosten 2011, Lunden et al. 2011), to make ultra sensitive measurements of small deflections (Hosten & Kwiat 2008, Dixon et al. 2008) and to demonstrate counterfactual results involving both negative and positive post-selection probabilities, which still add up to certainty, when two interference pathways overlap in a way which could result in annihilation (Lundeen & Steinberg 2009). WQM provides a potential way that the brain might use its brain waves and phase coherence to evoke entangled (coherent) states that carry quantum encrypted information about immediate future states of experience as well as immediately past states, in an expanded envelope - the quantum present. It is this coordinated state that corresponds to subjective experience of the present moment, encoded through the parallel feature envelope of

the cerebral cortex, including the areas associated with consciousness. Effectively the brain is a massively parallel ensemble of wave excitations reverberating with one another, through couplings of varying strength in which excitations are emitted, modulated and absorbed. Interpreted in terms of quantum excitations, the ongoing conscious brain state could be a reverberating system of massively parallel weak quantum measurements (MPWQMs) of its ongoing state.

This could in principle give the conscious brain a capacity to anticipate immediate future threats through the intuitive avenues of prescience, paranoia and foreboding. This suggests that the reverberating ensemble of the quantum present could provide an intuitive form of anticipation complementing computational predictions. This would require significant differences from the post-selection paradigm of weak quantum measurement experiments, which are designed to produce a classically confirmed result from an eventual statistical distribution in the future. In the brain, consciousness being identified with the coherent excitations and hence the entangled condition could reverse the implication of backwards causality of advanced waves, with the future effectively informing the present of itself in quantum encrypted form through the space-time expansion of the quantum present.

Discovering a molecular-biological basis for such an effect would pose an ultimate challenge to experimental neuroscience. An indication of how quantum chaos might lead to complex forms of quantum entanglement can be gleaned from an ingenious experiment forming a quantum analogue of a kicked top using an ultra-cold cesium atom kicked by a laser pulse in a magnetic field. It is shown that the classical dynamical space of the kicked top, showing domains of order where there is periodic motion and complementary regions of chaos where there is sensitive dependence on initial conditions. In the quantum system (middle pair), in the ordered dynamic (left), the linear entropy of the system (bottom pair) is reduced and there is no quantum entanglement between the orbital and nuclear spin of the atom. However in the chaotic dynamic (right) there is no such dip, as the orbital and nuclear spins have become entangled as a result of the chaotic perturbations of the quantum tops motion (**Chaudhury et al. 2009, Steck 2009**). This shows that, rather than the suppression of classical chaos seen in closed quantum systems (**King, 2013**), reverberating chaotic quantum systems can introduce new entanglements.

The prevailing theory for loss of phase coherence and entanglement is decoherence caused by the interaction of a wave-particle with other wave particles in the environmental milieu. The coherence of the original entanglement becomes perturbed by other successive forms of entanglement, which successively reduce the coherence exponentially over time in the manner of an open system chaotic billiards. However in a closed universe, such as the global excitations of a brain state, decoherence does not necessarily approach the classical limit, but may retain encoded entangled information, just as the above example of the quantum kicked top does in a simpler atomic system, which could be referenced by the brain in the same way

multiple hippocampal representations over time can, as an organism explores a changing habitat. Intriguingly, continued weak quantum measurement, rather than provoking decoherence tends to preserve entanglement because the ordered nature of the weak quantum measurements reduces the disordered nature of the environment (**Hosten 2011, Lundeen et al. 2011**). Massively parallel weak quantum measurements in the brain might thus function to maintain the ongoing entanglement.

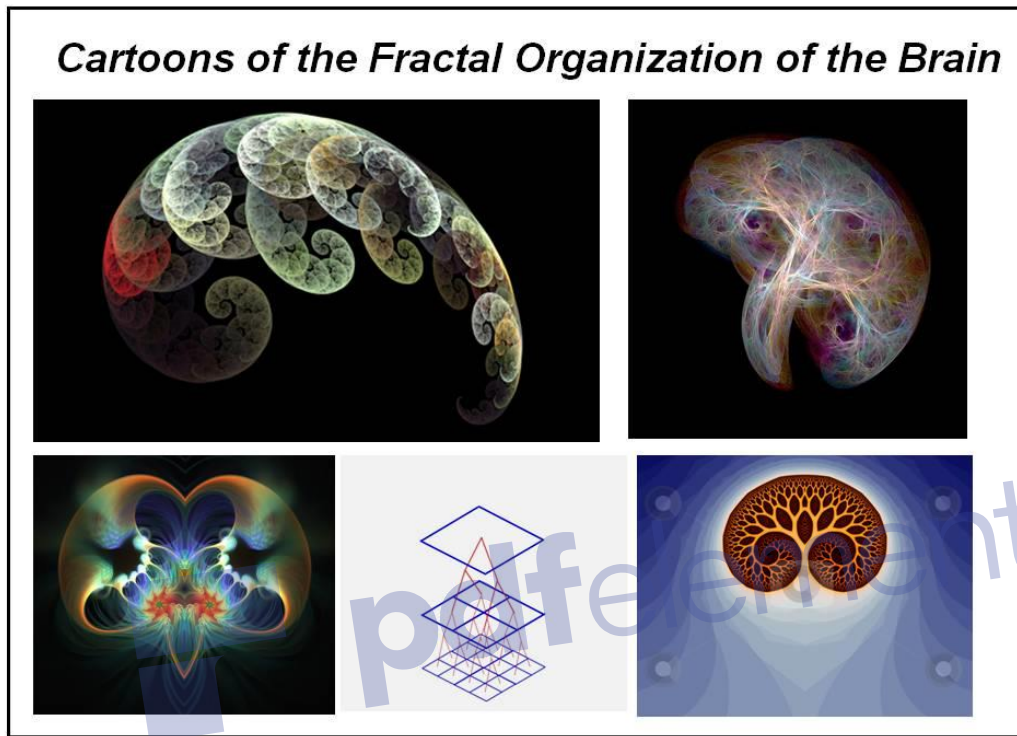


Fig. 29: Cartoons of the fractal structure of the anatomy and function of the brain

He also stresses the complex structure of neurons which contrasts to the simplistic way in which their interactions are sometimes modeled in neuroscience. It is suggested that 'edge-of-chaos' transition in and out of chaos could be involved in perception (**Fig. 29**). Studies of the olfactory cortex show that there is chaotic excitation forming a wave that eventually settles into a basin in the energy landscape. Sometimes this comprises a new basin, in which case this is part of the learning process. The advantage of a chaotic system is its sensitivity to small differences, allowing them to explore a wide range of possibilities, rather than quickly being trapped in one possibility far from the global optimum. Chaotic activity leads to states where the brain would be very finely balanced between different possibilities, and at this point it might be sufficiently sensitive to be influenced by quantum uncertainty. It has been demonstrated that a single ion channel can excite a hippocampal neuron, which can in turn lead to global changes. The brain explores ongoing situations which have no deductive solution, by evoking an edge-of-chaos state which, when it transitions out of chaos, results in

the a ha of insight learning. The same process remains sensitively tuned for anticipating any signs of danger in the wild. This is pretty much how we do experience waking consciousness. If this process involves sensitivity to quantum indeterminacy the coherent excitations would be quantum entangled, invoking new forms of quantum computation. However, King argues that for good adaptive reasons, the brain goes beyond the brute force of quantum computing, to achieve intuitive decisions and creativity both of which involves subjective consciousness. These ideas appear to be similar in spirit to the Penrose concept of non-computability. In general computation seeks a single outcome while creative activity and some other behaviors, seeks diversity. Chaotic excitability is suggested as one of the earliest features of eukaryote cells. This would allow the single cell to get feedback from the environment, rather than becoming stuck in a particular and unsatisfactory oscillation. The behavior of single cell organisms in being able to navigate and behave adaptively in their environment is in any case a problem for cognitive theory. The human brain also exhibits a fractal structure (See Fig. 29), that forms a suitable platform for chaotic (non-linear) reception and expression of neuronal activity. In his recent brilliant review on the cosmology of consciousness King addresses the unfolding of consciousness in the Universe (King, 2012).

King formulates several ultimate questions:

- Is there any intrinsic meaning to life, or is it we ourselves, as living beings, who express the meaning by unfolding it in our creative lives as conscious participants?
- Is the world heading for an apocalyptic falling out and a triage of nature caused by a failure to protect our generations' own futures, or is the entire universe evolving towards a state of ever-deepening realization and enlightenment?
- Is the fulfillment of life in the universe found in some future ultimate state of enlightenment, or is it expressed eternally across space-time in the consciousness of all sentient beings who will come to witness or have witnessed the ongoing existential condition, who together bring about the historical evolution of the conscious universe?

Hence King turns to the other side of the coin. Is there some way in which the universe is coming to fruition through an accumulating sense of our own immanent conscious integration? The Noösphere, according to the thoughts of Vladimir Vernadsky, Édouard Le Roy and Teilhard de Chardin, denotes the "sphere of human thought" in a succession of phases of development of the Earth, after the geosphere and the biosphere. Just as the emergence of life fundamentally transformed the geosphere, the emergence of human cognition fundamentally transforms the biosphere. Teilhard argued the noösphere is growing towards an even greater integration and unification, culminating in the Omega Point, which he saw as the goal of history in an apex of thought/consciousness.

That said, King states that it is clear that decisions we make which seek to protect the long-

term diversity of life and to cherish and replenish it for the future generations lay the groundwork for such an unfolding, as do the creative expressions we make of our engagement together in music, art literature and science and social and natural justice, realizing the compassionate existence together and celebrating it. Neither is it a limitation on ourselves that this potential future is something we can merely glimpse but not fully understand, for already as conscious beings we stand male and female in the archetype of cosmic consciousness to witness the totality in our visions and contemplations, and despite the tragedy of life in the mortal coil, and the implicit violence of nature and entropy, we have the wonder of a free lunch in this magical world to love and beget offspring through the sexual mystery which spawned us and to appreciate the sheer magic of coexistence. Neuroscientist Chris Koch echoes this view "Throughout my quest to understand consciousness, I never lost my sense of living in a magical universe. I do believe some deep and elemental organizing principle created the universe and set it in motion for a purpose I cannot comprehend. ... But I do believe the laws of physics overwhelmingly favored the emergence of consciousness, and that those laws will lead us to a more or less complete knowledge of it."

We need to appreciate every moment and every act, good and bad, for its unique preciousness, for life is all too short and transient and yet our consciousness stands inscrutable in the eternal moment and there are so many of these moments in a lifetime, they literally are enough to fill the entire history of the universe.

Piero Scaruffi: Consciousness as an intrinsic feature of matter



Piero Scaruffi, 2006, takes the view that the more we come to know about the brain, the less easy it becomes to explain consciousness in terms of classical physics. This is the direct opposite of the mainstream view according to which greater knowledge of the brain will inevitably reveal an explanation that can be described in terms of classical physics.

Neurobiology is by implication criticized for being so dependent on Newtonian physics, despite this being known to be limited in its correctness. Neurobiologists have remained attached to classical physics, despite the fact that the objects and processes they are studying

have become smaller, and therefore closer to needing a quantum interpretation. A further problem is that consciousness was from the beginning excluded from Newtonian theory.

Scaruffi's provides an outline of the main theories of quantum consciousness. Quantum models of consciousness date back to the 1920's and the birth of quantum theory itself. However, the earliest detailed model appears to have been produced by **Evan Walker, 2000** already in 1970. This proposed that electrons could quantum tunnel between adjacent neurons to produce a virtual nervous system that direct the synapse-based system. The idea finds echoes in the later Penrose/Hameroff model, where Hameroff suggests that quantum states can extend across macroscopic areas of the brain, as a result of quantum tunnelling at gap junctions linking the dendrites of different neurons.

As mentioned above, the physicist, **Herbert Fröhlich, 1989**, suggested that a quantum phenomenon called Bose-Einstein condensation could arise in biological matter. Living matter comprises mainly water and biomolecules, both of which are electrical dipoles. It is suggested that when such oscillators are maintained at a constant temperature, as they are in the thermal non-equilibrium of biological tissue, condensates can arise. These may also encode information and transmit signals. At a later date, the Penrose/Hameroff model also used condensates, which in conjunction with quantum tunneling at gap junctions allowed quantum states to extend over macroscopic areas of the brain. In **1989, Ian Marshall** also suggested that consciousness could arise from the excitation of condensates in the brain.

The philosopher, **Michael Lockwood, 1989** approached quantum consciousness from a different angle. He argued that special relativity meant that mental states must be physical states. Mental states existed in time, and because space and time were part of the same thing, mental states must also exist in space. He viewed consciousness as having the role that the observer has in the orthodox Bohr view of quantum mechanics, but also because of his argument from special relativity argument, they have to be part of the physical state of the brain. Consciousness is put in the position of scanning the brain looking for sensations.

Scaruffi also discusses the position of **Karl Pribram, 1991**, who considers that brain processes have many of the properties of holograms. Sensory perception is seen as electromagnetic activation propagating through the brain. These sensory waves can interfere with memory also propagating as a wave to produce a holographic structure. Perceptions can be analysed into component frequencies, and therefore dealt with by Fourier analyse. Dirac's least action principle constrains the trajectories of these waves.

The ideas of the philosopher, David Chalmers's are also discussed. Chalmers is critical of mainstream consciousness thinking, but does not see the solution in quantum theories of consciousness. **Chalmers, 2000** makes a distinction between the phenomenal concept of mind

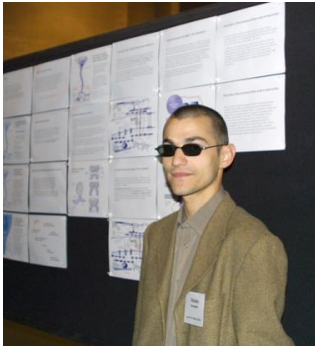
(the way it feels) and the psychological concept (what the mind does). Every mental property is considered to be either phenomenal or psychological or some combination of the two. Pain, often viewed as an example of the qualia, is experienced subjectively, but can also be analysed functionally. Chalmer's proposed solution to the problem of consciousness is based on the concept of information. Information is seen as the link between the physical and the conscious. Information is pattern seen from the inside, and consciousness is seen as information about the pattern of the self.

A Darwinist theory of consciousness

Scaruffi's seeks to develop his own view on the subject of consciousness. He rejects the notion that sensations or subjective experience can be reduced to particles. He suggests that we should analyze why consciousness is limited to the brain, or in another words, what is special about the brain that can't be found elsewhere. The brain is described as being made by common and well-known constituents of matter, with no explanation as to why they produce consciousness, when configured as a brain, but not when configured as a foot. He does not think that any account of the brain, however detailed it may become, will ever be able to explain how the material components of the brain turn into consciousness.

Instead, consciousness itself must be an intrinsic physical property (Scaruffi, 2001), rather than something that is created by other physical components. He compares those neuroscientists who do not accept this, to a scientist that did not accept that electrical charge is a fundamental property, but tried to explain it in terms of some other property such as gravity. He takes the view that any paradigm that tries to manufacture consciousness out of something else is doomed to failure. In such a paradigm, consciousness will seem to appear by magic by putting neurons or similar components which have no sign of consciousness in their make up together. He says that his theory is neither dualist nor reductionist. Consciousness is seen as separate from physical science as described, but still a physical property. This approach seems close to a physical defined panpsychism.

Danko Georgiev: The Quantum Neuron



Georgiev, 2003 is one of the few researchers actively investigating consciousness on the basis of quantum activity in neurons. He disagrees with Hameroff's model in a number of respects, including the function of gap junctions relative to the binding of consciousness and instead proposes a mechanism based on quantum brain dynamics, as developed by Jibu and Yasue and also Vitiello. Georgiev suggests a direct fundamental experience/consciousness manifested by quantum systems. Thus he thinks of the quantum events/collapses as "decisions" done by the experiencing quantum system, not as "events producing consciousness". In this new view the OR event will be a "decision making", not an "experience creating" event. If consciousness is an irreducible phenomenon at the quantum level there is no need for it to "emerge" from "subconsciousness" which is a pseudo-scientific Freudian concept. In summary, he sees the quantum state as a mental state of experience. OR (collapse, reduction, etc.) is making a "decision" or "choice" i.e. it is not providing access to experience, the experience is necessary before the decision or choice is made.

In this model, quantum entanglement can unify consciousness, because it entangles quantum states, and quantum states are mental states of experience. Entanglement/binding may be extended from the axon of one neuron to the dendrite of the next by a protein bridge formed by neurexin-neuroligin. Georgiev sees this as a more effective way of connecting neurons than the idea of gap junctions. The idea is based on studies of split-brain patients who had their corpus callosum cut surgically in order to alleviate epilepsy. Such patients host not one, but two minds, one mind per hemisphere, each mind being unaware of the other mind in the opposite hemisphere. Because corpus callosum is built up of axons projecting from one of the brain hemispheres to the other one, this necessarily implies that cognitive binding involves axons, and cannot be done through gap junctions between dendrite.

For your knowledge: Curiously, aware of my work but not citing it, Hameroff speculated that dendrites also project from one hemisphere to the other one, so that to connect with gap junctions to dendrites in the opposite hemisphere. This is ridiculous, because dendrites are not myelinated and the currents in dendrites are passive, that is they do not use extra energy and decay 3 times approximately every half millimetre. For a distance of 20 centimetres, the

electric current will decay $3^{40} = 1.2 \times 10^{19}$ times i.e. effectively drop to zero. Axon's function is to propagate electric current without decay – for this axons use action potentials and huge amounts of metabolic energy, also axons are myelinated to avoid the leakage of current out of the axon. See Figure 4f, in the following open access article:

Hameroff S. The "conscious pilot" - dendritic synchrony moves through the brain to mediate consciousness. *Journal of Biological Physics* 2010; 36 (1): 71-93.

<http://dx.doi.org/10.1007/s10867-009-9148-x>

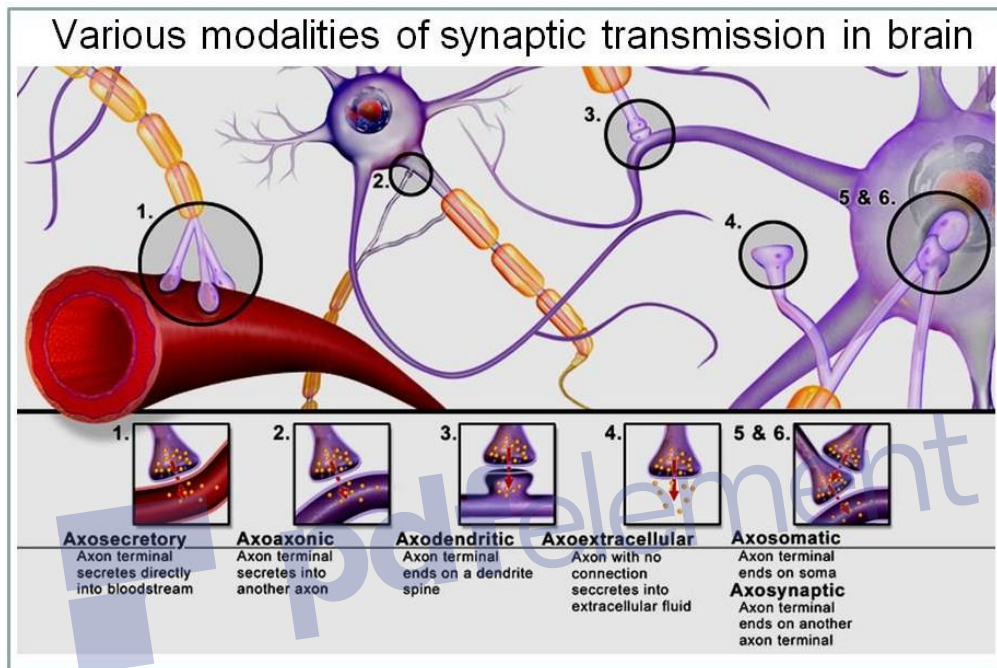


Fig.28: An overview of the various modalities of synaptic transmission in brain

The development of molecular biology during the latter part of the 20th century made it clear that neurons were highly complex, and from this it became apparent that features such as memory and some diseases such as dementias might be better understood in terms of molecular changes within the neurons. In these cases, it has been shown that not only are there changes in neuronal firing, but also in cytoskeletal organization, the cytoskeleton being composed of biomolecules that are the basis of life. The DNA of the cell nucleus contains essential information, but is viewed here as being driven by the transfer of information from the cytoskeleton.

In looking at the synapses between neurons (see Fig. 30), the author draws particular attention to the metabotropic links, as distinct from the ionotropic links that take the form of electrical signals via membrane ion channels. With the metabotropic links, neurotransmitters bind to G-protein coupled receptors (GPCR). These activate second messengers, which in turn act on protein kinases and phosphatases that modulate the cytoskeleton. The cytoskeleton in its turn

signals protein production requirements to the nucleus of the cell. The fast electrical activity of the ion channels is contrasted with the slower biochemical processes within the neuron. Georgiev says that the Hameroff model only takes account of the biochemical and not the electrical activity. He disagrees with this exclusion of electrical activity, pointing out that Penfield's ground breaking research in the mid 20th century showed that conscious memories could be evoked by inserting electrodes into parts of the cortex.

Georgiev argues that in neurons, the electric field is not confined to the ion channels in the membrane, which is the conventional view, but that it can also act directly on the microtubules. This concept is in line with ideas put forward by **Jibu and Yasue, 1992, 1993** and also by **Vitiello 1995, 2001**. The approach of these researchers involves a quantum field theory of the electric dipoles of water molecules in the brain, and here, particularly within the neurons. The dipole rotational symmetry of the water molecules is proposed to break into the quanta of dipole vibrational waves or dipole wave quanta (dwq), which manifest as long-range correlations in water. As such, they transmit information in water.

These correlations are suggested by Georgiev to influence the conformation of the microtubule tubulin 'tails' that protrude from microtubules. The coherent behavior of the tubulin tails can be modeled as solitary waves (solitons) propagating along the outer surface of the microtubules, and acting as a dissipationless mechanism for the transmission of information along the microtubule. Collisions of the waves formed by the tubulin tails are suggested to act as a computational gate for the control of cytoskeletal processes. It is already experimentally verified that tubulin activity controls the sites where microtubule associated proteins (MAPs) attach to microtubules, and also controls the transport of vesicles of neurotransmitters towards synapses. The output of the computation performed by the tubulin tails is here suggested to come via the MAP attachments and also the kinesin motor transport along the microtubules.

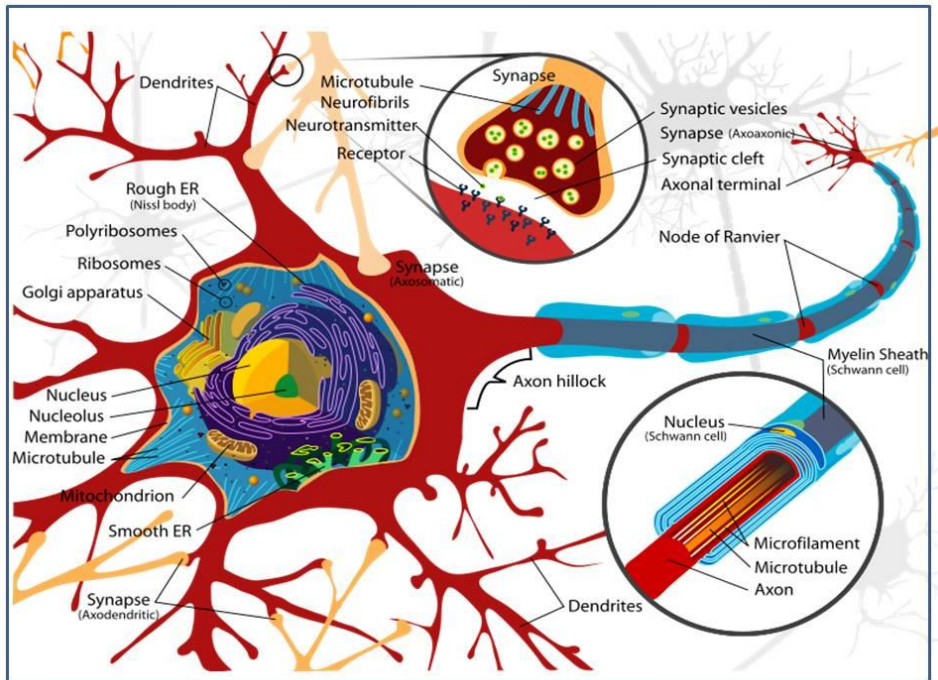
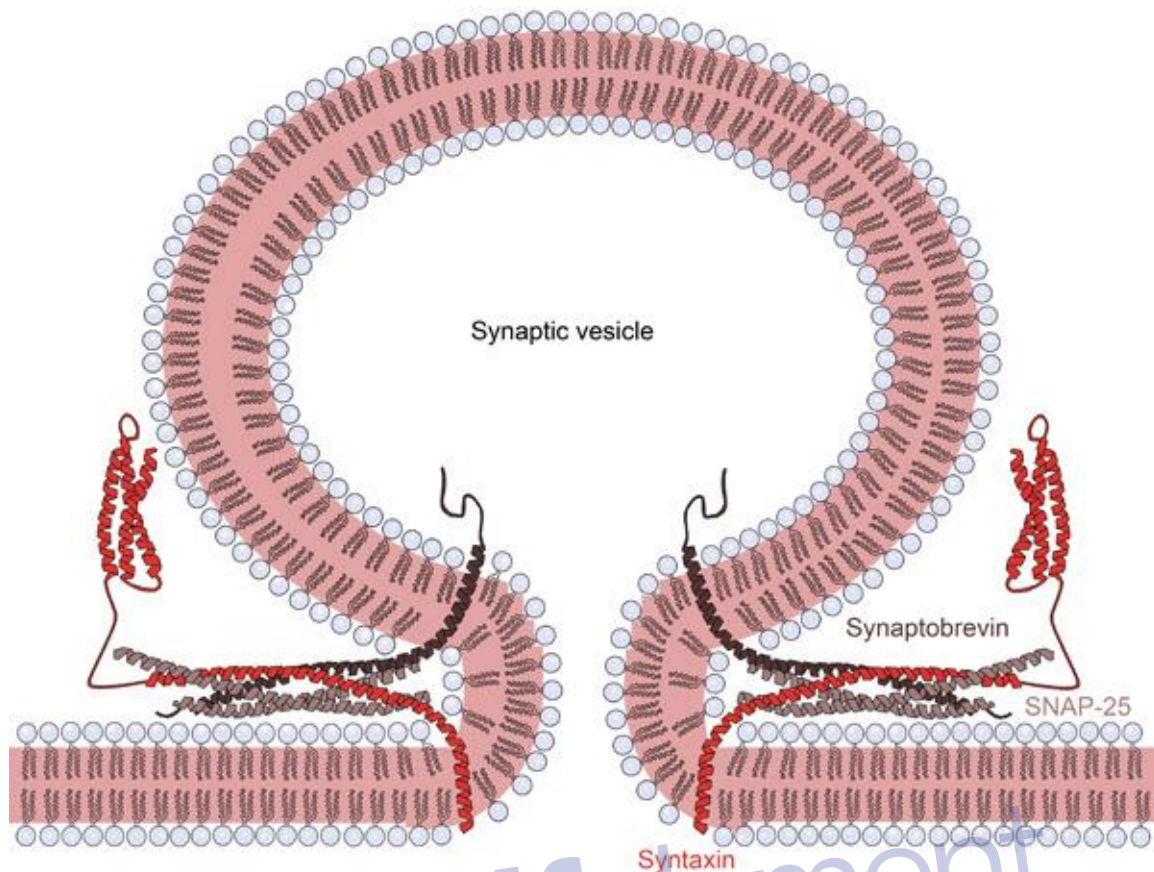


Fig.31 : A schematic representation of a neuron with its dendrites and axon, and the synaptic structure that enables the release of chemical messengers: the neurotransmitters. Fine structure of microfilaments and tubules is indicated.

The author goes on to discuss the probabilistic nature of neurotransmitter release at the synapses, and the possible connection this has with quantum activity in the brain. The probability of the synapse firing in response to an electrical signal is estimated at only around 25%. Georgiev points out that an axon forms synapses with hundreds of other neurons, and that if the firing of all these synapses was random, the operation of the brain could prove chaotic. He suggests instead the choice of which synapses will fire is connected to consciousness, and that consciousness acts within neurons, an idea that dates back to Sir John Eccles. In a later amendment of Eccles idea and in collaboration with James Glazebrook, Georgiev is now suggesting that quantum tunnelling with SNARE (an acronym derived from "SNAP (Soluble NSF Attachment Protein) REceptor") proteins could control the release of neurotransmitters from vesicles in the synapse.



SNARE proteins as molecular masters of interneuronal communication :: Danko Georgiev, James F. Glazebrook Biomedical Reviews 2010; 21: 17-23 :: <http://dx.doi.org/10.14748/bmr.v21.43>

The structure of the grid in which the vesicles are held is claimed to be suitable to support vibrationally assisted quantum tunneling. Georgiev also thinks that B-neurexin and neuroligin-1 proteins that form a bridge between the axonal and dendritic cytoskeletons are relevant to consciousness. Georgiev also discusses **Max Tegmark's paper, 2000**, which conventional consciousness study thinking views as having completely dismissed the possibility of consciousness based on quantum coherence in the brain. In respect of this debate, Georgiev points out that the real question is whether the time to decoherence is greater or lesser than the timescale of dynamical changes in the brain. He agrees that if the decoherence time is shorter than the dynamical time, it is not feasible for quantum coherence to be involved in brain activity. In his 2000 paper, Tegmark has a decoherence time of 10^{-13} seconds. It is suggested that neuronal activity is orchestrated via the conformational activity of tubulin subunits (**Fig.32**), and that this activity has a dynamical timescale that could fall within the Tegmark timescale. The conformational transition times within the tubular proteins of the microtubules coincides with transition times for the microtubules as a whole. Georgiev's answer to Tegmark is also an answer to the main thrust of the **Koch and Hepp (2006)** paper also purporting to dismiss quantum mind theories.

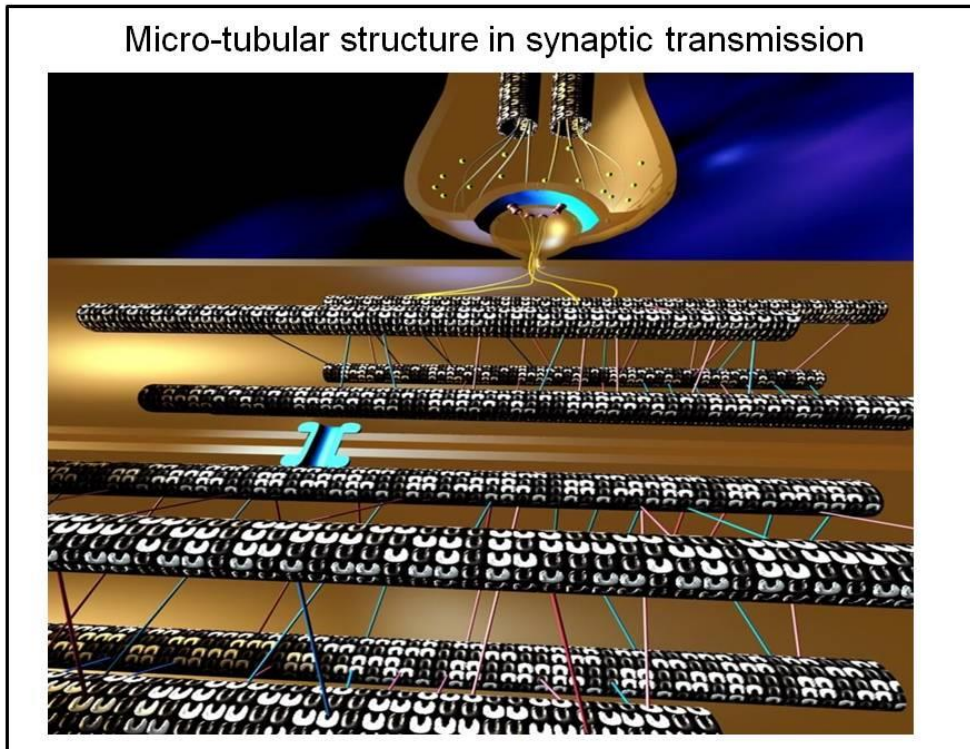


Fig. 32: The arrangement of micro-tubules, as associated with vesicular bodies in the synapse showing the fine structure of the tubulin protein lattice.

Georgiev's work represents something of a hybrid theory mixing the quantum brain dynamics model promoted in recent years by Jibu and Yasue and also Vitiello with the quantum consciousness theory of **Penrose and Hameroff, 2013**. Georgiev thinks that the Hameroff scheme for instantiating quantum consciousness in the brain is flawed in a number of respects, and proposes a neuronal mechanism that is closer to quantum brain dynamics. Georgiev also rejects Hameroff's idea of quantum tunnelling at gap junctions between dendrites, citing a lack of suitable structures for coherence in the dendritic spines where the junctions are located. In Georgiev's model, objective reductions occur so that choices can be made, with quantum states of the brain providing a continuous stream of consciousness because the quantum state is always present.

Andrei Khrennikov: Quantum like brain and metaphoric QM models



Khrennikov, 1999, 2002, 2003, 2004, and 2006, regards quantum mechanics as a general mathematical formalism for describing incomplete information about events. He suggests that quantum-like (QL) processing occurs in the brain. He is at pains to stress that he does not see this as related to actual quantum states in the brain, as is the case with most other theories of quantum consciousness. QL processing is suggested to arise from the brain as described by conventional neuroscience with neurons/synapses as the basic units. It is suggested that the unconscious mind uses classical processing, while only the conscious mind runs on QL.

Unconscious information is projected into consciousness, where it is subject to QL processing. In the manner of quantum mechanics, complex-number probability amplitudes constitute a wave function, in this case a mental wave function, related to probability by the algorithms of quantum mechanics. Consciousness is here claimed to operate with quantum algorithms that are essentially different from those used by existing (classical) computers. In the case of the brain, this theory suggests that the quantum algorithms can be used without involving actual quantum states, but instead spring from the already known biological processes that are themselves described by classical physics. The system is seen as being based on and created by the parallel workings of billions of neurons, with a QL facility much faster than any classical computer. Khrennikov also thinks the neural processing depends on two distinct timescales, a fine grained timescale for classical processing, and a less exact timescale of possibly about 100 ms produced by quantum averaging. He discusses some recent studies that he considers supportive of this suggestion.

The author argues that there is nothing surprising about algorithms derived from quantum mechanics being implemented on biological processes that can themselves be understood in a strictly classical way. He points out that differential calculus was developed to serve Newtonian mechanics, but proved useful for other areas of physics. I am not sure that this argument is completely convincing. The common feature of the theories for which calculus was useful is that they described the movement of matter and energy in space and time, without the acausal disjuncture involved in the randomness of the quantum wave function collapse. In the case of Khrennikov's theory, we are asked to accept the application of a system which does involve an acausal disjuncture to resolve the processing of a biological system that

is deemed to be classical. The two systems, at first sight, appear much more dissimilar than the various classical theories for which calculus is useful.

Khrennikov argues that his QL scheme does not suffer from the difficulty of explaining how quantum states could persist in the brain for a length of time likely to be relevant to neural processing. This has long been the most cogent argument against theories of quantum consciousness. However, in common with more conventional researchers, Krennikov's discussion of quantum theories of consciousness appears skimpy. He mentions in passing the problem of likely rapid quantum decoherence in the conditions of the brain, without discussing the possibility of quantum features being shielded, which is an important aspect of some quantum consciousness theories. He says that it is hard not to view the neurons as the basic units of neural processing, and suggests that quantum consciousness more-or-less ignores the processing of neurons. However, this is not always the case. The Penrose/Hameroff theory involves an interactive exchange between microtubular processing and synapses, while with Bernroider's ion channel theory the quantum processes drive the ion channels, which in turn constitute a fundamental element within the conventional neuron theory.

Khrennikov is more convincing when he discusses the advantages of QL. If an organism does not have access to complete information, or does not have time to classically process the information that it possesses, QL can create a model based on partial information. He argues that in classical processing the brain would need to perform integration over space having the dimension of a few billions. From this, he argues that in an advanced brain simple acts of cognition would take an impossibly long time. Similar arguments have been advanced by other researchers on perception, who argue that while bottom up calculations do not yield a unique solution, bottom down calculations take an impractically long time.

The real problem with this theory, as with all classical approaches and quite a few quantum approaches to consciousness, is that while it is insightful, at the end of the day it seems to lack explanatory power as regards the essential subjective experience of consciousness. If quantum algorithms did arise from a classical biological strata, in order to deal with the perception problems of the brain, there is no apparent reason why such quantum processing should not be achieved unconsciously, as is quantum processing in physics outside the brain. Quantum consciousness theories appear to have no special advantage over classical theories, unless they can appeal to some special function at the fundamental level of energy or possibly spacetime that is possibly capable of acting as the source of consciousness.

Other related metaphoric models

With regard to quantum models a distinction is made between QM models in which intentional conscious acts are correlated with physical state reductions including QM field

models in which mental states are treated as vacuum states of quantum fields as opposed to QM metaphoric models (see **Meijer and Korf, 2013**), who stated the following:

“With regard to the latter, Niels Bohr has already suggested that mutually excluding images (see below) have aided the formulation of the complementary hypothesis of quantum mechanics (**Busemeyer and Bruza 2012**). Many authors (references in **Atmanspacher, 2007, 2004; Busemeyer and Bruza 2012**), have recognized the potential of using a quantum probability approach in the psychology of cognition and decision making rather than more classical approaches. Quantum mechanics and its formalisms should be viewed upon here as a metaphors, **Atmanspacher et al. (2004)**, in that “particular features of the quantum theoretical formalism are realized in a non-physical context”.

Recent research has been focused on modeling of decision making (**Busemeyer and Bruza, 2012; Pothos and Busemeyer, 2011**). In experimental settings subjects were asked to make easy choices with game cards between a few alternatives. These alternatives were best described with stochastic models, rather than as deterministic processes. Other research did focus on the idea of geometric sub-spaces, where the probability of choices became order- and context-dependent. This means that decisions are made not only by taking into account the grounds as independently contributing factors, but also by their order of exposure to the subject. Again, this has been related to the “real” quantum theory, where a wave function (in a superposition and without a distinct spatial location) becomes a well-localized particle after interference with a physical body, including an observer.

The authors of the latter studies emphasized the quantum nature of their models, because they use terms such as superposition, entanglement and collapse as they are used in quantum physics to denote an undetermined state (a wave function), that after collapse behaves as a particle. Entanglement is used in QM to denote that, for instance, spin properties of a particle (entities) are correlated with a related particle, in the sense that. the orientation of the spin of one particle becomes determined after the collapse through observation of the related particle. Related to these QM ideas are rapidly alternating brain and mind states as, for example, illustrated with classical ambiguity pictures, picturing the brain in a state of superposition (**Atmanspacher et al., 2004**), see also **Fig.33**.

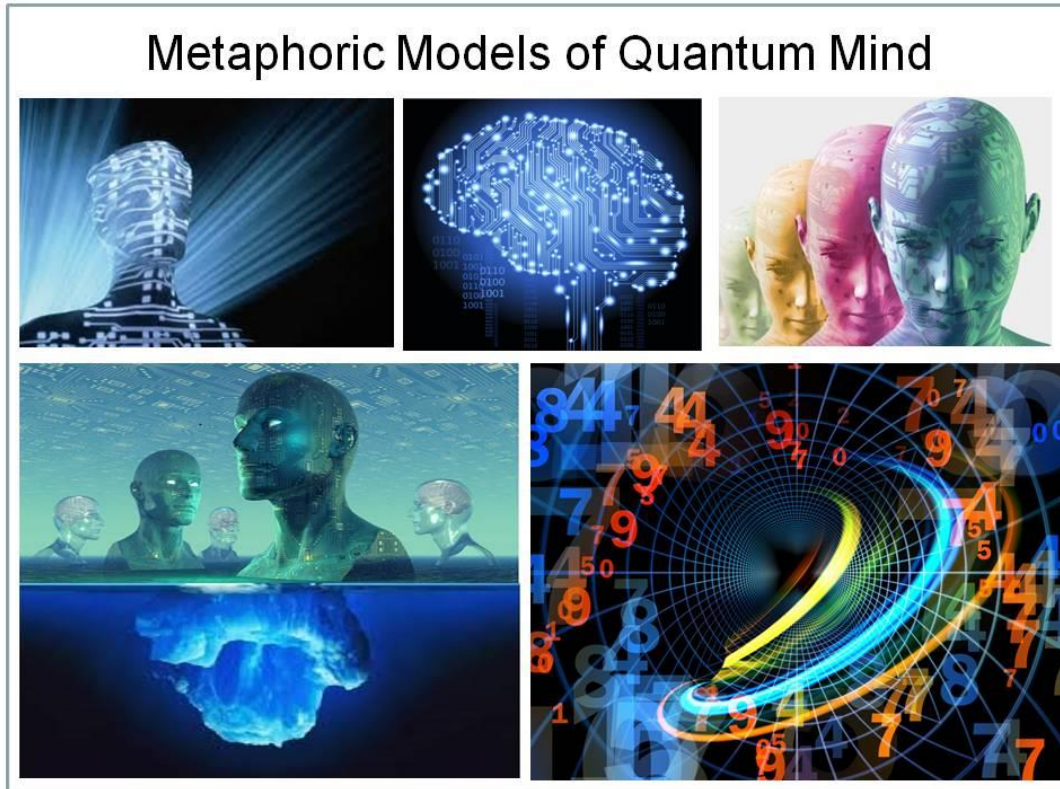


Fig. 31: Metaphoric representations of quantum consciousness

A quantum approach was also used to model bi-stable perceptions: figures such as the Necker cube, can be interpreted as either of the particular spatial configurations. The switch between these interpretations are assumed to be short as compared to observation time (“Zeno effect”, see **Schwartz et al., 2004; Stapp, 2009, 2012**), and, moreover, the two interpretations are mutually exclusive: the interwoven objects cannot simultaneously be conceptualized. During a short period of time only one configuration is recognized and alternating views are more or less subject to the will of the observer. Despite such persuading theorizing, **Busemeyer and Bruza (2012)** lay to heart the lesson that in the psychological experiment a superposition is merely a word that can be interpreted as representing a number of different senses, while an entangled cognitive state is highly biased towards one subset of interpretive senses. Finally, collapse is merely the process “by which a subject decides upon a particular interpretation in the context of a set of cues and stimuli.” The question remains how and when such subconscious thoughts or arguments become manifest prior to the very moment that the subject definitely chooses or decides.

The related time course of the cerebral electrophysiological activity was described during the initiation and execution of voluntarily behavior (e.g. movement of the fingers) by the classical experiments of Libet and later by others. This approach (**Libet 2006; Haggard 2005; Soon et al., 2008; Bode et al., 2011**) might be regarded as a decision making experiment and the readiness

potential can be seen as to reflect the superposition state of the brain. Following regional brain activity using fMRI technology (see **Bode et al., 2011**) showed that the preparation phase in the anterior frontopolar cortex might precede the decision as much as 6 seconds. Once in the superposition state, decisions in a laboratory context are made in a very short period of time (already within 50 milliseconds; as in the **Turennout, 1998** study) as compared to the preparation time.

Spivey and coworkers, 2007, have emphasized the continuity of mind, rather than sequential states, as opposed to the quantum approach. They illustrate their ideas with decision-making experiments, showing that the subjects in an, apparently indecisive, state, stay longer indecisive when the decisions are more ambivalent, once the choice has been made, the decision is realized faster (**Pezzulo et al., 2011; Spivey 2007**). These studies show that decisions are anticipated far before the overt behavior (**Bode et al., 2011**). These laboratory experiments are compatible with the idea that the central nervous system (the subject) develops a kind of superposition state before making the choice (the “collapse”). For the subject, the significance of artificial problem solving, is evidently modest and requires little “mind-space.” More important decisions might require a “larger space of the personal universe”, and more processing time.

Trueblood and Busemeyer (2012) summarize four reasons for considering a quantum approach to human judgments: (1) human judgment is not a simple readout from pre-existing or recorded state, it is rather the process of imposing measurements that forces the resolution of the indeterminacy; (2) before measurement cognition behaves more like a wave than a particle allowing the individual to feel a sense of ambiguity about different belief states simultaneously, as if beliefs remain in a superimposed state until a final decision must be reached; (3) changes in the context produced by one judgment can affect later judgments: quantum probability theory captures this phenomenon through the notion of incompatibility about another; (4) cognitive logic does not necessarily obey the rules of classic logic such as the commutative and distributive axioms. Quantum logic is more generalized than classic logic and can model human judgments that do not obey Boolean logic”.

Hu and Wu/ Persinger: Spin- mediated consciousness



Maoxin Wu



Huping Hu



Michael Persinger

This recent theory of quantum consciousness relates to work by the physicists, **Hu, and Wu, 2004, 2010** carried out within the last ten years. Harking back to Penrose's concept of a spin network, the quantum property of spin is seen as being embedded in the structure and shape of spacetime. Quantum entanglement is seen as deriving from spin, presumably because spin and polarisation are the properties that can be altered by entanglement. Spin is also seen as primordial, pre-dating in the early universe the emergence of matter that involves mass and charge. With respect to consciousness theory, spins are regarded as the 'pixels' of consciousness (**Fig. 27**). This is therefore a fundamental theory of consciousness. Consciousness is not arbitrarily related either to some classical feature or some particular quanta, but indicated as a given property of the universe that cannot be explained in terms of other physics or biology, and is also related to conditions that are only known to arise in the brain.

In relation to spin, the authors envisage a number of processes in the brain. They start with action potentials, which are suggested to indirectly modulate networks of nuclear spins via the electrons associated with the nuclei. The authors studies are claimed to support this idea via three indicators, being photon emissions, EEG activity and alterations in the immediate geomagnetic field. Further to this, a reduction in the local geomagnetic field running from the rear to the front of the cortex is related to neural rhythms and in particular the gamma synchrony, running in the opposite direction to the geomagnetic gradient. This presumably allows the inter-connection of conscious spin activities in different parts of the brain. The rest of this review deals mainly with studies that claim to support the above proposals.

In one study (**Hu & Wu, 2004**), it was proposed that networks of nuclear spins in neural membranes are associated with strongly fluctuating magnetic fields that are modulated by the indirect dipole-to-dipole coupling in action potentials. Interactions between two nuclear spins result indirectly from the interactions of electrons around the nuclei. Hu and Wu found that these couplings had frequencies of 5-25 Hz, which are within the EEG range of activity. They predicted that magnetic fields associated with spin-related coupling across the cell membrane would have an energy value equivalent to photon emission (**Fig.34**).

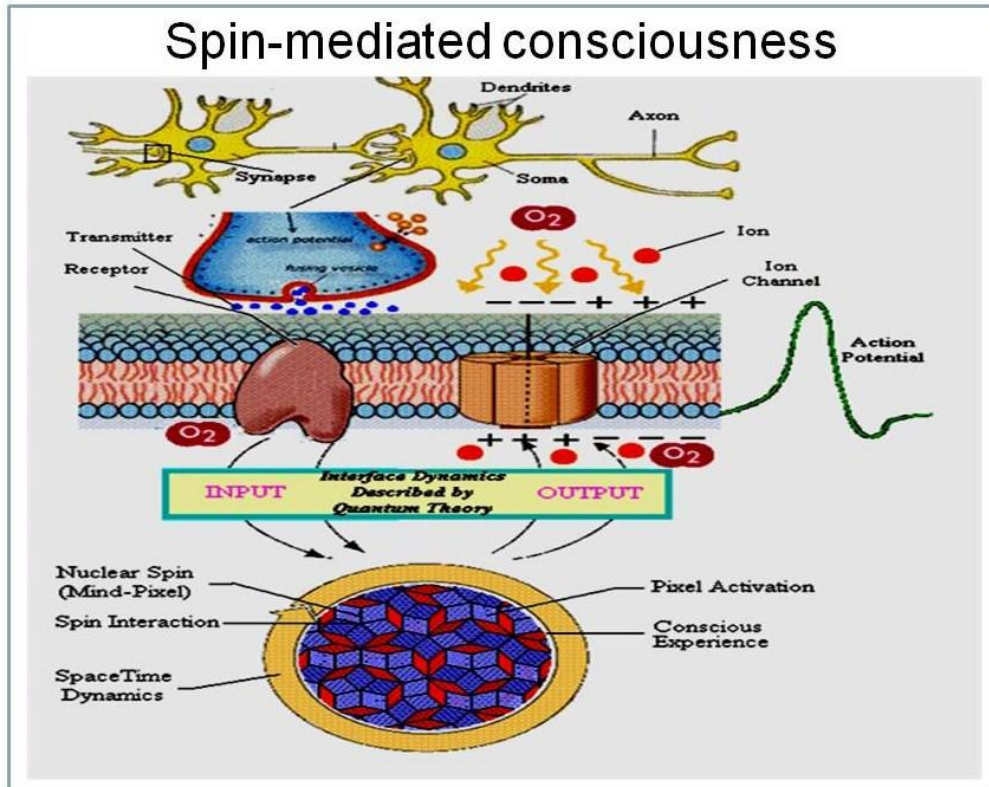


Fig. 34: The plasma membrane structure and membrane potential of neurons exhibiting channel proteins that enable electric activity through trans-membrane flux of Na⁺ and K⁺ ions, that may be influenced by quantum spin information of the constituting elementary particles of channel proteins.

It is proposed by Persinger et al, 2013 that the underlying spin networks could be linked to photon emissions observed with particular brain activities. The energies available to the neuronal membrane are suggested to be within the range associated with photon emission, and therefore capable of interacting with it, or altering it. A recent study by one of the authors showed that photon emissions from cell cultures were mainly emitted from cell membranes. Another study showed that photon emissions in brain tissue varied strongly, when the tissue was either oxygen deprived, or alternatively exposed to pure oxygen. In further studies involving the authors, subjects thought about either bright white light or else random experiences. It was found that the intensity of emissions from the right hemisphere of the brain were correlated with EEG activity over the left prefrontal, when the subjects were imagining white light, but not at other times. In another study, photon emissions while the subject was imagining white light had a pronounced inverse correlation with the intensity of the horizontal geomagnetic field.

A further study of Dotta and Persinger, 2011 looked at the behavior of the parahippocampal gyri in both hemispheres, when the subject was and alternatively was not thinking about light. When light was imagined by the subject, there was a marked increase in power in the delta,

beta and gamma bands associated with activation of the parahippocampal gyri. Photon emissions were elevated in the 16-17 Hz range, while the subject imagined light, and this corresponds to the range of proton couplings predicted by **Hu and Wu, 2004**

One pattern revealed in these studies was the change in geomagnetic intensity between the rear and front of the cortex, while the subject was experiencing white light, something which was much less marked in the absence of thinking about light. A decrease in geomagnetic intensity was associated with increased photon emission in the cortex. The decrease was consistent with Wu and Hu's prediction for proton-proton spin interactions over the cell membrane. The authors suggest that both the energy increase from photon emissions and the energy decrease in the geomagnetic field derive from the same source. The energy associated with changes in the geomagnetic field was of the same order as the energy associated with photon emissions.

The authors (**Dotta et al, 2012**) argue that the state of consciousness associated with imagining white light relates to changes in the intensity of the geomagnetic field within the brain. Photon emissions were also related to the strength of activity within the beta and gamma wave ranges, where the gamma synchrony is the best known correlate of consciousness. The change in the geomagnetic intensity is within Hu and Wu's predicted range for proton-proton interactions.

The change in the geomagnetic field occurred in a specific direction from the back to the front of the brain, and the authors relate this to a movement in the opposite direction by gamma and other electromagnetic waves. It is suggested that gamma and other oscillations interact with the geomagnetic field to emit photons. This could be expected to be represented within photon fields associated with action potentials. The suggestion is that photon emissions, geomagnetic intensity and the gamma and other oscillations in the brain are interrelated. These geomagnetic studies are argued to support Hu and Wu's hypothesis of nuclear spin-spin interactions in response to action potentials that could relate to wider neural activity, consciousness and spacetime patterns of spin.

Hu and Wu (2004 and 2010), suggested a spin mediated theory of consciousness with the quantum spin as the seat of consciousness. The spins provide an interface between the composition of the brain and the electromagnetic waves that cross the brain. Consciousness is seen as emerging from the collapse of spin states that are entangled with one another.

Chris Clarke: Qualia and free will



Chris JS Clarke, 1995, 2000, 2001 discusses qualia and free will. Clarke defines the irreducible aspect of qualia and also free will as the essence of human consciousness. He thinks that qualia arise from an 'entanglement' between a person and the perceived object. Free will is suggested to arise from the use of self-reflection to change the reference frame within which decisions are taken. This change in the reference frame is likened to the change between quantum wave and particle. Clarke does not think that these characteristics can be derived by just summing up the microscopic events found in quantum theory.

In discussing qualia, Clarke remarks that consciousness is a unity and some aspects of this are qualia such as colour. However, the totality of consciousness is more than just the total of various qualia. Clarke takes the view that in looking at, for instance a tree, we perceive a variety of qualia, but that there is no tree quale. Clarke also distinguishes between internal experience, such as anger etc, and the perception of external objects. Clarke argues, in line with Heidegger, that the primal qualia is the internal experience, with infants gradually learning to split off the perceived external world from their internal experience. The last has been confirmed by studies of child development.

The present scientific orthodoxy is seen as going only half way to describe qualia. The perceptual world and its qualia are seen as only a model of external reality. There are one-to-one correspondences between external things and perceptions, but they are not at all the same thing. Thus a particular frequency of oscillation of photons corresponds to the quale of the colour red, but in contrast to the external behaviour of the photon, the physical nature of the redness quale is completely unknown, and it is not apparent how it would be discovered by a conventional scientific approach.

Clarke, in line with Max Velmán wants to stand the traditional scientific view on its head. Instead of our perceptions being a model of external reality, external reality is modelled by our perceptions, with the qualia being out there in the external world, and apparently being the product of entanglement between the two systems.

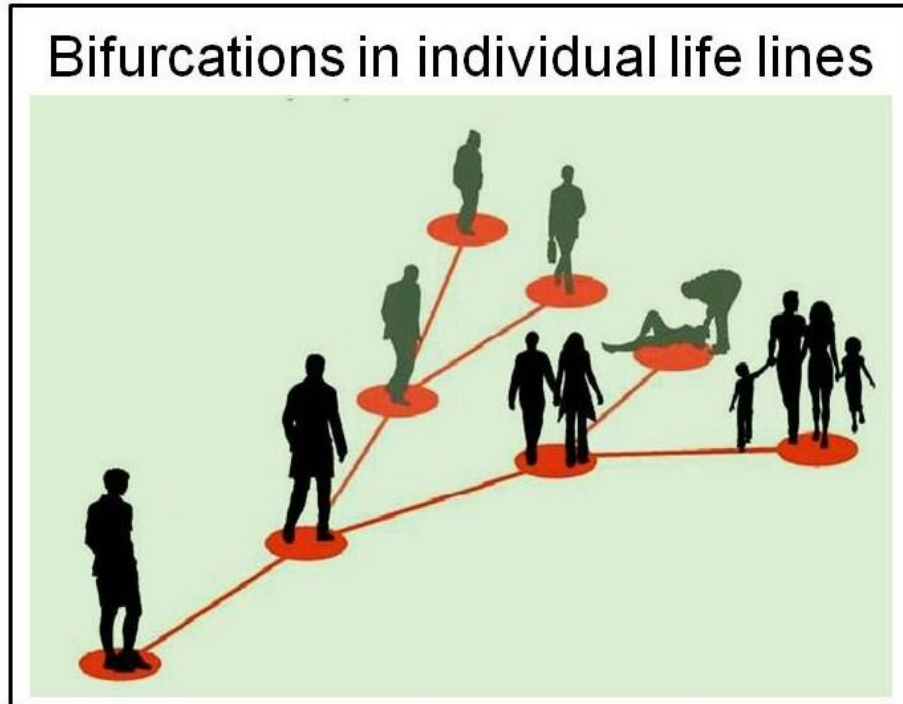


Fig. 35: Mental participation implies bifurcation of individual life lines and free choice

In discussing free will, Clarke looks at our process of decision taking where we envisage the possible outcome of actions and evaluate our emotional response to these. This approach is often effective in reaching a decision, but on some occasions we are still left without a decision. Clarke suggests that free will or something like it cuts in at this point, and changes the frame of reference so that we might suddenly bring in the thought, what would X have done or thought in this situation, thus moving the decision making process into a new frame of reference. (Fig. 35)

Chris Clarke claims that the stories that society tells itself about the physical nature of the world really matter because this affects the values of the society, and reinforces or undermines its power structures. The current mainstream paradigm derives from Newton, with subsequent additions from 19th century physics and 20th century molecular biology, and is now entrenched in the modern educational and medical systems. In earlier centuries, western thinking was dualistic. Clarke traces this back to ancient Greek philosophy, with humans comprised of two distinct substances, body and spirit. This idea was inherited by Christianity, and then given a more definite form by Descartes in the 17th century.

In the subsequent centuries, there was a gradual squeezing out of the spirit from this initially dualist view. This resulted from the ability of science to give a physical explanation to more and more things that had previously seemed to be the role of the spirit. The invention of computers, as a form of mechanical brain, seemed to round off this world view. The world is

viewed as a system of isolated atoms and ideas such as meaning and purpose are deemed to be an illusion. At the same time, physics seems to leave out consciousness and the possibly related concepts of meaning and creativity. Further, the mainstream idea of phenomena, referring to mental experience appears to presuppose the idea of perceptions being mere mental appearances produced by an external reality.

Clarke is particularly critical of the current mainstream approach to consciousness. He criticizes writers who replace the basic experience of the subjective with something at once more restricted and more complicated, such as self-consciousness, reasoning or problem solving. These writers appear not to notice the basic substratum of the subjective, thus rendering most of their discussion irrelevant.

Dennett, 2007, who is pre-eminent amongst mainstream thinkers on consciousness and taken as sole guide by some popular writers, is particularly criticized for looking at the problem from only a third person point of view, when the very concept of the third person assumes the existence of the first person.

Newtonian physics had in principle the ability to specify the position and velocity of every particle in the universe, and all properties of the universe could be specified in these terms. However, this approach is undermined by quantum mechanics. With respect to quantum mechanics, Clarke stresses two concepts, complementarity and non-locality.

Complimentarity does not allow us to specify all the properties of a physical system. Observation by an observer on the macroscopic world can determine which properties of a quantum system can be given values such as position or momentum. Clarke interprets this to mean that reality does not run from the quantum to the macroscopic, but constitutes an interplay between the two. This is related to Heisenberg's uncertainty principle, where two values such as position and momentum cannot be specified at the same time, but only two approximations, with the product of these uncertainties being equal to or greater than Planck's constant. Clarke also argues that the majority of physicists who ignore quantum effects at the macroscopic or classical level are wrong, because with something like a living organism that has intermeshed interactions at many different scales, quantum unpredictability could manifest at the macroscopic level.

Clarke further discusses the problem of non-locality. A field, such as the electromagnetic field is regarded as local. At each point in spacetime the field takes a particular value. The field changes in time as a result of the value of the field at neighbouring points and never as a function of the values of distant points.

However, quantum states can be non-local. The **Alain Aspect, 1982** experiment showed that there could be a correlation between distant quantum particles that could not be a function of

any of the particles that were local to the particles concerned. This suggests to Clarke that the particles are integrated into a larger system by underlying non-local connections. There is no possibility of communication between these particles, and this hard to explain characteristic leads Clarke to claim that existing physics, including quantum mechanics, is incomplete.

Clarke puts interpretations of quantum mechanics into two groups. Firstly, there are those that envisage the collapse of the wave function as a real physical event, while in the other camp views such as the Copenhagen interpretation regard the quantum states as mere abstractions necessary to predict and understand the outcome of experiments.

Clarke builds on the latter approach at the same time as saying that physics needs to be extended in order to provide a complete theory. First, he proposes a version known as histories of interpretation of quantum theory. Here the basic fact about a quantum state is the history that created the particular state, and a calculation of a probability of any particular history. An admitted problem here is the vast number of possible histories that could account for a state. There has to be a way of paring these down, and consciousness is suggested as the way of doing this.

Clarke describes the conscious 'I' as on the one hand linked with the various subsystems of the body but on the other hand, through quantum locality, including within it aspects of the people and things that it perceives. This represents a distinct view of quantum consciousness based mainly on non-locality.

It is disappointing that Clarke does not at least speculate on the practicalities of his proposal. For instance, non-locality does not allow the transmission of matter or energy, or of normal information, which is instantiated in matter or energy, but only of quantum properties, such as the spin of a particle. This leads on to Clarke's take with respect to free will, where his stance is somewhat confusing. In the first place, he suggests that decisions are based on a mixture of deterministic problem solving and randomness, the latter presumably quantum related. However, the mind is allowed to move into new frameworks of meaning, when consciousness changes the way in which it selects from different quantum histories. It is not really clear what triggers these changes of framework or how important they are in the overall workings of the mind, nor why it is the selection of histories rather than futures that is important. Altogether, Clarke puts forward an interesting concept, but one that needs much more development.

Hermes Romijn: Photon- mediated consciousness



Romijn, 1997 puts forward the concept that subjectivity or consciousness is coded into the virtual photons that generate electric and magnetic fields. This approach has considerable advantages. Photons intermediating the electromagnetic force are, as far as we know, the most basic level of the universe. At this level the fundamental components of the universe have given properties that cannot be explained, analysed or reduced further. So both the charge on the electron and the ability of the photon to intermediate it across space are given properties that cannot be explained or reduced. This is the only physical level at which it is possible to have properties that cannot be reduced to something more fundamental.

The article suggests that photons carry subjectivity or consciousness as such a given property. This is in principle possible because irreducible properties are present at this level. It is more reasonable than the mainstream approach, which suggests that a new property of consciousness can be produced by banging together previously unconscious bits of matter. The problem would be the same if we tried to say that electrical charge was a function of banging things together in some complex system. It might look plausible, but we would forever be looking for what actually happened that produced the charge. Romijn's theory is not fully panpsychic. Although subjectivity is present at the level of photons, it requires brain systems to generate ordered patterns that are the basis of actual conscious experience.

Romijn views the brain as a chaotic self-organising process, the outcome of which is the pattern of electric and magnetic fields generated by the dendritic trees of neurons. The author thinks that these patterns code for the qualia. Virtual photons comprise the electric and magnetic fields and it is these which are claimed to encode conscious experience. Romijn argues that they are causally necessary and sufficient for consciousness. Romijn takes an initially conventional approach in pointing out that brain scan studies show a correlation between neural activity and subjective experiences (**Raichle, 1998; Schacter et al, 1998**). Romijn takes the view that subjective experience is as real for the experiencer as brain scan activity is for the third party investigator.

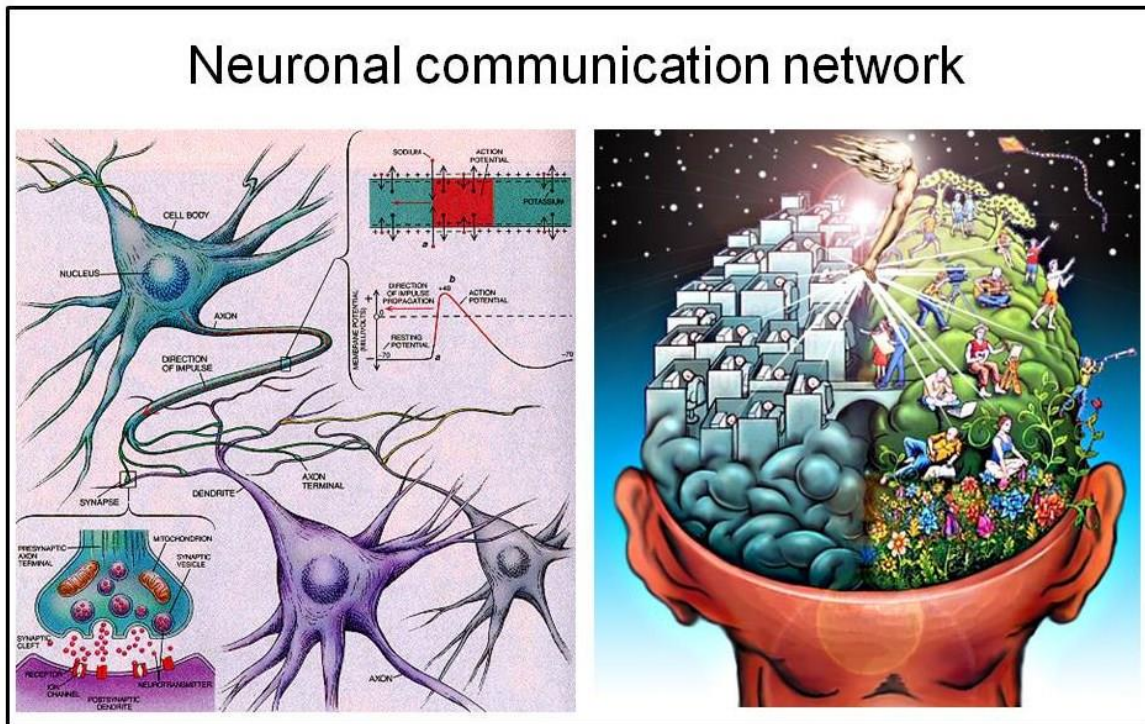


Fig. 36: Cartoon of neuronal communication network on the basis of propagated action potentials(a) and a schematic representation of the left and right hemispheres of the brain supposed to bear different functions

The Role of Dendrites

Romijn discusses the detailed behaviour of dendrites. When a dendrite receives a signal from another neuron there is a depolarisation of the membrane, in the case of an excitatory signal, and hyperpolarisation in the event of an inhibitory signal. This creates an electric field between the the part of the dendrite membrane that has become polarised or hyperpolarised and the rest of the membrane. The greater part of the electric field will flow towards the cell body and the axon hillock because the dendrite is thicker in that direction. This action along the dendrite also generates a magnetic field (**Fig.36**).

The dendritic tree has been shown to use several different forms of information processing. At the synapse the incoming pattern of action potentials determines which of various neurotransmitters stored there are released. On the dendritic side, receptors are sensitive to particular neurotransmitters. The receptors are clustered in complex spatial patterns. Receptors can modulate each other performance. Outside the synaptic cleft, the extracellular fluid has a low concentration of ions, neurotransmitters and hormones that may exert a synchronising effect between neurons. Studies have shown that the dendritic tree can detect the individual discharge of synapses and has mechanisms for amplifying the signal to noise ratio. Dendritic spines provide the postsynaptic contact sites for 80% of excitatory synapses.

Spines can change their shape in a period of milliseconds, which changes the flow of information into the dendrites.

Protein molecules constitute ion channels, receptors and enzymes and have electrically charged groups held together by van der Waals forces. These electrostatic binding forces determine the tertiary structure of proteins, and thence some of their properties. The ions, receptors and enzymes experience fluctuations as a result of the electrical field around the dendrite (Fröhlich, 1975, Goodman et al, 1995). It has been shown that postsynaptic receptor and ion distribution continually undergoes non-linear changes because of the synaptic electric fields. All this means that the dendritic tree has the ability to tune itself to the inflow of information, which in turn results in ordered electric and magnetic fields.

Romijn points out that synaptic transmissions are probabilistic. When an action potential reaches a synapse, there is no certainty that the synapse will fire. There is only a probability, of between 30% and 80%, depending on the type of synapse, that it will fire. In some studies (Lehman et al, 1998; Zeki & Bartels, 1998), field configurations, which had to remain stable in the cortex for a minimal time such as 120ms were related to various types of mental activity. Shorter lived fields are thought to relate to the unconscious level. The electrical and magnetic fields are seen as having a vast number of possible semi-stable configurations they can take up in response to either external stimuli or existing memories (Sakai & Miyashita, 1994) and Tononi et al, 2008). These fields formed out of virtual photons, the intermediating particle/waves of the electromagnetic force, are deemed to be the carriers of consciousness in the brain.

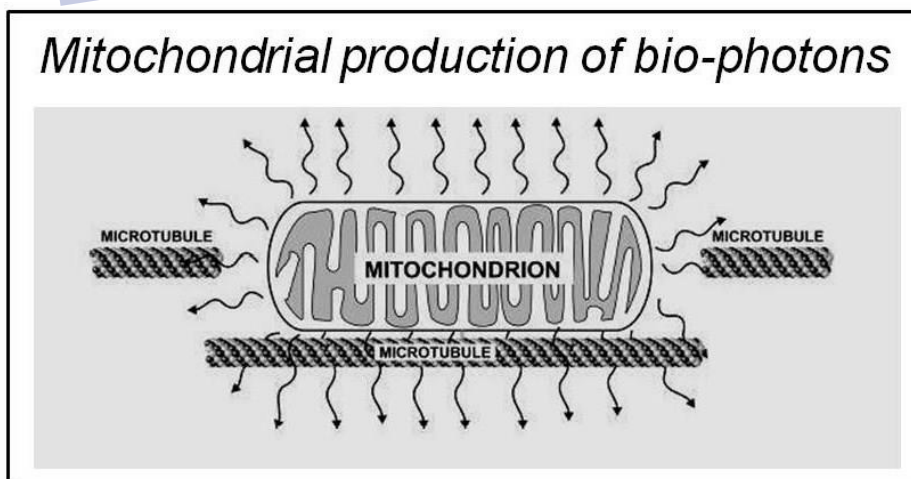


Fig. 37 : Mitochondrial production of bio-photons in the cell and their further transmission via microtubules.

More recent developments in photon-mediated consciousness hypothesis

Recent experiments confirm Romijn's ideas in the sense that a biophoton coherent system may constitute an ultra rapid communication system not only in the brain but also functioning in the whole organism, explaining the amazing concerted actions of complex living organisms. Regarding the biophysical visual representation idea, it should be stressed that the phrase "ultraweak biophoton emission" is confusing, as it suggests that ultraweak biophotons are not important in cellular mechanisms but are by-products of free radical reactions. In contrast externally measured ultraweak biophoton emission from cells and neurons is principally produced from natural oxidation processes on the surfaces of cellular membranes as demonstrated by **Blake et al. 2011, Fig 37**). However, the real biophoton intensity, as produced in mitochondria (see **Fig. 30**), as well as DNA/RNA, can be fundamentally higher inside cells and neurons (**Bókkon et al., 2010**) compared with the biophoton intensity in their surrounding environment which makes it possible for the emergence of intrinsic biophysical pictures in V1 visual areas (**Fig. 38**).

Long-term visual memories may not be stored as biophysical pictures but as redox regulated epigenetic codes. During visual imagery, top-down processes trigger and regulate the epigenetic encoded long-term visual information. Next, according to retrieved neural epigenetic information, mitochondrial networks in synchronized neurons generate patterns of biophotons through redox reactions, which can produce intrinsic biophysical pictures in retinotopic and mitochondrial rich visual neurons during visual imagery, REMS associated dreams or visual hallucination (**Bókkon, 2009; Bókkon and D'Angiulli, 2009; Bókkon et al., 2010a**). First biophoton experiments may support our biophysical pictures representation. Namely, **Dotta and Persinger, (2011) and Dotta et al. (2012)** observed cognitive coupling with biophoton emission in the brain during subjective visual imagery (**Fig. 31**). In addition, the biophoton emissions were strongly correlated with EEG activity and the emergence of action potentials in axons. In addition, **Sun et al., (2010)**, revealed that biophotons can conduct along the neural fibers which supports this biophysical picture hypothesis. It appears that biophotonic and bioelectronic activities are not independent biological processes in the nervous system, and their synergistic action may play a significant role in neural signal processes

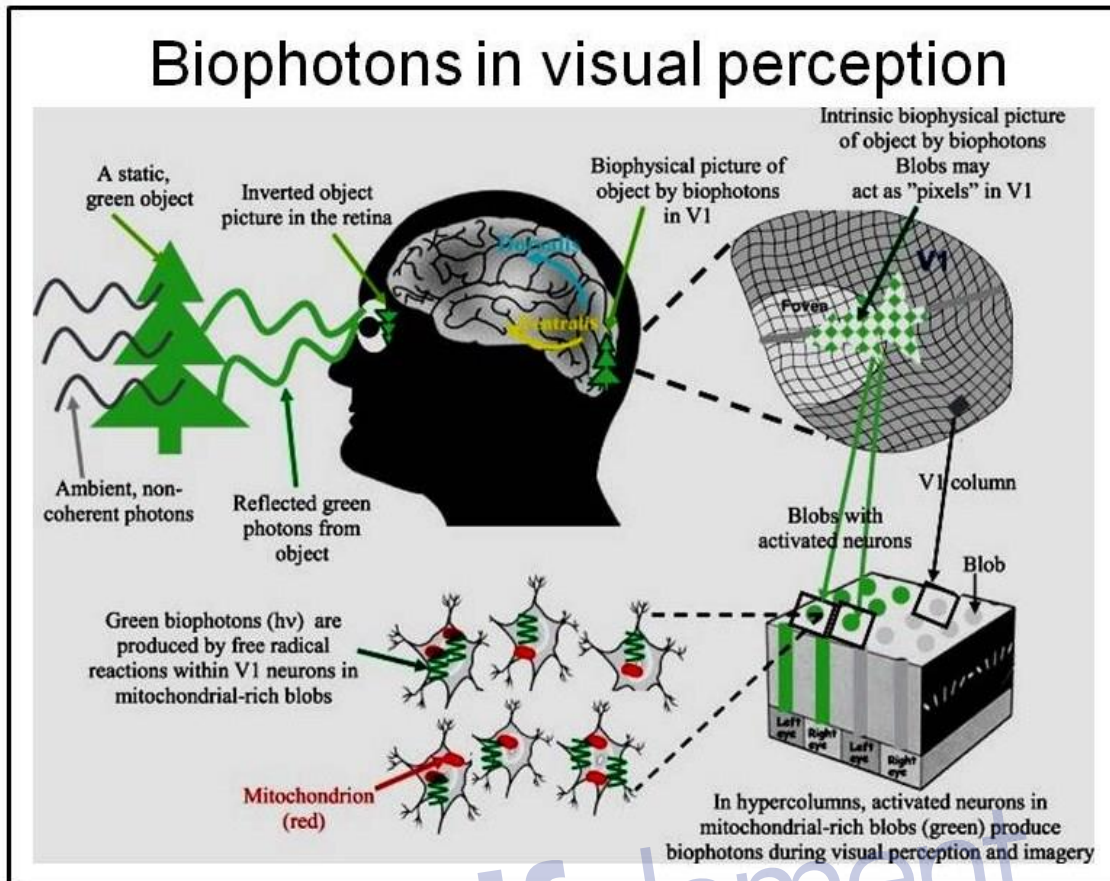


Fig. 38 : Bio-photons locally produced in brain tissue may play a role in visual perception of green- colored object.

Stuart Kauffman: Consciousness & the Poised State



In the final stage of his book *Reinventing the Sacred*, **Kauffman, 2008**, argues that consciousness derives from a 'poised state' between quantum coherence and decoherence into classical states. He looks to the transition from a quantum world of persisting possibilities to a classical world of actual possibilities. The acausal nature of quantum mechanics is central to his thinking. The Schrödinger equation is solved for the amplitude of the electron at each point in space. These eigenfunctions square the amplitude at each point in space, and define the

probability of finding an electron at each point in space. Nothing known causes the electron's choice of position, there are only probabilities at every point in space. For Kauffman, quantum mechanics breaks out of the causal closure of the reductionistic tradition. Amongst other things he suggests that this might resolve the problem of freewill, which cannot exist within deterministic physics.

Kauffman discusses the concept of phase information. The interference pattern seen in the two-slit experiment requires all the phase information on the final screen to add together to give the peaks and troughs of the interference pattern. Decoherence involves the loss of phase information as a result of interaction with the environment, often described as a heat bath of quantum oscillators. The interaction with the environment is seen as comparable to the interaction with the measuring device in the Copenhagen interpretation. However decoherence may not be as clear cut as the Copenhagen type measurement. In certain circumstances, only part of a system decoheres and some coherence remains.

Kauffman, 2012, places consciousness at this 'poised state' where part of the system decoheres and part is coherent. The coherent state is suggested to influence the classical decoherent state. In looking for such a system, Kauffman examines the recent research on photosynthetic systems. In photosynthesis photons are captured by the chlorophyll molecule that is held by antenna protein. The chlorophyll molecule maintains quantum coherence for up to 750 femtoseconds. This is longer than the classical prediction, and is viewed as responsible for the higher than classically predicted efficiency of energy transfer. The antenna protein plays a role in preventing more rapid decoherence, or in inducing recoherence in decohering parts of the chlorophyll molecule. Part of the quantum system may start to decohere, but be forced back into coherence, sometimes described as quantum error correction. Within the chlorophyll molecule the superposition of the Schrodinger solutions allows the simultaneous exploration of all the possible pathways. This is more efficient than the serial or one-path-at-a-time exploration, and is taken as an explanation for the mid 90 percentage efficiency of the system, in contrast with the 60-70% predicted for a classical system.

Kauffman thinks that the system seen in the chlorophyll molecule raises the possibility that webs of quantum coherence or partial coherence can extend across a large part of a neuron, and can remain poised between coherence and decoherence. Kauffman's discussion refers to coherent electron transport, but he recognizes that other forms of coherence such as phonons and electron spin could be relevant.

The 'poised state' is supposed to span states that are between being mainly coherent and partly decoherent. Information injected into the system can induce recoherence. The flow of information into cells is seen as a means by which recoherence could be induced and coherence maintained. In other writing, **Kauffman, 2012** suggests a two-way flow of influence,

with quantum possibilities effecting classical systems, while classical systems could influence recohering quantum systems (**Fig.39**).

In relating quantum coherence to consciousness, Kauffman assumes like Hameroff that coherence would have to be sustained for the milliseconds timescales associated with neural

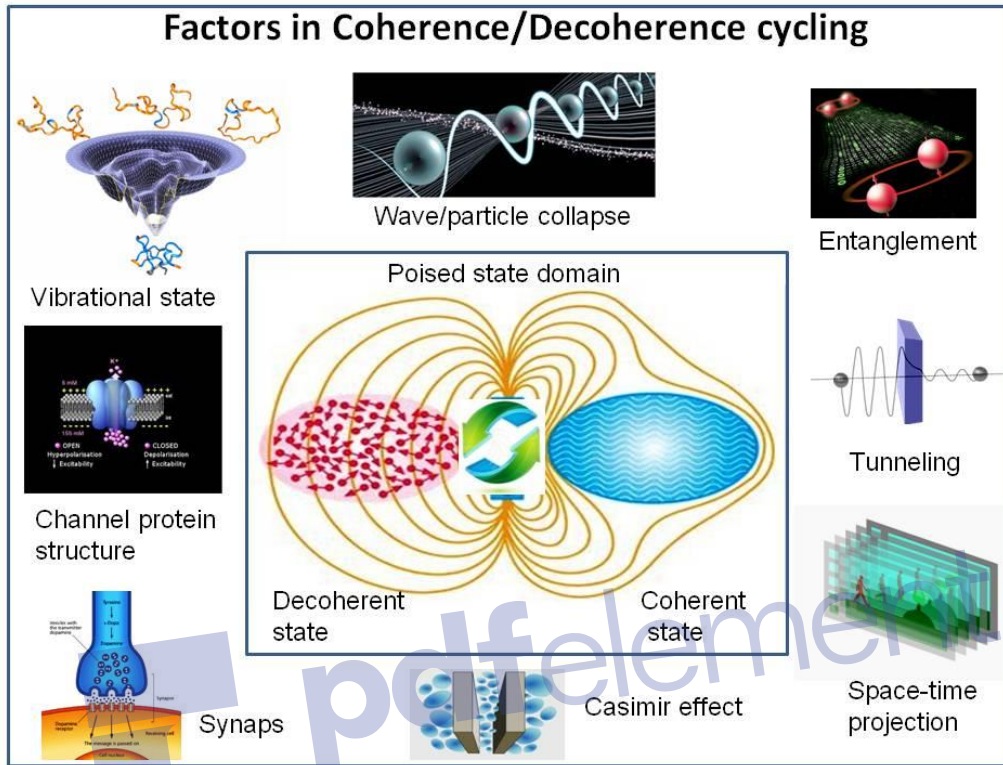


Fig. 39: Schematic representation of a poised realm allowing coherence and de-coherence cycles, potentially occurring at the level of channel proteins as related to neurotransmission (left) and involving quantum features such as wave function reduction, entanglement, superposition and a super-causal projection in a hypothesized space-time projection or alternatively quantum geometric space time perturbations at the Planck scale (right part). Taken from Meijer, 2014.

processing, rather than the femto- and picosecond timescales associated with quantum coherence in photosynthetic organisms. It might be debatable if a direct one-to-one correlation between processing activity and conscious episodes is necessary.

Post-Bohmian concepts of a Universal Quantum Field

The concept of a Universal knowledge field was previously also framed as Universal Consciousness, Cosmic Consciousness, Universal Mind, Universal Memory, Universal Intelligence, Holographic Memory, Collective Consciousness, and the Plenum, among many

other terms. The concept that information can take a universal character and that all information is present in a general knowledge field can be treated from a number of backgrounds and perspectives (see below). In principle, this item can only be approached through a general treatment of the modality of evolution of intelligence and therefore is purely based on human knowledge: natural laws, evolutionary theories, historical analyses and philosophy, since clearly everything we discuss and project and all we can say on observed nature entails the product of human deliberation. One could say that there is no known source of knowledge outside human experience.

In the above mentioned studies, the human brain is generally seen to function as an interface between individual and such a universal consciousness. It is worthwhile therefore to take a further look at a number of potential modalities for such an "information" domain in the following. In the "Noetic Field Theory" of **Amoroso et al. (1999)**, vacuum (zero-point) quantum fluctuations and gravitation were introduced as potential mechanisms explaining non-local information exchange. So called noetic effects couple operators of a noetic field to specific loci of pumped Frohlich-like coherent states. This was seen as a phase regulator into the patterns of Pribram's holonomic formations. The pumping mechanism for this process is inherent in the self organization of the system. The radiation pressure of the Bose states, Fermi-quasi-particle transitions, vacuum zero point fluctuations, and string dynamics are considered to be instrumental in driving this dynamic transpersonal 'memory of being'. This was supposed to be a dynamic Hilbert space storing archetypal forms of the personality or psyche.

The force carrier of the electromagnetic field is the photon. At a microscopic level, therefore, the interaction between the constituent particles of matter and the quantum vacuum involves photons being exchanged between the virtual particles of the vacuum and the quarks and electrons in matter. Basically, any charge in elementary matter, may distort, or "polarize", the quantum vacuum in the immediate vicinity, through attracting virtual particles with opposite electrical charges and repel virtual particles with similar electrical charges.

In quantum field theory, the fabric of space is visualized as consisting of fields, that at every point in space and time exhibit a quantum harmonic oscillator, interacting with neighboring oscillators. Further, and also critically importantly, the wave solutions are in pairs. This means that whenever the phase arrangements of intersecting plane waves produce an electron, they will also necessarily produce the opposite phase positron next to it (they will also have opposite spin states). This explains matter-antimatter pair production, which is occurring everywhere in space all the time, because space vibrates in two distinct patterns (particles and quantum fields) that are constantly switching (see also **Fig. 40**). Splendid work on teleportation, both in theory and experiment as reported in Nature by **Sudbury (1997)** and **Bouwmeester et al. (1997)** and in line with the work by **Marcer and Schempp (1997)**, makes it

clear that non-local quantum information represented by entanglement of particles in this field could be recovered locally as useable information.

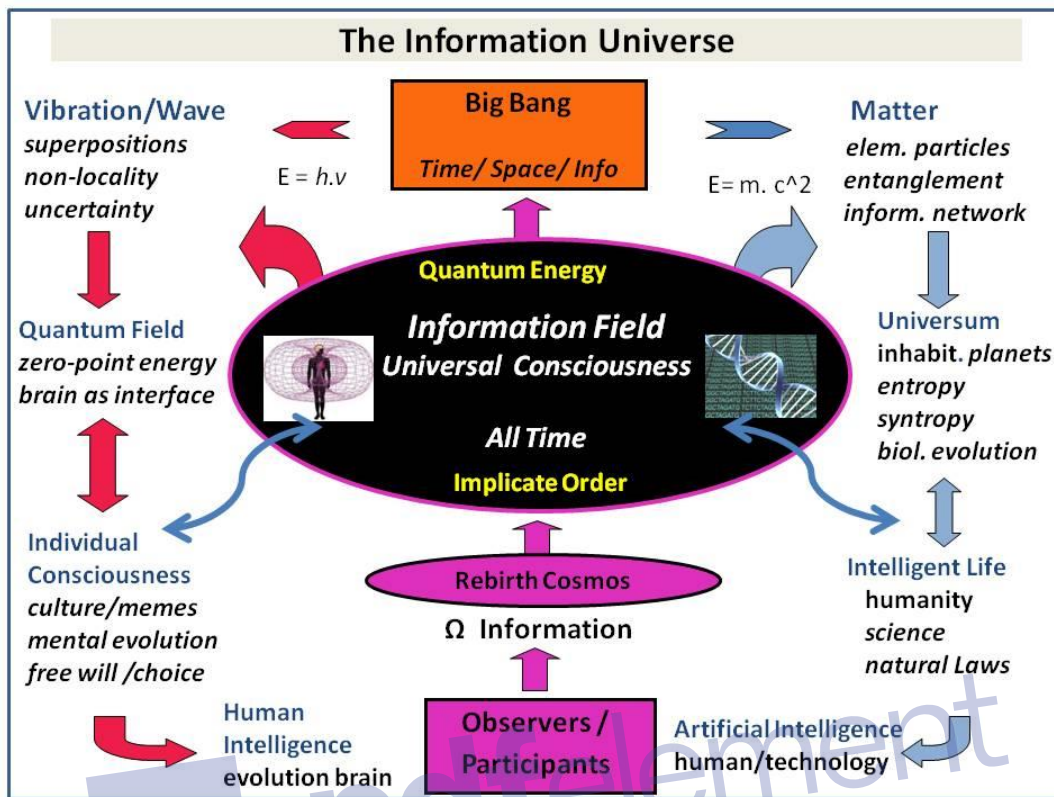


Fig. 40 : An integrated scheme depicting the Universe as a circular flow of information with its material (right part of the figure) and mental (left), aspects. The latter does not imply a dualistic approach, rather a complimentary and unitary matter/mind modality is assumed. This concept assumes a central quantum information field, that provides the very basis for creation of our universe and dynamically evolves further through cyclic feed-back processes from the present reality, in which natural (among others human) and artificial intelligence play crucial roles in observation and participation (see text for further explanation, see also Meijer, 2012).

Of note, if we assume a collective storage of all *information* that is present and/or evolves in our Universe and that humans and other intelligent species in the cosmos interact with such a knowledge field, it intrinsically implies that it cannot be solely treated as a by-product of our brain and intelligence in general (Fig. 40). At first sight this conflicts with current mainstream science and conventional pictures of reality. However the following may show that in fact there is solid ground and even overwhelming evidence for the hypothesis/concept of a universal knowledge field. These considerations are based on the current descriptions of nature on the micro level (string and spin theories), quantum mechanical concepts (such as entanglement, non-locality and resonance), cosmological models on energy (zero point energy and negative energy) as well as holographic concepts of reality and space/time modalities. In

addition, universal consciousness can be approached from transcendental human experience, including transpersonal consciousness and should be discussed against a meta-physical background, also in relation to the phenomenon of consciousness and self-consciousness as well as information theory (See Table 3).

Table 3: Aspects Supporting the Concept of an Universal Information Field

- **Quantized spacetime of Leibniz, Whitehead and Penrose**
- **Consciousness from a hyperspace view of Sirag**
- **Implicate and explicate order of Bohm**
- **Entanglement/non-locality in QM of Aspect and Bell**
- **Domain of wave/particle duality and observer effect of Wigner and von Neuman**
- **Tensed time and physical time of Primas**
- **Holographic model of reality of Susskind, Bekenstein and t’Hooft**
- **Fine-tuned Universe and Anthropic principle of Barrow and Tipler**
- **Zero-point Energy Field of Heisenberg, Haisch and Ruedy**
- **Block universe concept of Minkowsky and Einstein**
- **Negative energy and syntropy of Fantapie and Di Corpo**
- **Cosmometric description of consciousness of Penrose, Hameroff and King**
- **Morphogenetic field concept of Sheldrake and Goshwami**
- **Hard problem in consciousness studies of Chalmers**
- **Transpersonal experiences and PSI Phenomena of Jahn and Dunne**
- **Collective memory and synchronicity of Jung and Pauli**
- **Metaphysics of universal consciousness of Gornitz and Grandpierre**
- **Mathematical models for the fabric of reality of Tegmark and Deutsch**
- **Noetic and holographic field theories of Amoroso, Mitschell, Di Biase and Germinie**
- **Extra-corporal organization of biological information processing of Berkovich**

In fact these collective aspects form an integral framework for the formulation for the architecture of reality and therefore should finally be expressed in the scientific dream of a “*Theory of Everything (TOE)*” that obviously should be consistent with itself, yet due to limitations of intelligence, even in the far future, can never obtain the full status of an “final or ultimate theory”.

Various attempts have been made earlier to define a physical basis for a universal consciousness and/or a general information field. Apart from the seminal work of **Jung and Pauli (1955)** on collective consciousness and synchronicity, and that of **Bergson (1991)** on matter and memory, **Bohm (1980)**, **Susskind (1994)** as well as ‘t Hooft (2001) and **Bekenstein (2003)**, described the world as an information storing hologram. **Hagelin (1987)**, and **Sarfatti**

(2011) described a unified information field and a “psychosphere”, respectively, based on quantum physics, integrating various aspects of the work of the earlier mentioned Bohm, Berkovich, 2001 elaborated on extra-corporal and collective processing of biological information. In the studies of Wolf (2008) tachyons (particles traveling backwards in time) were considered as instrumental in the creation of universal consciousness and discussed in a religious context, while Sarfatti (2011) proposed retrocausal (back from the future) holographic image computing. Di Biase (2009a and 2009b) proposed a quantum holographic model of brain-consciousness-universe interactions, based on the holonomic neural networks of the earlier mentioned Karl Pribram, the holographic quantum theory developed by David Bohm, and based on the non-locality property of the quantum field described by Umezawa, a subject that also was thoroughly discussed by Mitchell and Staretz (2011).

Dirk Meijer: Bi-cyclic operating workspace with a top-down and bottom up flow of information

The quantum field theories of the mind display both bottom up and top-down aspects as to brain function, and this is also true for the various isoenergetic (emergent) processes (Meijer and Korf, 2013). The latter would start at the Planck scale and gradually become expressed at higher molecular and cellular levels. Interestingly, such a combined vertical counter-flux of information (see Fig. 33) would provide an integrated cybernetic control system that may enable highly efficient and rapid perturbations in brain function, with some delay also being expressed at the “horizontal” neuronal network level.

Within the various domains, an optimal communication might occur between the isoenergetic and quantum-based information flows, through wave/particle transitions as well as coherence/decoherence cycles (horizontal arrows in Fig. 33). Within this dynamic context, the causal (our normal) time perception and tensed time perception are separated but can be in correlated states. The supposed interacting cycles of both the isoenergetic and quantum mediated streams of information may exhibit nonlinear features, enabling the amplification of minimal information signals for the realization of rapid action of the organism in relation to interpreting the environment. In a sense this micro-model shows similarities with the sequence-seeking and counter stream macro-model for information processing in the cortex (Ullman, 1991).

In order to show how such a cyclic mental workspace could operate at the atomic/molecular and field levels, Meijer, 2014, Meijer and Korf, 2013 presented one example of a potential bidirectional information flow, that is based on the central role of Ca²⁺ ions under the control of various neuronal proteins. In this concept Ca²⁺ is viewed upon as an informational vehicle influencing the activity state of the neuron, (Pereira and Furlan, 2007). Similar schemes could

be imagined for other molecular mechanisms, mediating the tuning of cellular activity into large scale patterns, in the context of the creation of higher mental functions. As potential candidates, the hydrogen atom in relation to H₂O and unpaired electron spins as present in DNA, other metal ions, as well as present in O₂ and NO molecules (if associated with membrane proteins), have been proposed (Hu and Wu, 2004).

The Concept of a Bi-cyclic Operating Workspace in Brain

The quantum field theories display both bottom up and top-down aspects, and this is also true for the various isoenergetic (emergent) processes (Korf, 2010, 2012). Top-down supervenience was proposed to be mediated by a space-time memory domain build up during life time. Bottom up information transfer could originate at geometric space-time at the Planck scale, as earlier proposed by Penrose and Hameroff, 2012, and gradually may become expressed at higher molecular and cellular levels, while vice versa, wave state reduction in the brain may inform quantum fields on a continuous basis. Such a versatile operating bi-cyclic system may also allow neural signal amplification as well as forward and backward causation, the latter through holographic interference (Pribram, 1986, Mitchell and Staretz, 2011, Levin, 2012, Germino, 2007) of past (memory) and future informational aspects.

This physically based brain structure may be instrumental in a *complementary mode* of recurrent types of information processing that may be crucial for integral mental perception and causation and can also accommodate symmetric time concepts (for the latter see: Atmanspacher, 2011; Primas, 2009; Aharonov et al., 2010). It is proposed that such a specialized “multi-layered” physical brain compartment, may represent a workspace in which the two bridging and super-causal isoenergetic and quantum processes, act in concert and in a complementary manner. The author envisions such an operating system being organized as a number of nested, spatio-temporal, domains that allow the bidirectional flow of information (bottom up and top-down, large arrows in the center block of Fig. 6). A multi-layered operational organization of brain in conscious perception, requiring a nested organization of electromagnetic fields, was recently proposed by Fingelkurts et al, 2013.

Within the various domains, an optimal communication might occur between the isoenergetic and quantum-based information flows, through wave/particle transitions as well as coherence/decoherence cycles (horizontal arrows in Fig. 41). In such a dynamic context, the causal (our normal) time perception and tensed time perception are separated but can be in correlated states (Primas, 2003). The here proposed interacting cycles of both the isoenergetic and quantum mediated streams of information may exhibit nonlinear features (see Freeman and Vitiello, 2008), enabling the amplification of minimal information signals for the realization of rapid action of the organism in relation to interpreting the environment. In a

sense, this micro-model shows similarities with the sequence- seeking and counter stream macro-model for information processing in the cortex (Ullman, 1991)

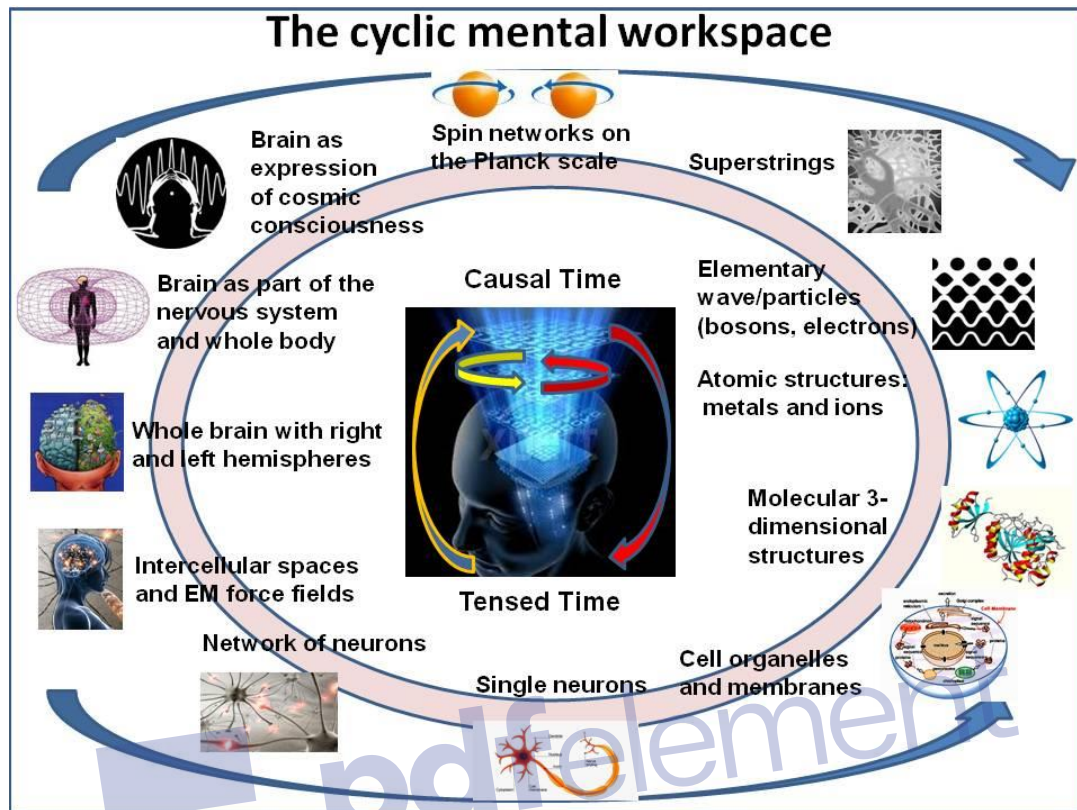


Fig. 41: Potential cybernetic effects on various levels of brain organization: Starting in the upper middle part and following a sequence to the right the following elements are pictured: spin networks on the Planck scale, superstring modalities of elementary particles, elementary wave/particles (bosons, electrons), atomic structures such as metals and ions, molecular 3-dimensional structures, cell organelles and membranes, single neurons, networks of neurons, intercellular spaces and electromagnetic force fields, whole brain with right and left hemispheres, brain as part of the nervous system and whole body, and finally brain as holographic expression of cosmic consciousness. A hypothesized mental workspace is depicted in the center with bidirectional (circular) of quantum and isoenergetic information flows. The two domains may be quantum correlated.

It should be emphasize that the sequential steps (on the right in Fig. 41) may contain classical neurological mechanisms, except spin- and/or string-mediated initiation events that should be merely seen as quantum processes. At the bottom micro-level, such an information flow may be initiated on the level of string mediated collapse of wave function (Mavromatos and Nanopoulos, 1995) and/or may operate through spin-dependent transformation of classical and quantum mechanical information, that may also be the basis for the so-called quantum potential or pilot waves of the implicate order proposed by David Bohm, 1987. The corresponding 4-dimensional space-time domain also introduces aspects of two-times physics, tensed and causal time (see also Fig. 41).

As mentioned above, **Penrose, 1989**, proposed that spin networks could be fundamental in the description of space-time in a background lacking manner (see for the latter also **Rovelli, 1996 and Smolin, 2004**). In the brain, spin-networks were pictured as electron-unpaired electron spins that represent pixels, collectively forming a “mind screen” that is known to be highly sensitive to fluctuating internal magnetic fields and action potentials. Such perturbations were considered to modulate neural dynamics, but also could enhance synchronization and stochastic resonance as have been noticed in brain (**Hu and Wu, 2004**). The particular spin chemistry bridges classical neural activity, serving as input via the magnetic influences on biochemical processing. Spin network dynamics may enable a quantum decoherence-resistant entangled modality of wave collapse since, through tunneling, they are rather insulated from the environment in decoherence-free subspaces, while repeated attention/intention (Zeno effect, see **Stapp, 2012**), may help in promoting coherent quantum states (**Hu and Wu, 2004**).

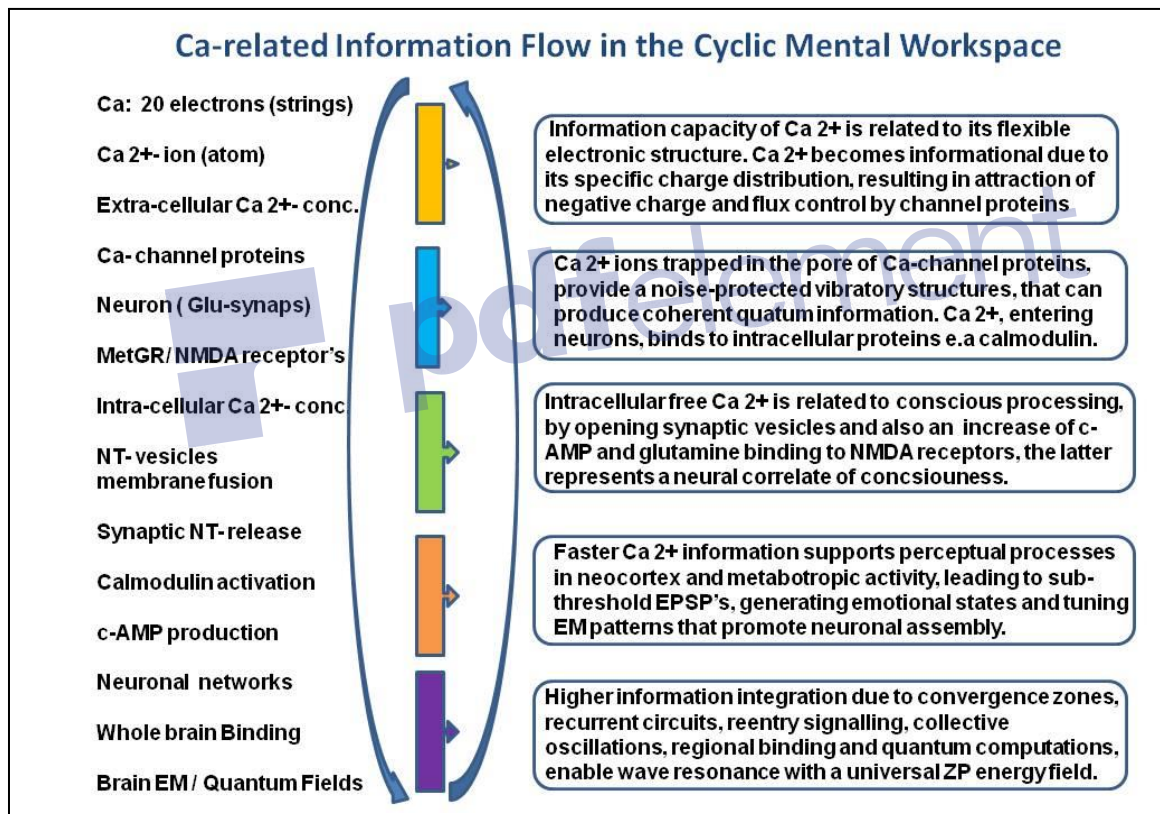


Fig. 42: The role of Ca²⁺ ions in the bottom-up and top-down information flow from the micro- to macro- level in the neuronal organization of the brain, as related to higher cognitive functions and consciousness.

In order to show how such a cyclic mental workspace could operate at the atomic/molecular and field levels, we present one example of a potential bidirectional information flow, that is based on the central role of Ca²⁺ ions under the control of various neuronal proteins. In this

concept Ca^{2+} is viewed upon as an informational vehicle influencing the activity state of the neuron, (**Fig. 42**, based on the data of **Pereira and Furlan, 2007**). Similar schemes could be imagined for other molecular mechanisms, mediating the tuning of cellular activity into large scale patterns, in the context of the creation of higher mental functions. As potential candidates, the hydrogen atom in relation to H_2O and unpaired electron spins as present in DNA, other metal ions, as well as present in O_2 and NO molecules (if associated with membrane proteins), have been proposed (**Hu and Wu, 2004**).

The informational aspect of Ca^{2+} is encoded in positive and negative charges within micro-sites on the surface of a spectrum of flexible macromolecules that allow binary choices at various spatio-temporal levels. The latter may also depend on ultra-rapid conformational changes in proteins in pico-seconds, as influenced by locally induced electromagnetic fields, that thereby obtain a probabilistic electro-magnetic vibratory character, an aspect that could also play a role in the present isoenergetic brain model. In turn, local magnetic fields can influence neural firing patterns and induce regional convergent zones of brain activity that are produced through sub-threshold EPSP 's and inhibitory inter-neuronal synaptic activity, being amplified by reentry and recurrent circuitry (**Pereira and Furlan, 2007**). The importance of Ca^{2+} waves in fast strategic search algorithms in a sort of bioreaction quantum computing was stressed by **Clark (2012)**.

Total brain activity is determined by genetic and epigenetic information, neuro-plasticity, as well as functional cycles of efferent and afferent signals (internal copies and external mirror information), that reflect the interaction with the whole body and its environment and dynamically produce our inner worldview, earlier referred to as "personal universe" (**Fig. 3**).

Of note, much of the sequential steps depicted in **Fig. 41 and 42** are situated in *single neurons*. Yet, our model, in the higher-order levels, requires an integrating modality in which the firing patterns of millions of neuronal networks are translated in an meaningful overall brain response. Sensory processing involves the formation of wave packets affecting large populations of neurons, instrumental in the reciprocal *broadcasting* of excitatory patterns located at several brain regions (**Freeman and Vitiello, 2006**), and inducing neuronal assembly. Interestingly, in this process calcium waves along the astroglial syncytium may play a role, contributing to collective oscillations and synchrony and thereby to efficient binding of distributed neuronal activity. (bottom part of **Fig. 42**). Yet, proper information integration, transmission and exchange with outer information domains requires a guided interactive quantum process, in which the classical separation of sender and receiver is overcome through an act of measurement and/or proper resonance with the information source. This implicitly should be based on the phenomenon of entanglement and consequently on unitary and conscious field properties of the neural and exo-systems (**McFadden, 2007, John, 2001, Bohm and Hiley, 1987**). This allows the continuous exchange of meaningful information with global

magnetic fields as proposed by **Mc Fadden, 2007** and **Burke and Persinger, 2013** and/or a universal quantum knowledge field as earlier proposed by **Bohm and Hiley, 1987**). The implicate order concept was suggested to also contain personal information (our mental double in the universal consciousness domain, (**Vitiello, 1995**). In order to operate in a conscious as well as sub-conscious modes and also to enable modalities of self-consciousness, it was proposed that apart from the known 4 dimensions at least one or two imaginary dimensions are required (**Carter 2013 a and b, Smythies, 2003**), see **Fig. 43**.

Neural interaction sites for bridging quantum information and rapid isoenergetic information transfer

The bottom-up and top-down vertical neural pathways as schematically depicted in **Fig. 41** , likely form a fine-tuned organization of neurological/biochemical signature, functionally connected with deep quantum-based information processing. This requires that each sequential step should provide an output of the type that can be used in either of the two supposed systems: quantum wave information should be collapsed or de-cohered to material signals. This could occur for instance during synaptic vesicle release or through potential Casimir effects induced by zero-point quantum fluctuations in the synaptic cleft, or alternatively, in microtubuli (**Hameroff, 2012**), where material/physical information should be translated to a wave form and vice versa.

Where in the brain, and how, could coherent wave superposition and quantum coherence occur? A number of sites and various types of quantum interactions have been proposed. Microtubules may indeed be an important ingredient (**Hameroff and Penrose, 2013**), however various organelles and bio-molecular structures including clathrins, myelin (glial cells), pre-synaptic vesicular grids (**Beck and Eccles, 1992**) and neural membrane proteins (**Marshall, 1989**) might also participate. In this framework, quantum coherence may be induced by pumping by thermal and biochemical energies (perhaps in the manner proposed by **Frohlich, 1968; 1970; 1975**).

As mentioned in the previous sections, it was inferred by **Korf, 2010, 2012**, that the ultra rapid responses of the brain cannot be explained by classical nerve excitation, action potentials, neurotransmitter release and further propagation and integration of neuronal activity. Instead molecular perturbations were suggested mediating high frequency conformational changes in neural proteins that have been shown to exhibit a vibrational state. Evidence for coherent excitations in proteins has indeed been reported, (see for example **Georgiev, 2008; Vos et al, 1993**). Tests show that there is a minimum timescale of about 30 ms needed for a subject to distinguish two sensory inputs as being separate. This means that consciousness cannot be slower than 30 ms. However, patients with time agnosia, who have subjective experience of the passage of time, confirm that it is physically possible to have consecutive conscious steps

that are experienced as simultaneous. From this it is argued that the real units of consciousness could be at the picoseconds level, although such units cannot be discerned by the conscious subject.

The poised realm of reversible coherence/ de-coherence process (Kauffman, 2012a, 2012b, could be situated in micro-sites that house such a conversion capability (Fig. 39). Mathematician Shor, 1996 proved a quantum error correction theorem for quantum computers. If quantum degrees of freedom in a quantum computer are de-cohering due to loss of phase information from the computer (the system) to its environment, then Shor showed that if information is added to the system from the outside, the decohering degrees of freedom could be made to re-cohere again. Re-coherence can occur, for instance, being driven by coherent electromagnetic field whose intensity and period distribution can be tuned non-randomly, thereby injecting information that results in a new controlled superposition state (Kauffman, 2012b). This clearly says that re-coherence is, in principle, possible. This idea finds support in the papers of physicist Briegel, 2006 showing that a quantum coherent "entangled" system can decohere to classicity than re-cohere to quantum entangled coherence.

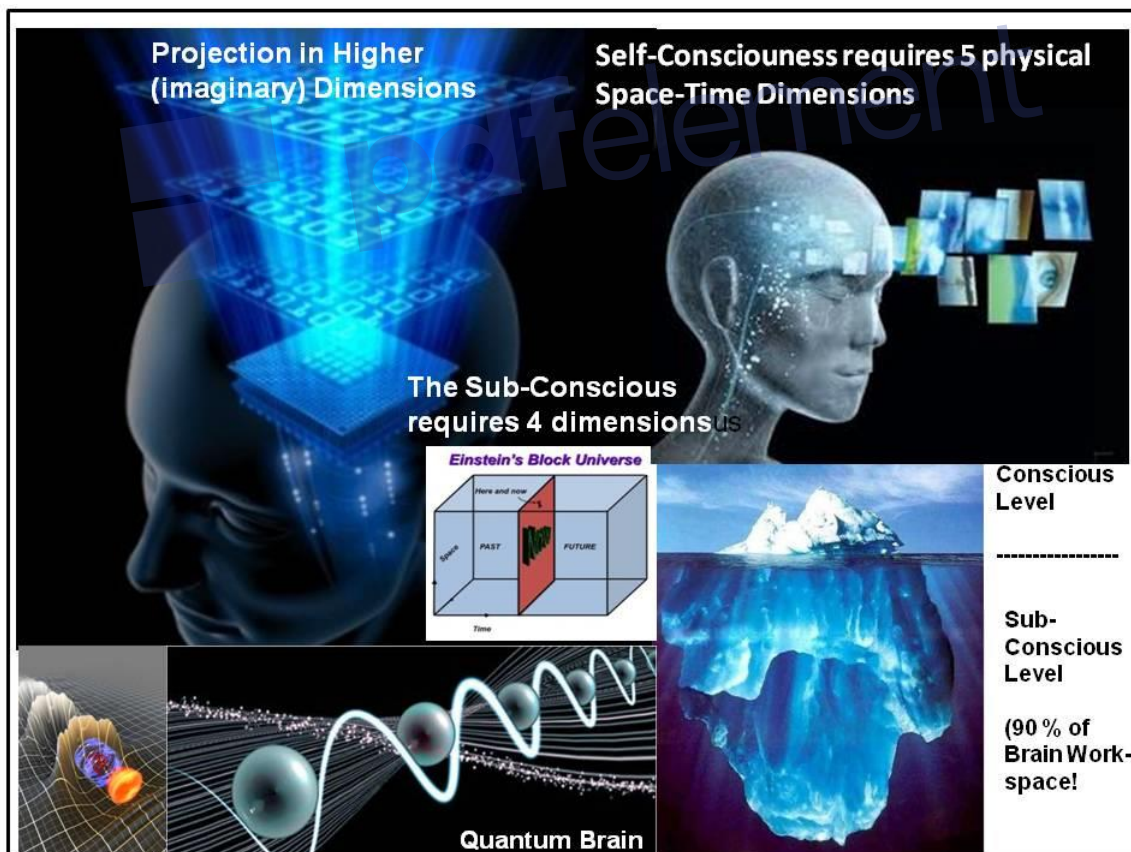


Fig. 43: Consciousness and the self requires at least five physical dimensions (see Carter, 2013 and Smythies, 2003).

In looking for such a system, **Vattay et al., 2012**), examined the recent research on quantum properties of photosynthetic systems (reviewed by **Arndt, 2010, Lloyd, 2012**). In photosynthesis photons are captured by the chlorophyll molecule that is held by antenna protein. The chlorophyll molecule maintains quantum coherence for up to 750 femtoseconds. This is much longer than the classical prediction, and is viewed as responsible for the higher than classically predicted efficiency of energy transfer. The particular antenna protein plays a role in preventing more rapid decoherence, or in inducing recoherence in decohering parts of the chlorophyll molecule. Part of the quantum system may start to decohere, but be forced back into coherence, described by the abovementioned quantum error correction. Kauffman thinks that this raises the possibility that webs of quantum coherence or partial coherence can extend across a large part of a neuron, and can remain poised between coherence and decoherence (**Fig. 39**).

In relating quantum coherence to consciousness, Kauffman assumes like Hameroff that coherence would have to be sustained for the milliseconds timescales associated with neural processing, rather than the femto- and picosecond timescales associated with quantum coherence in photosynthetic organisms.

Hameroff and Penrose, 2011, 2012, required quantum coherence to be sustained for 25 ms. **Tegmark's, 2005** paper, aimed at refuting Hameroff's Orch OR theory did not consider coherence over shorter timescales, because he was directing his argument at the longer timescales of Hameroff's primary theory. **Georgiev, 2000**, queried whether there is any evidence that consciousness has to arise over a milliseconds timescale. If consciousness could operate over a picosecond or shorter timescale, then Tegmark's calculations do not present any problem for quantum consciousness.

In addition to vertical bottom up and top down information transfer, rather separately organized neurological and quantum pathways could "horizontally" communicate by correlated time domains or be helped by local resonant or entanglement properties (**see Fig. 41 and 39**). In this respect, a number of potential intra-neuronal and inter-neuronal connective mechanisms should be taken into account. Solitons, described as dissipative waves or tunneling bio-photons, have been proposed as intracellular local effectors by **Georgiev and Glazebrook, 2006; Dotta, 2012**. Interestingly, even a process of photon quantum teleportation (**Salari et al., 2010**) have been suggested for long distance signaling in the brain, a process that both employs classical and quantum elements. **Ehresmann et al., 2011**, stresses the dynamic character of a multi-scale flexible brain structure, varying over time and with a hierarchy of complexification levels, in which higher cognitive and mental processes can develop. This occurs within a 5-dimensional global landscape with retrospective and prospective elements that, among others, result in changes in the synchronization of neuronal assemblies as well as dynamic adaption of neuronal contacts. In this sense the dynamic flow of information in the

brain may mirror the circular flow as it occurs from the micro- to macro scale in the whole universe and vice versa (**Fig. 44**).

Such a multidimensional space/time brain structure, being open to external electromagnetic and quantum fields, could also provide an interpretation framework for understanding of the, until now, non-comprehensible time delays in subconscious and conscious perception, the inner knowing of qualia as well as the subjective experience of transpersonal and extra-sensory events such as intuition, serendipity, clairvoyance and telepathy (**Libet, 2001, 2006, Jahn and Dunne, 2004**).

In summary: A double “countercurrent” operating workspace in the brain is postulated (see **Fig. 41**), representing a complementary mode of isoenergetic and quantum information processing. This workspace houses cycling (vertically and horizontally interacting) information flows that may be instrumental in highly rapid mental perception and causation and can accommodate time symmetry as well as nonlinear elements. The vertically directed cycle of flow includes interaction with electromagnetic and quantum fields that enable vice versa exchange of information with a universal knowledge field.

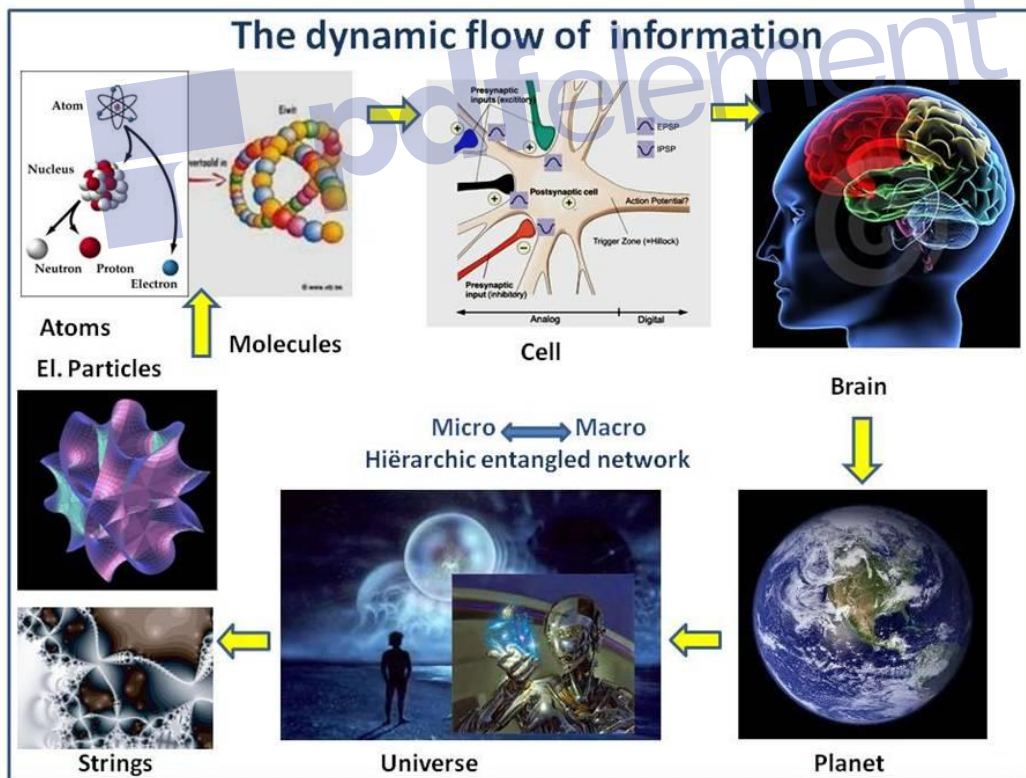


Fig. 44: Information flow at the micro- and macro scales of the universe

Zero-point energy: the vacuum

Quantum mechanics predicts the existence of what are usually called "zero-point" energies for the strong, the weak and the electromagnetic interactions, where "zero-point" refers to the energy of the system at temperature $T=0$, or the lowest quantized energy level of a quantum mechanical system. Zero-point energy is the energy that remains when all other energy is removed from a system. A harmonic oscillator is a useful conceptual tool in physics.

Classically, a harmonic oscillator, such as a mass on a spring, can always be brought to rest. However a quantum harmonic oscillator does not permit this. A residual motion will always remain due to the requirements of the Heisenberg uncertainty principle, resulting in a zero-point energy, equal to $1/2 hf$, where f is the oscillation frequency. Zero-point energy was experimentally demonstrated with the so called Casimir Effect, a unique attractive quantum force between closely-spaced metal plates. Casimir force was shown to be due to radiation pressure from the background electromagnetic zero-point energy which has become unbalanced due to the presence of the plates, and which results in the plates being pushed together. (Fig. 45)

Electromagnetic radiation can be pictured as waves flowing through space at the speed of light. The waves are not waves of anything substantive, but are ripples in a state of a theoretically defined field. However these waves do carry energy (and momentum), and each wave has a specific direction, frequency and polarization state. Each wave represents a "propagating mode of the electromagnetic field." Each mode is equivalent to a harmonic oscillator and is thus subject to the Heisenberg uncertainty principle. From this line of reasoning, quantum physics predicts that all of space must be filled with electromagnetic zero-point fluctuations (also called the zero-point field) creating a universal sea of zero-point energy. The density of this energy depends critically on where in frequency the zero-point fluctuations cease. Since space itself is thought to break up into a kind of quantum foam at a tiny distance scale called the Planck scale (10^{-33} cm), it is argued that the zero point fluctuations must cease at a corresponding Planck frequency (10^{43} Hz). If that is the case, the zero-point energy density would be 110 orders of magnitude greater than the radiant energy at the center of the Sun).

Zero-point energy has the desired property of driving an accelerated expansion, and thus having the requisite properties of dark energy, but to an absurdly greater degree than required, i.e. 120 orders of magnitude. Work by **Christian Beck**, and **Michael Mackey, 2006** may have resolved the 120 order of magnitude problem. In that case dark energy is nothing other than zero-point energy. In "Measureability of vacuum fluctuations and dark energy" and "Electromagnetic dark energy" they propose that a phase transition occurs so that zero-point photons below a frequency of about 1.7 THz are gravitationally active whereas above that they are not. If this is the case, then the dark energy problem is solved: dark energy is the low frequency gravitationally active component of zero-point energy. SED studies published

in the 1990s showed that a massless point-charge oscillator accelerating through the zero-point field will experience a Lorentz force (from the magnetic components of the zero-point fluctuations) that turns out to be directly proportional to acceleration, allowing the derivation of the fundamental $F=ma$ relationship of mechanics from electrodynamics. This points to the electromagnetic quantum vacuum as the origin of forces which appear as inertial mass.

Andrei Linde, in a seminal article in 2003, postulated that our rather homogeneous part of the universe emerged from a chaotic initial state and that the universe may consist of different exponentially large domains where the properties of elementary particles may be different. According to quantum field theory, the so called empty space is filled with quantum fluctuations, a scalar field that grew during inflation, which also may have led to different domains with different properties. Our part of the universe is considered to be a selection with specific inflation conditions in which the physical constants take values that enabled our kind of life. According to Linde, this provides a simple justification for the so called Anthropic principle (**Barrow and Tipler, 1986**) and does not require a multiverse concept. The question then arose how the laws of Nature in our part in the universe became into existence. The answer formulated by the author is very much in line with the principles of quantum physics: the final structure becomes only fixed after measurements are performed!

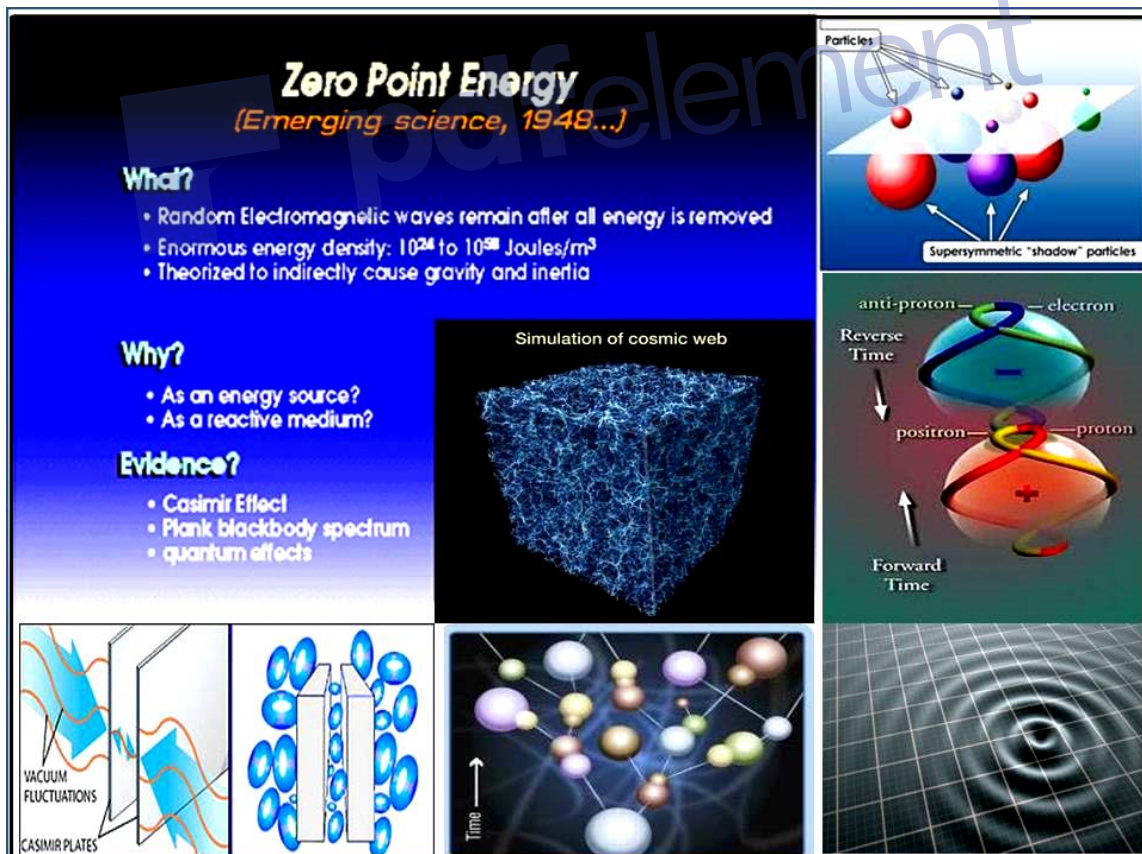
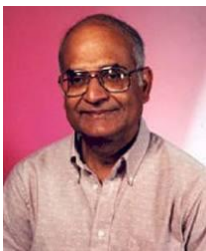


Fig. 43 : Left: The universal, all pervading "zero energy field" as a vacuum with fluctuations of quantum waves or particle/antiparticles (insets right). Through superposition and photon

polarization) information storage is possible. Two plates at a very narrow distance (left below) show attraction since the virtual particles outside can exert more pressure than the spatially expelled particles inside (the so called Casimir effect that demonstrated the universal presence of zero point energy). The anti-particles travel in a reversed time mode.

This implies that the final fine tuning of our world somehow is closely related to the evolution of life and consciousness. If our universe is a wave function, without observers or participants it would be a dead universe. Our knowledge of the world begins not with matter but with perceptions, said **Linde, 2005**. It is possible that consciousness, like spacetime has its own degrees of freedom and that neglecting it leads to a description of the universe that is fundamentally incomplete. He finally stated: all matter in the universe was produced with quantum fluctuations after the end of inflation. Quantum effects combined with inflation made the universe not only infinitely large but also immortal and afforded a beautiful and self-consistent pattern. Are we uncovering the universal truth or does this beauty rather deceives us? We should be kept in touch with solid and well established facts, without forgetting the urge of scientific freedom and speculation.

Amit Goswami: The vacuum as universal information field



Quantum aspects of life

The following section largely sites and summarizes the excellent article of **Goswami, 2005**. "Morphogenesis, the growth of a complete organism from a single cell embryo, is a phenomenon of biological order of unprecedented precision timing of correlated events of both spatial and temporal nature. One doesn't see anything like this in dealing with inanimate matter. Naturally, beginning with **Erwin Schrodinger, 1959, 1986**, an impressive group of scientists have suggested that the currently known laws of physics may not be enough to explain morphogenesis. Many biologists have propounded the idea of a morphogenetic field -- a condition of space that retains the memory of the form that the embryo evolves towards under the guidance of the fields. But these earlier works hold on to the concept of local fields and also to the materialist belief in "upward causation" -- the supremacy of matter as the cause of everything.

But morphogenesis, as proposed by **Sheldrake, 2005**, has overtones of *teleology* (the idea that some final purpose is driving the system) to many. One has recently injected new principles in the old idea of morphogenetic fields to incorporate teleology, non-locality, and downward causation. Sheldrake's morphogenetic fields are purposive and non-local. They are not material. They are capable of downward causation in matter through a new principle called "morphic resonance". As soon as a new form comes about, it sets up its own field which is continually reinforced with its ongoing replication, thus explaining the memory exhibited in morphogenesis. However, there is the fundamental question of the source of the morphogenetic fields that resonate with matter, since this exhibits an implicit dualism.

The purpose of the following section is to show that although dualistic in its original form, morphogenesis can be given sound footing on the basis of Quantum principles applied in the conceptualization of the living cell within the context of a new *science -- science within consciousness*, a science based on the primacy of consciousness. This will take up the necessity of a new formulation of biology within the primacy of consciousness and indicate how morphogenesis theory is a precursor and a special case of this new theory. The dualist objections against this new are next resolved. A quantum explanation of morphic resonance is then given. The question of experimental verification is briefly discussed.

How Form is Remembered

A real problem of morphogenesis is non-locality -- how local interactions can control global development. How does a cell in the big toe know where it is with respect to the whole body so that its function in form-making is switched 'on' appropriately so that the cell can do what is required of it at its position in the toe? If the blueprint of switching is itself in the DNA (as materialist biologists would have it), then how does the toe cell know only to activate the relevant part of the blueprint? We can see that there has to be a "*metaplan*" -- a meta-blueprint that functions in a non-local way, both spatially and temporally. Somehow the micro DNA strand of one single cell has to exert influence on a vast collection of cells spread across a Macro region of spatial volume and over the whole time that the embryo development takes

In materialist theories (apart from the concept of particles), there is also the concept of "force fields". The difference between the two concepts is interesting. Whereas particles are discrete, fields form a continuum. They have a wholeness. For example, if we cut a magnet that generates a magnetic field, we get two of the same magnetic field -- not two halves of the original one. This generates the idea that perhaps the holistic field concept has some usefulness for discussing a holistic phenomenon such as morphogenesis in biology.

The field concept has been used in biology quite powerfully and in connection with morphogenesis by the theoretical biologist Waddington who had a flare for language. He

created important words in his characterization of the morphogenetic field called "chreode", which is a "canalized" pathway in an "epigenetic landscape". As an illustration, consider the motion of the ball sliding down a landscape of hills and valleys. The ball follows particular valleys. Its motion downward is canalized. Similarly, the development of particular parts of the embryo is canalized toward particular end points. The canalized motion of the ball is relatively immune to perturbation because of the hills that separate it from other neighboring valleys. Similarly, said Waddington, the canalized development of the embryo is also immune to small amounts of environmental perturbations. But Waddington's fields -- interesting as they are as an idea -- will not do for morphogenesis for they are local.

So is it the morphogenetic field that tells the particular DNA of a cell which part of the form-making plan to activate? They can if a plan is stored in the fields themselves which are non-local. Suppose the DNA are just receivers (like radio receivers) rather than the generators of the information of the plan. Radio receivers can receive a signal because they resonate with the electromagnetic wave of the signal. Similarly, the DNAs receive the morphogenetic signal (the instructions for activation of a particular part) via morphic resonance.



Fig. 46: Perception of Universal consciousness at all levels (middle), requires a holistic approach to cultural, historic and personal experience of reality

Thus morphogenesis explicitly deviates from materialist models of biology where everything is assumed to be the product of upward causation, emergent as they may be. Morphic resonance is one way of introducing downward causation in biology. The purposeiveness exhibited in biological form-making arises from this downward causation.

Of course, since the plan is global and non-local, morphogenetic fields also have to be non-local. And here, the theory is departing from the philosophy of scientific or material realism (according to which nothing can exist outside of matter and its rules of locality). And the theory is explicit about the non-locality of his "morphic" (short for morphogenetic) fields -- a non-locality, he says, that may even be of Quantum origin. Morphic resonance is also postulated to be the basis of memory or repetition of living forms. Morphic resonance consists of influence of "like upon like" previous patterns of form on present patterns of form, reinforcing the pooled memory of the species. In this way, morphic fields are different from any other postulated in biology by virtue of his bold hypothesis of (a) downward causation and purposiveness; (b) non-locality; and (c) morphic resonance with memory property. Indeed, with these properties of morphic fields, all of the difficulties of biological morphogenesis of materialist theories are resolved. But morphic field theory, seemingly has an implicit dualism, if postulated to transcend matter. They are capable of influencing matter. Resonance phenomenon in radio needs electromagnetic wave propagation between a source and a receptor. In this theory, there is the receptor (the living object) and there is the information being received (the morphogenetic fields). But the source is left ambiguous and implicit. But leaving out the source of morphogenetic information is the reason that one cannot explain how the first such field comes into being. He leaves it to "some inherent creative intelligence in mind and nature" (Fig.46).

This intuition is correct, and that this intelligence is consciousness itself, looked upon as the ground of all being. Consciousness acts on matter in conjunction with a vital body that contains the blueprints of biological forms. That is the source of morphic information. And the function of morphic fields and resonance is carried out by consciousness simultaneously choosing actuality from possibility forms of both the vital and the physical body of an organism. And yet, this process does not involve dualism. Instead, the process involves self-referential quantum measurement (see later).

Who Programs?

Materialist biologists talk about programs of morphogenesis stored in DNA, but are confused by the question of who programs the DNA, the biocomputer? The only answer for the materialist is environmental conditioning driven by competition for survival and natural selection. Furthermore, as Gregory Bateson pointed out a long time ago, computer learning is low-level learning. It is learning by producing memory. Computers cannot learn the context of learning. In other words, they can learn within fixed contexts, but they cannot change contexts. In other words, genetic programming may be adequate for understanding morphogenesis under ordinary circumstances, but not for situations where regulation or regeneration of forms

(see later) takes place. Nor is genetic programming able to explain how a new context for morphogenesis is learned.

Another difficulty with the concept of genetic programming, within the strict materialist philosophy, is that classical programs can never simulate non-local behavior. So even with genes forming a cooperative program, can we understand the non-locality of morphogenesis with this concept?

In science *within consciousness*, we propose that there is a creative programmer -- consciousness itself. Consciousness is creative and changes the contexts of learning in the programs of the living cell. Not only is morphogenesis explainable with this hypothesis but also is the evolution of new forms. And not only morphogenesis and evolution, but the door is also opened to understand Life itself as a manifestation of consciousness as different from insentient matter.

For Life, there has to be a new organizing principle. But it is unlikely that such organizing principles reside in matter emerging at the appropriate level of complexity. But if downward causation and purpose are phenomena of consciousness, and if consciousness is the organizing principle for Life, how does consciousness intervene into the behavior of matter that make up the world of manifestation? If the world really ran by Newtonian laws, there would be no way for such intervention. Fortunately, the world is not Newtonian. Ever since the beginning of this century we have been discovering the novelties of a new mechanics that originated with the study of motion of submicroscopic objects. The matter of the world obeys this new mechanics called Quantum Mechanics. But this mechanics lacks closure, thus making room for consciousness to intervene in the affairs of matter. Quantum Mechanics -- broadly interpreted within the philosophy that consciousness is the ground of all being (perennial philosophy or monistic idealism) -- gives us an adequate science of becoming in the biological world.

There is one more important question -- the question of meaning. Computers process symbols but not the meaning of symbols. The meaning exists in the mind of the programmer. Computer scientists routinely assume such a psychophysical parallelism in their theories as discussed by **Varela, Thomson, and Rosch, 1991**, and even by **Dennett, 2007**. Similarly, the meaning of living functions and attributes such as maintenance, reproduction, evolution, and form must be carried in a separate body within consciousness. This body is traditionally called the "vital body. In summary, we need a theory of bio-physical parallelism -- a simultaneous and parallel functioning of a vital body and a physical body. But the introduction of the vital body (and consciousness) in biology surely raises the specter of dualism. It is the solution of the problem of dualism with the help of quantum measurement theory that makes science within consciousness a viable concept for biology.

How Consciousness Creates Biological Order Without Dualism

It is well-known that Quantum Mechanics is not deterministic but probabilistic. Quantum mathematics (the Schrodinger equation) calculate possibility waves (the wave functions, the square of which determines probability). Normally for doing physics and chemistry, since one is always dealing with myriad objects, the probability calculus works in a statistically deterministic fashion and dealing with grave questions of philosophy can be postponed. But this is not possible in certain situations of biology because a single system -- such as a single living cell (assuming that there is a quantum mechanism within the cell) -- is involved.

For a single system, the question of quantum measurement become paramount. Who-or-what collapses the possibility wave into actuality? The possibility wave is a superposition of eigenstates. The process of measurement is always found to have reduced the superposition into a single eigenstate. But what causes this reduction? The mathematician John von Neumann said that consciousness does. When we look, when we measure, we choose the space-time actuality from superpositions of possibilities that exist in transcendent potentia. But von Neumann's idea that it is consciousness that brings into being the world of manifestation from the transcendent possibility waves of Quantum Mechanics met with considerable resistance. It was labeled dualistic. How can consciousness act on matter without violating the law of Conservation of Energy? If there are two simultaneous observers, whose choice counts for the outcome? Many alternative resolutions of the quantum measurement problem were proposed (e.g. hidden variables) to close down this window of idealism. But none succeeded.

Progress toward opening the window of monistic idealism came in 3 steps. The first step was an epoch-making discovery by the theorist **John Bell** in **1966**. Bell showed that the introduction of hidden variables into Quantum Mmechanics (i.e., a resolution of the quantum measurement problem suggested by many physicists) conflicts with the locality principle of material realism -- that influence can propagate only within the Einsteinian speed-of-light limit. But the basic non-locality of Quantum Mechanics has been verified experimentally by Alain Aspect and his collaborators in France.

In the crucial second step, ignoring conventional wisdom, **E. Harris Walker, 2000 Fred Alan Wolf, 1996, Ludwig Bass, 1971, Stuart et al, 1978, Henry Stapp, 2009 and Beck and Eccles, 2003**, all proposed -- implicitly or explicitly -- that our consciousness is related to the processes of quantum measurement in the brain. This opened the door for the third step. The measurement problem is squarely resolved when we turn the metaphysics of science upside down and posit consciousness as the ground of all being and thus -- having causal efficacy -- downward causation. What else can we say about a consciousness that collapses the quantum

possibility wave into actuality? All objects are quantum objects. Therefore, any machine -- such as the ones called "measurement apparatuses" that we use to amplify a quantum phenomenon -- itself becomes a possibility wave (a superposition of Macroscopically distinguishable possibilities) when in contact with micro-quantum possibility waves that they purport to measure. This includes such measurement apparatuses in our brain.

Consciousness can collapse the whole conglomerate because it transcends the material Universe. Does such collapse constitute mind over matter? No, consciousness transcends the brain, whose states exist as possibilities within consciousness before collapse. Collapse consists of recognition and choice of one of these possibilities. The human brain may thereby function as an interface between personal and universal consciousness (**Fig. 47**).

If transcendent consciousness is always looking and collapsing, quantum possibilities would never develop and all the wonderful phenomena of quantum physics that give us the technologies of computers, lasers, and superconductors would be impossible. This is called a "tangled hierarchy" because the causal efficacy does not lie entirely with either the subject or the predicate but instead fluctuates unendingly between them.

Thus, realizing that the quantum measurement in an observer's brain is a tangled-hierarchical process helps us to understand our self-reference -- our capacity to look at the (collapsed) object of our observation separate from us, the subjects. Note also that this subject-object split is only appearance, just as the self-referential separation in the liar's paradox of the sentence from the rest of the world of discourse is only appearance. The subject that collapses, that chooses, that observes (or measures), that experiences dependently co-arises with awareness of the object(s) that are observed and experienced. They dependently co-arise (as appearance) from one undivided, transcendent consciousness and its possibilities. When consciousness identifies with the subject, there is (apparent) separation -- the subject-object split. Notice how, in this description, dualism is avoided because ultimately there is only undivided consciousness.

Notice also that the self of self-reference in the quantum measurement of an unlearned stimulus operates with complete freedom to choose from the macroscopically distinguishable quantum possibilities offered by the brain (in other words, with creativity). However, due to conditioning, the freedom of choice is compromised for a learned stimulus. As a result of experience, the self thus acquires a conditioned mode, conventionally called the "ego". Therefore, in a self-referential system, consciousness can act in and identify with 2 different modalities: one is creative or quantum modality, and the other is conditioned or classical determined modality, as was also proposed by Vitiello.

To make quantum measurement theory relevant in biology, we must postulate that self-referential quantum measurement already takes place in the living cell and is responsible for

the split of one consciousness and its possibilities into life and environment. This gives us a profound distinction of the living as opposed to non-living. This also opens the door for the explanation of both creative and conditioned modalities of biological evolution in the theory of punctuated equilibrium. According to this theory, the famous fossil gaps represent rapid evolution that gives rise to speciation. In between rapid epochs of speciation, there is gradual neo-Darwinian evolution which maintains species homeostasis. In the present theory, the rapid evolution is due to discontinuous, creative quantum leaps in the quantum mechanism of gene mutation in the cell. In between, the cell operates in the conditioned modality which is continuous and gradual -- in other words, neo-Darwinian. Now to the problem of bio-physical parallelism introduced in the previous section, how can we avoid dualism there?



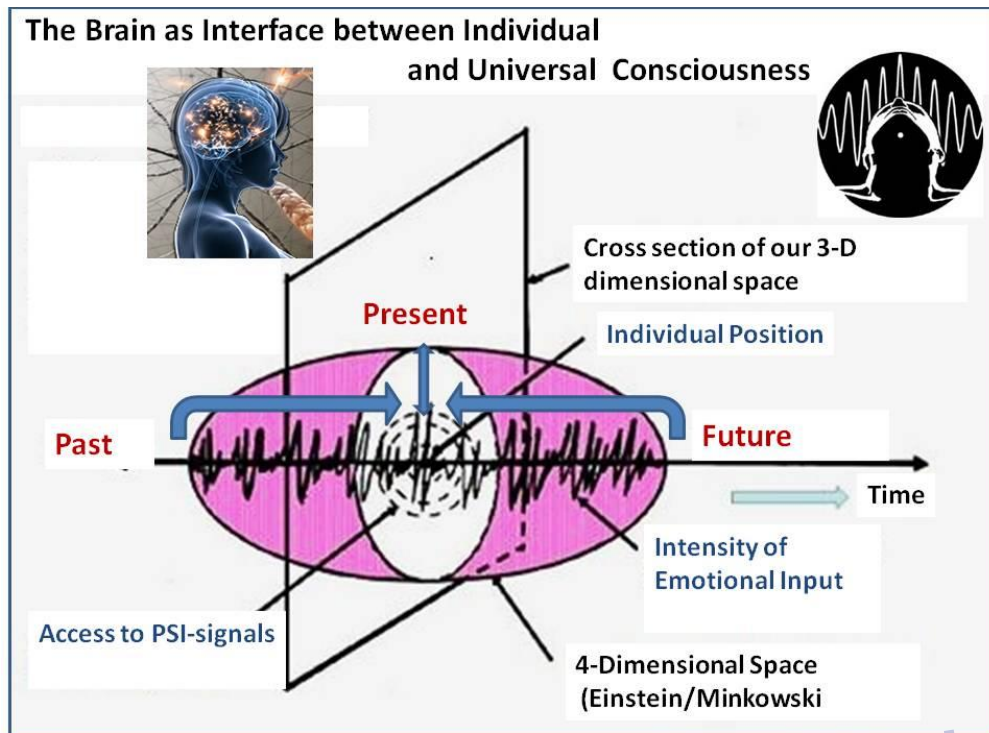


Fig. 47: The human brain acting as an interface between individual and universal consciousness. The working space of the brain is depicted as a 3-dimensional concept of a 4-dimensional space (pink ellipse), allowing input of information from both the past and future. This information includes ESP and PSI signals, the intensity of which is determined from emotional history and the emotional projections from anticipation of the future.

Avoiding Dualism in Bio-physical Parallelism

Vitalism was rejected in biology because of its problem with interaction dualism (faced by all Cartesian type of dualism in general). If there are two separate dual bodies, what mediates their interaction and without violating conservation laws such as the Conservation of Energy? If the vital body exists in a parallel existence with the physical in exact correspondence (biophysical parallelism as enunciated by Leibnitz), the problem of dualism still larks. What maintains the exact correspondence? The solution that quantum measurement theory gives us is this: consciousness mediates the parallelism between the physical and the vital body. This is not dualism, because consciousness simultaneously collapses (non-locally) the quantum possibilities of the physical and vital bodies for its self-referential experience. These quantum superposition of possibilities already exists within consciousness which is only choosing by recognizing a particular possibility. Thus, it is not "mind over matter". This resolution of the problem of dualism requires that the vital body be a quantum body (i.e., its states describable by Quantum Mechanics as waves of possibility).

Evidence for the quantum nature of the vital body is found in the demonstration of non-locality. *Qigong* masters can non-locally affect the vital field of plants enough to enhance or reduce the rate of biochemical reactions involved in plant growth. Quantum objects obey the uncertainty principle. That is, we cannot simultaneously measure both their position and velocity with utmost accuracy. In order to determine the trajectory of an object, we need to know not only where an object is now but also where it will be a little later. In other words, both position and velocity simultaneously. So we can never determine accurate trajectories of quantum objects.

Although the macro-bodies of our environment are made of the micro quantum objects that obey the uncertainty principle because of their grossness, the cloud of ignorance that the uncertainty principle imposes on their motion is very small. So small that it can be discounted in most situations. This is the so called "correspondence principle". Thus, macro-bodies can be attributed both approximate position and approximate momentum and, therefore, trajectories (their possibility waves spread, but extremely sluggishly). For the physical world, we use the intermediary of the macro-bodies (a macro "measurement" apparatus) to amplify the states of the micro quantum objects before we can observe them. This is the price we pay, loosing direct contact with the microcosm so that we have a shared reality of physical objects in the macrocosm. Everybody can simultaneously see the physical macro-bodies. But vital substance is indivisible. For this substance, there is no reduction to smaller-and-smaller bits. There is no micro out of which the macro is made. The vital world is a whole or what physicists sometimes call an "infinite medium". There are waves in this infinite medium -- modes of movement that must be described as quantum possibility waves obeying a probability calculus. And we directly observe these quantum without the intermediary of the Macro measurement apparatus (there isn't any). But there is a price that we pay for the direct experience. The observation and experience of the vital modes of movement are subject to the uncertainty principle. What this means is that any observation disturbs the vital object so much so that another observation would not lead to the same experience. Therefore, *experience* cannot ordinarily be shared by two different observers. It is private, since it is experienced internally. In this sense a mental expression of individuality, operating in 5 dimensions can be inferred (Fig.48).

Further note that the quantum picture enables us to think about the physical and the vital worlds differently from what we are used to. Normally, we tend to think of both of these worlds as made of substances (something "concrete"). Sure, the vital substance is more subtle. We cannot quantify it in the same way as we can the physical. But it is still a substance, or so we think. We must change our view. Even the physical is not substance in the ordinary sense, let alone the "vital". Both physical and vital worlds remain as quantum superposition of possibilities until consciousness gives them substantiality by collapsing an actual experience.

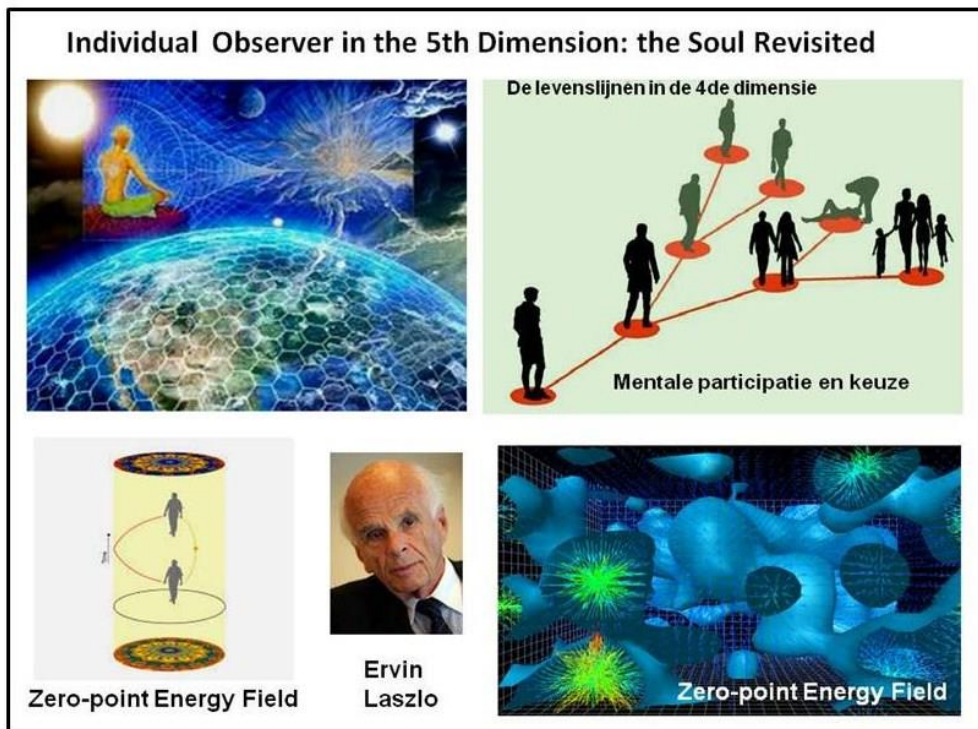


Fig. 48: The human mind is positioned in a 4-dimensional domain, that may be constituted by a universal knowledge field (physically the zero-point energy field), in contact with its individual life line that consists of subsequent binary choices (upper right inset). The observer (soul) of the individual mind and its history is situated in a 5th dimension, (up left cartoon).

The quantum system in the cell along with Macro-measurement apparatuses that amplify its states (and also make a record of the actualized states upon measurement) -- whose states are collapsed in a correlated parallel fashion with the states of the vital body -- can be said to have mapped the blueprint, the meaning, contained in the latter. This is similar to how we write software on computer hardware. The maps are inherited by all the cells of the body of a multi-cellular organism through cell division. The shared maps can solve some of the profound puzzles of biological morphogenesis.

Non-locality in Morphogenesis

The embryo of a highly-developed organism starts as a homogeneous structure-less entity that develops in successive stages that shows the evolutionary history of the organism.

In materialism, we look for a materialistic beginning for everything. All development must be contained within the reductive components and their interactions. Materialist biologists now believe that the genes -- the DNA of the embryo cell -- contains a blueprint of the form that develops. The DNA is analogized to a computer. Its components behave according to

programs that contains all the necessary instructions for cell differentiation. But as already mentioned, there is a grave problem in this kind of thinking.

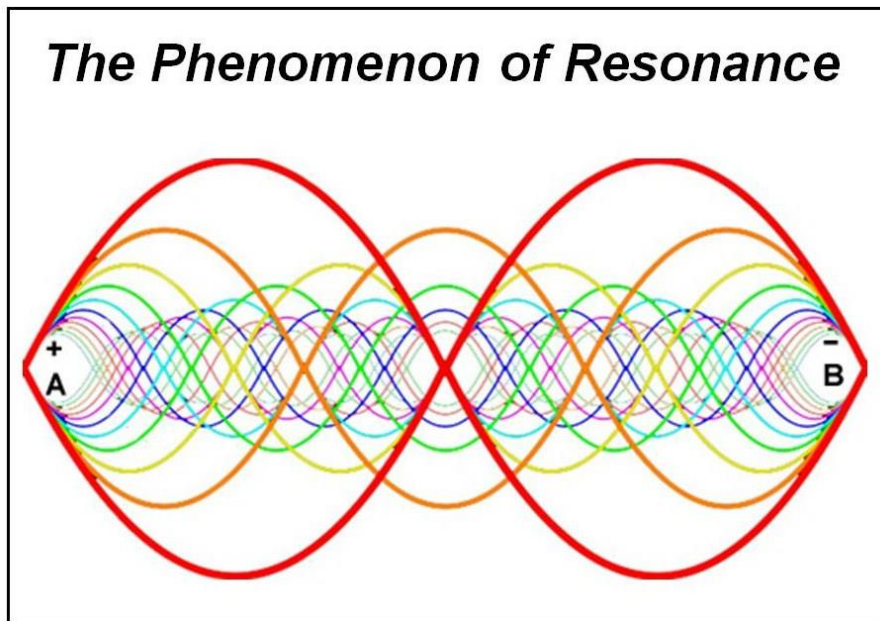


Fig. 49: A schematic representation of resonance of two sources of wave information A and B

The problem is this. How can local interactions among the components of the DNA give rise to such spectacular non-local correlations as exhibited by morphogenesis? If we think of the DNA as a computer, a classical computer, then the problem is that a classical computer can never simulate non-locality as shown by the physicist Richard Feynman. But if we assume a quantum component to the computing machinery of the cell, then non-locality is no longer a problem, and together with resonance (Fig. 49) may be instrumental in instructing the organism. It is readily recognized that biological correlations exhibited in morphogenesis are not only correlations that persist over distances but also over time. The distance correlations can be understood easily as the play of quantum non-locality. But how about the correlation over time? It turns out that the latter is also the play of quantum non-locality. The name of this particular play is "delayed choice" of John Wheeler. The crucial point is that in the quantum picture, the morphogenetic forms take shape first as possibility forms. They are not manifest until a bifurcation of form occurs that necessitates choice. Such a bifurcation may involve a particular form that occurred in the past or a brand new form. Once collapse occurs, the entire causal pathway leading to the chosen form manifests at once as if by "delayed choice". Obviously this seems a teleological and future-oriented choice of form. But delayed choice is a well-known characteristic of non-locality in quantum measurement. It has been verified by laboratory experiments.

Evolution and Morphogenesis: a Quantum explanation of Morphic Resonance

The lesson of the "delayed choice" -- that possibilities can wait in limbo until consciousness chooses actuality from among them - is crucial to understand not only morphogenesis but also the creative quantum leap in evolution and how evolution and morphogenesis work together to map the meaning-forms of the vital body onto the physical as physical forms.

According to neo-Darwinian dogma, evolution is gradual. But a creative change requires many individual micro mutations at the gene level working together making a Macro-mutation that gives rise to a new phenotype trait leading to a new species. If neo-Darwinist ideas of selection on every individual mutation were at work, most mutations -- since individually they are not beneficial -- would be eliminated. But why assume that individual mutations are selected for or against? It is a fact that mutations (either point mutations or mutations acquired in gene recombination) are quantum in nature. They are mere superpositions of possibilities before consciousness has collapsed them. Suppose the quantum superpositions of mutated genes wait in limbo until enough of them accumulate to give rise to a phenotype trait leading to new form. Not only the gene mutations are quantum processes, but also the making of form from genes (morphogenesis). Both evolution (of the mutated genes) and morphogenesis of the new trait wait in limbo as superpositions of many possibilities, from among which consciousness can see a pattern that is just right for mapping a meaning-blueprint contained in its vital body. See also Davies, 2004.

Why should a form that occurred in the past be chosen? The answer is that forms are conditioned as part of the developmental history of Life. Initially, forms exist as degenerate multitudes of coherent superposition, and the choice among them requires creativity and purposiveness. However, a collapse of a self-referential quantum system conditions the system. Thus once a form has manifested through a creative breakthrough, the probability of its repetition increases. In biology, since all life is connected to some first living cell, conditioning propagates down-the-line throughout the tree of Life. This is the explanation of why certain forms repeat over-and-over in morphogenesis. In a sense, this is a kind of memory, and its manifestation does involve non-locality. But the mechanism is quantum. In other words, we have arrived at all the virtues of the theory of morphic resonance without the implicit dualism.

Conclusions: The theory of formative causation via a physical information field and bidirectional interaction through morphic resonance will go down in history as a bold departure in the right direction, in that it introduces many of the right elements -- downward causation, purpose, and non-locality -- in this theory. Because of its initiative, the theory inspired many scientists to investigate similar ideas in other fields. Measurement is seen as a *tangled-hierarchical* and produces self-reference -- our ability to distinguish between us,

subjects, and the objects we experience. The theory does not contain an implicit dualism, recognizing that consciousness is the creative organizing principle behind biological evolution and morphogenesis of organism and brain”.

Comments of Bromberg on Goswami's monistic idealism theory

The concept of Goswami was critically discussed by Bromberg, 2000. We cite from this article:

“Science is experiencing one of the most difficult challenges of all history: to explain human most basic capacity, the mental. It was for long thought that human mental abilities were insurmountable difficult to understand and therefore excluded to transcendental and disconnected world and relegated to religion. But the advent of the paradoxes in our understanding of the physical world, plus the undergoing serious and spread research in artificial intelligence and cognitive science faced science with the necessity of dealing with the mysteries of the mind (**Bromberg, 2000**).

Every single discipline in humanity has something to say on the issue: science, religion, art, poetry, etc. But none has yet the capacity of proving its assumptions. If **Dyer's, 1994** AI enterprise is successful in explaining consciousness and the mental, then we scientist, Goswami included, will have to welcome it, but if on the other hand, quantum mechanics appears to be more than a mathematical practical tool and shows to contains ontological relevance then scientist, including Dyer, will certainly have to accept it. But science discoveries not only take time but resources, and for that we should try to stop an evidently contradictory theory.

With the introduction of Goswami's alternative model of nature, Science is left with (at least) two opposite models: materialistic realism and monistic idealism. Since none of them is not yet usefulness. Goswami claims his new theory overcome some inconsistencies (paradoxes) of materialistic realism and completes Cognitive science with the inclusion of the "subjective". If his claims were true, his theory would clearly outrun materialistic realism. Any attempt then to keep materialistic realism as the more plausible model, needs to attack those claims. Dyer, instead of arguing the invalidity of his argumentation - that his theory does overcome those inconsistencies - he attack his argumentations by discarding the existences of the inconsistencies: "Idealist science is not needed because cognitive science is already developing computer programs which can emulate human creativity, ethics and free will". Moreover, Dyer never discuss the paradoxes of quantum mechanics, paradoxes in the materialistic realism model. Thus, even if Dyer's enterprise were successful, it would leave monistic idealism with the same level of credibility of materialistic realism. This is what is pretended to be argued, not that Dyer is incorrect in his attacks, but incomplete. He does not then succeeded in undermining Goswami's theory, at most he may have succeeded in leaving it at the same level of credibility than materialistic realism.

The current undergoing lines of research in both materialistic (algorithmic) and idealistic (nonalgorithmic) Cognitive Sciences have many adepts each, with strong evidence of correctness and consistency in each of them. Probably it is the case that Goswami theory is not only correct but inclusive of current algorithmic Cognitive Science as Goswami claims. In such a case both lines of research will not only survive but contribute positively to Science.

In the meanwhile, **Bromberg, 2000**, believes that both lines has chances and he does not see any strong reason for eliminating any of them. A key point is that quantum downward causation of choice is discontinuously exerted (if it were continuous, a mathematical model could be constructed for it and the choice would be predictable and not free), but our ordinary state of consciousness smoothes out the discontinuity. To be aware that we choose is to wake up to the non-ordinary oneness taking a discontinuous leap. In this way, the dictum of the new physics is: I choose, therefore I am (my cosmic quantum self).

So the new paradigm of reality based on the rediscovery of consciousness within science is not only giving us back our free will, but also is identifying the source of that free will as the spirit within us, the oneness that spiritual traditions have always propounded. The new paradigm is showing us great promise for integrating science and spirit and art. It is also promising a breakthrough integral approach to medicine that integrates conventional and alternative medicine”.

Simon Ragget: A final attempt to formulate a theory of consciousness

At this stage, we might think we have covered enough ground to try to put together a theory of consciousness that has explanatory power, and is not obviously at variance with what we know about physics, neuroscience or evolution.

We have tried to define consciousness, as our subjective experience, or as the fact of it ‘being like something’ to experience things. Consciousness also involves our subjective awareness of the real or apparent ability to subjectively envisage future scenarios, and to use these for our choice of actions. We have further suggested that there is only one problem with consciousness, the problem of how qualia or subjective experience arises, and that we have to address this and essentially only this in discussing consciousness.

We have examined theories of consciousness that operate within the context of classical physics, and always come up against essentially the same explanatory gap. Classical physics gives a full explanation of the relationships of macroscopic matter, without any need for consciousness, and also without any ability to generate consciousness. This creates a problem as to how the brain can generate consciousness, given that neuroscience describes the brain in

terms of the macroscopic matter made up of carbon, hydrogen, oxygen and other atoms, the relationships of which can be described without either requiring or generating consciousness.

The failure to find a theory with satisfactory explanatory power within classical physics pushes us towards identifying consciousness as a fundamental or given property of the universe. What does this really mean? Explanation in science works by breaking things down into their components and the forces or processes that make them function. But this downward arrow of explanation does not reach a floor. Mass, charge, spin and the particular strengths of the forces of nature are given properties of the universe that are not reducible to anything else and come without any explanation. Because consciousness has a similar lack of explanation, it is similarly suggested to be a fundamental property.

Although the powers of understanding of human senses and the scope of Newtonian science are limited to three spatial dimensions, the scope of our universe is not limited to three dimensions. In fact, new theories hypothesize there are eleven dimensions. Many of the natural phenomena happening within our universe transcend the three dimension scene. Therefore, it is not possible to assume that the mechanisms of operation of the brain and consciousness remain imprisoned within the confines of Isaac Newton's three dimensional material universe. Just as the Earth was proved not to be the center of the universe, our current theories that govern our physical universe such as Einstein's gravity theory and others may become obsolete in our understanding of reality.

It is reasonable to consider properties of the brain correlated with consciousness, but it is not possible at this stage to shut the possibility that, as Nobel Laureate Neurobiologist Sir John Eccles points out, the scope of consciousness may not remain limited within the confines of the human skull. This is especially so because many of our practical observations and those of many others clearly show that consciousness, at times, can remain completely des-embodied. We can hence, focus our attention on understanding three factors, the nature of consciousness, the property of the brain that enables consciousness to operate within the brain, and a model that explains the behavior of the brain and consciousness as practically observed.

The slow electrical pulses moving at a maximum speed of 120 mps may, perhaps, be adequate to account for some of the involuntary functions inside the human body. But they are certainly not adequate to account for the speed of human activities that involve computing and the mind. The similarities between the computer circuits and the brain cells have driven brain researchers to construct computer models for the brain. Initially, they tried serial computers, and then to account for the speed, parallel computers came into play. Today, computer models dominate most brain research, but are still no match for the human brain.

However, computer models are many orders of magnitude slower than needed to account for the speed of thought. A Neurologist has calculated that if the brain was a standard serial or a parallel computer, it would take more time than the age of the universe to perform all the necessary calculations associated with just one perceptual event. But if the brain were a quantum computer, it would try out all the various possible combinations of data arrangement at once, and thus, unify its experience. So, in essence, the brain operates very similar to how science theorizes a quantum computer to work even though quantum computers do not yet exist.

Many who research on the brain-mind problem proceed with a prior assumption that consciousness is an emergent property of the brain, but quantum physics indicates that consciousness is related to the awareness that an electron appears to show in the wave/particle duality (double slit experiment). Quantum physicists have shown that the electron behaves differently when being observed by a human.

When the electron is not being observed, the electron behaves like a wave, but when an observing instrument is placed in the experiment, the electron behaves like a particle. This experience indicates that the electron will change its behavior/reality depending on whether or not the electron is being observed as if the electron is aware that it is being observed. This awareness is very similar, if not the same, as human awareness and may be related to the same consciousness.

Consciousness is, therefore, a non-material entity capable of independent, eternal existence, and not a property. Consciousness is not emergent, and is eternal similar to the electron. It can remain localized in the human brain and interact with the brain, and thereby, control the activities of the human body. While electrons in the brain behave as particles, these electrons prevent the consciousness from realizing that it is part of a larger whole. When the electrons behave as a wave, the consciousness becomes aware of its existence outside the human mind, which makes OBE and NDE possible.

Whenever the electron wave function collapses, the OBE and NDE ends and the person returns to their physical body and its perception of reality similar to the collapsing of the wave function in the double slit experiment in quantum physics. During the OBE and NDE while the electron is behaving as a wave function, consciousness can leave the brain and go into an independent floating existence outside the human body where it can travel independent of space-time similar to the entangled electron.

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It has been shown using such techniques as PET and MRI that the above process of receiving data from a stimulus by a sensory organ, transmitting them to the brain, computing and processing the data, and passing the processed data to consciousness, can be reversed by hypnotizing a person. When a hypnotherapist suggests, for example, that he/she is seeing red light to a hypnotized subject, all above processes take place in the brain as if the subject is actually seeing red light. The consciousness gives the brain a perception of reality that is different from the hypnotherapist's perception of reality similarly to an observer in the example of general relativity where one observer on Earth watches another travel away at the speed of light. To the traveling observer, his perception of reality is different than the observer watching from Earth, and as a result, his experience of time is different than the observer on Earth.

The ability of a person to describe what his/her consciousness had observed or heard while it is in a des-embodied state makes us to believe that memory is, at least partly, non-material and unaffected by collapsing the wave function. Quantum systems are essentially unified, and so are our thought processes. David Bohm says, "Thought processes and quantum systems are analogous in that they cannot be analyzed too much in terms of distinct elements, because the intrinsic nature of each element is not a property existing separately from and independently of other elements, but is instead a property that arises partially from its relation with other elements."

We can conclude that consciousness is a quantum mechanical entity that can have an independent existence. It can localize in the human brain when the electron is in a particle state. This provides the necessary quantum mechanical base conducive for it to interact with and function in the brain. When the state changes to that of a wave, consciousness takes flight and starts floating. It takes away with it at least a part of the contents of the memory. It possesses the ability to acquire visual, auditory and olfactory information in spite of the fact that there are no sense organs associated with it. This information is produced by the

consciousness projection of a different reality caused by the change in state of the electron, which one may interpret later as a dream or hallucination that comes from an altered perception of reality.

The major stumbling block in solving the brain-mind problem is how does the brain-mind bind together millions of dissimilar neuron activities into an experience of a perceptual whole. How does the “I” or “self” or the perceived wholeness of one’s world emerge from a system consisting of so many parts, billions of neurons. What creates the “Oneness” of thought processes? What creates individuality and I-ness or “self”? What creates feelings, free will, and creativity? The eternal consciousness.

No mechanistic system consisting of separate interacting parts could give rise to the above. What are the structures in the brain that create the property which grant us access to the quantum realm? This is a good question and once this is known by all mankind, mankind will change. It has become clear that to explain this theory, one has to consider the most highly ordered and highly unified structures possible in the universe. The structure that possesses both characters, the most highly ordered and most highly unified is the Bose-Einstein condensate.

In classical science, the most ordered structure that we can find is the crystal. Crystals are rigid, immovable structures. In Bose-Einstein condensates, the quantum properties allow both a “fluid” order and a high degree of unity. Each particle in a Bose-Einstein condensate fills all the space and all the time in whatever container that holds the condensate. Many of their characteristics are correlated. They behave holistically as one. The condensate acts as one single particle. There is no “noise” or interference between separate parts. This is why super fluids and super conductors have their special frictionless qualities and lasers become so coherent. Super conductors, super fluids, and lasers are Bose-Einstein condensates. The photons of a laser beam overlap their boundaries and behave as one single photon and the whole system can be described by a single equation. Hence, the part always includes the whole like in fractal geometry.

Super conductors, super fluids, and lasers are either very low temperature or very high energy systems. Super conductors and super fluids lose their quantum coherence long before they reach room temperature. Quantum coherence at body temperature in body cells was found by Herbert Frohlich. Prior to that, quantum physicist Fritz Popp discovered that biological tissue emits a weak glow when stimulated at the right energy levels.

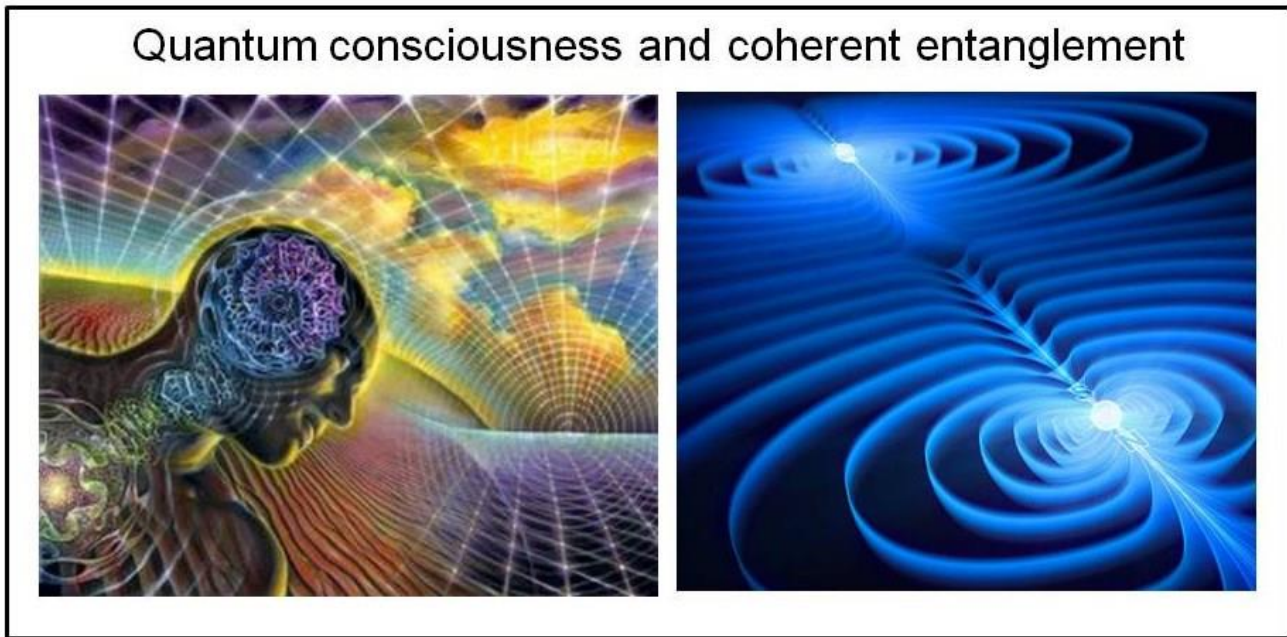


Fig. 50: The mind pictured as an integral part of the quantum realm (a) in which entanglement plays a crucial role (a), illustrated by the coherent entanglement of the magnetic interaction of two electrons (b).

Cell walls of biological tissue contain countless proteins and fat molecules which are electrical dipoles. When a cell is at rest, these dipoles are out of phase and arrange themselves in a haphazard way. But when they are stimulated they begin to oscillate or jiggle intensely and broadcast a tiny microwave signal. Frolich found that when the energy flowing through the cell reaches a certain critical level, all the cell wall molecular dipoles line up and come into phase. They oscillate in unison as though they are suddenly coordinated. This emergent quantum field is a Bose-Einstein condensate and has holistic properties common to any quantum field (Fig.50). Consciousness may work in a similar matter.

Zohar, 1990 suggests that ion channel oscillations in neurons are quantum phenomena which generate a Frolich like coherent electric field. There are ion channels (protein molecules) lining the membrane walls of individual neurons, which open or close in response to electrical fluctuations resulting from stimulation. They act like gates to let Sodium, Potassium, and other ions pass through. They are of a size to be subject to quantum fluctuations and superposition. Each channel, as it oscillates, generates a tiny electric field. When a large number of ion channels (there are 10 million in each neuron) open and close in unison, as they do when stimulated, the whole neuron fires or oscillates and a large scale electric field is generated across the neuron. Certain neurons act as pace makers. When a pacemaker neuron oscillates in response to stimulation, whole bundles of neurons oscillate with it. A finding by a neurobiologist that when a person sees an object, all neurons in the Cerebral Cortex, associated

with that perceptual object, oscillates in unison regardless of their location in the brain. These neurons behave similar to entangled electrons.

Zohar implies that the original ion channel oscillations are quantum phenomena; which, as in Frolich systems, generates a coherent quantum electric field. It is a Bose-Einstein condensate. Existence of such large scale coherent electrical fields across the brain explains how a large number of disparate and distant neurons can integrate their information to produce a holistic picture, hologram. The quantum entanglement proof that has been developed fairly recently says that non-local (instantaneous or faster than light) quantum correlations exists between particles apparently separated in space and time has helped scientists to understand these effects. Quantum entanglement, also called the quantum non-local connection, is a property of a quantum mechanical state of a system of two or more objects in which the quantum states of the constituting objects are linked together so that one object can no longer be adequately described without full mention of its counterpart – even if the individual objects are spatially separated in a space-like manner.

The crucial distinguishing feature of Bose-Einstein condensate is that many parts which go to make up the ordered system not only behave as a whole, but they become whole. Their identities merge and overlap in such a way that they lose their individuality entirely. This is a quantum property. Such a large quantum synchronicity exists in and accounts for the special properties of lasers, super conductors, and super fluids. Only this type of quantum correlated condensed state could explain the unbroken wholeness of the thought process. Consciousness behaves as a fractal. This is similar to a hologram where small fractal parts are identical to the whole part.

The property of the brain which is the non-local quantum correlate or the Bose-Einstein condensate behaves as above. It creates a unity from the diverse bits of information drawing them to a meaningful whole. The millions of sensory data from sense organs received every moment are channeled to various disparate areas of the brain and processed by the computing facility of the brain. Consciousness receives this processed information and creates a holistic scene, hologram. It is this integration of all the processed bits of information to create a one whole that creates the identity as a person, the self or the I-ness. Here is the coherent non-local quantum correlation of the brain and it is an emergent property.

Consciousness is a non-material entity in the quantum domain that is capable of independent existence. Consciousness can remain localized in the brain so long as the emergent quantum particle state does not change, just as an electron which is a quantum entity can remain localized in an atom so long as the energy of the electron matches the quantum state it occupies.

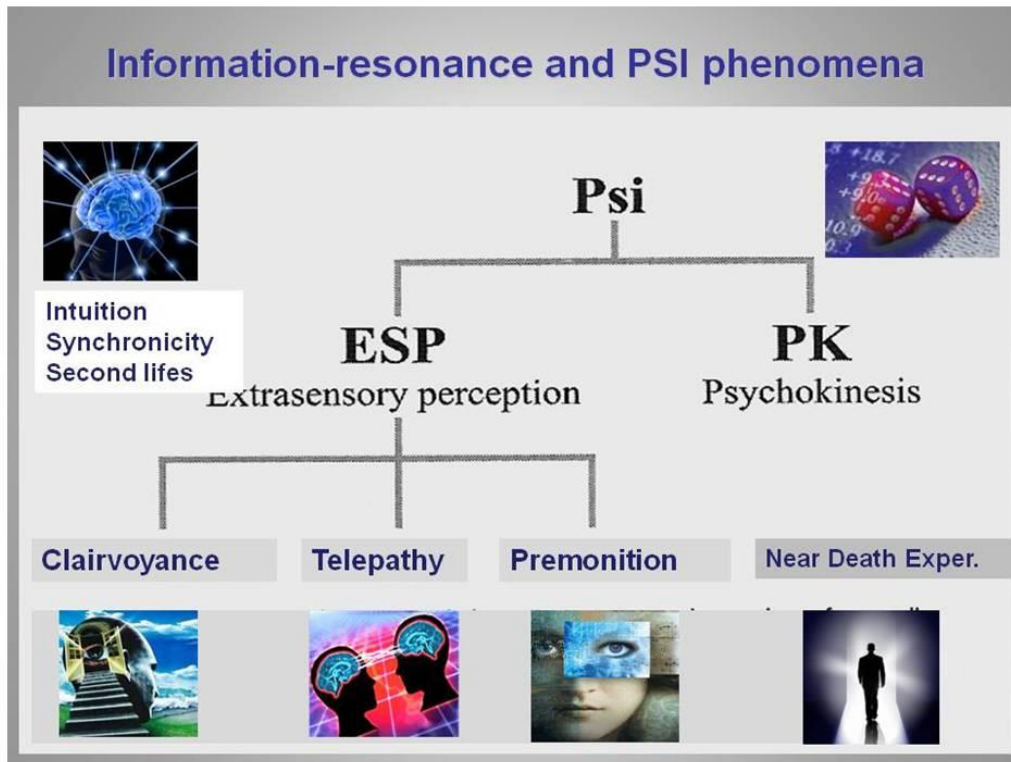


Fig. 50: An overview of PSI phenomena, transpersonal experiences and related conscious states.

Whenever the property breaks down, the mathematical function that governs the behavior of quantum particles changes, i.e. the electrons changes its behavior from that of a particle to a wave function. When this happens in the brain, consciousness can leave the brain and take up a floating existence in the way an electron leaves its atom if it acquires excess energy and starts a floating existence as a free electron. Consciousness can return to the brain if the property is re-established and the wave function collapses and the particle function prevails.

This model may explain all the observed properties of human consciousness including Psi-phenomena, NDE, OBE and reincarnation (**Fig.51**). Since all information transfer in a non-local quantum correlation is instantaneous, just like the speed of an electron and light is instantaneous, it explains the speed of human action. It can be extended to explain phenomena such as telepathy and also explains the individual identity, or the I-ness or self.

This is only a start. In itself it tells us nothing about how such a fundamental manifests in the brain. Rather than having a solution, we are only at the beginning of a very difficult journey towards something with explanatory value. Not only do we have to discover some system that is truly fundamental, but, given the lack of apparent consciousness in the rest of the universe, we need a process that is unique in operating only in brains, and not in other physical systems.

Quantum consciousness is really a misnomer for the sort of system that we are looking for. The philosopher, **David Chalmers, 2000** was correct in pointing out that there was no more reason for consciousness to arise from quanta than there was for it to arise from classical structures. Both permeate the universe outside of the brain without producing consciousness. The quanta and their behavior are only of interest if they can allow the brain access to a fundamental property not apparent in other matter.

This brings us also to the question of what really is fundamental. There are two sides to this question. The quanta and spacetime. The quanta are the fundamental particles/waves of energy, which also equates to the mass of physical objects. Some quanta such as the proton and the neutron are composed of other quanta, so are not truly fundamental or elementary. The quarks that make up the protons and neutrons of the nucleus of the atom and the force carrying particles such as photons appear to be the most fundamental quanta. But the quanta cannot be understood in isolation. They must be seen as having some form of relationship to spacetime, and that's a more difficult area than might appear at first sight.

Neither quantum theory, nor relativity which is our theory of spacetime, have ever been falsified, but they are, nevertheless, incompatible with one another. Many physicists are coming round to the notion that spacetime is not an abstraction but a real thing, and also something that is not continuous, but discrete, and perhaps best conceived in the form of a web or network. They are divided as to whether the quanta create spacetime, or spacetime generates the quanta, or the third possibility that the two are expressions of something more fundamental. However, whatever form it is conceived to take, the concept of a real and discrete structure also allows the possibility of some form of pattern or information capable of decision making, and this is the level of the universe where we need to look for an explanation of consciousness..

There are two routes leading to the conclusion that consciousness has to derive from such a fundamental level of the universe. In addition to the view that classical physics simply can't cut it in respect of consciousness, there is the Penrose approach via the function of consciousness. As described earlier, he proposed that the Gödel theorem meant that human understanding or conscious could perform tasks that no algorithm-based system such as a computer could perform. This is led to an arcane dispute with logicians and philosophers which few lay people can follow.

Individual consciousness is therefore considered as an expression of an underlying non-local quantum field, which exhibits holographic properties. It is postulated that the human brain is interfacing this universal information field, to our individual consciousness. This universal information domain may be physically identified as the zero-point-energy field. The interfacing brain may also explain the phenomena of binding, qualia, intuition, serendipity,

extra-sensory perception and some well established Psi-phenomena. It is stipulated that universal consciousness did also contain the recipe for biological evolution (Fig. 52), and that it was instrumental in the evolutionary creation of conscious observers.

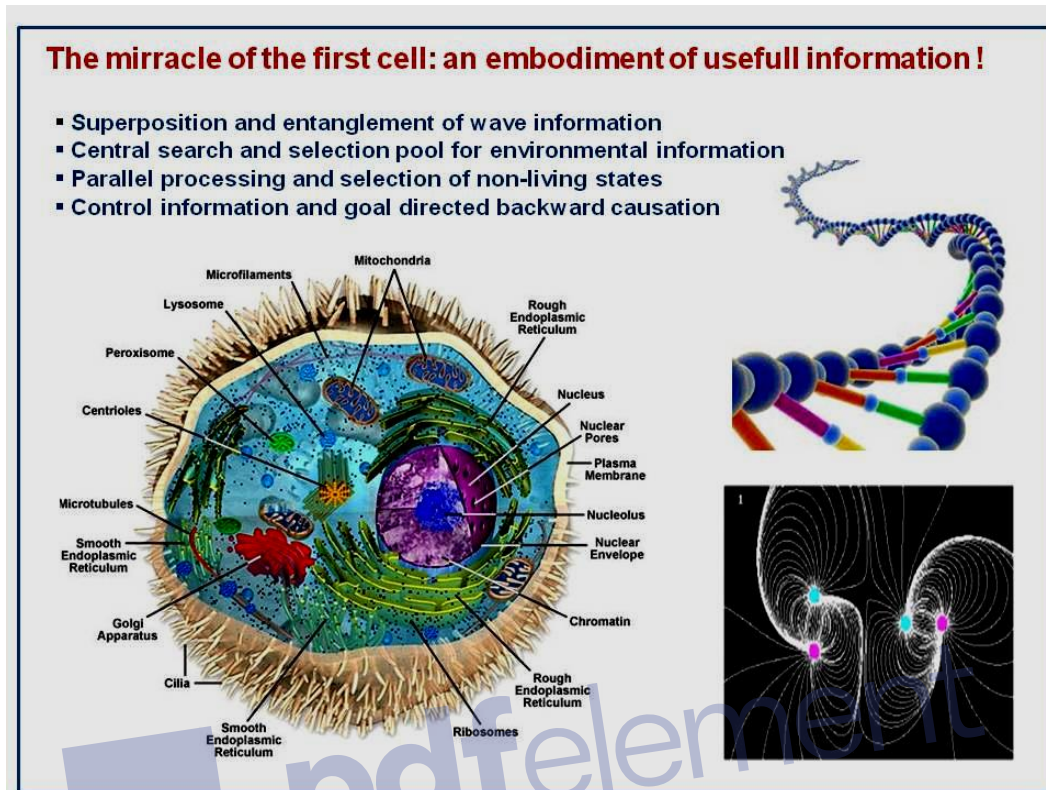


Fig. 52: Potential quantum mechanisms in the evolution to first life

However, it may be unnecessary to penetrate into such an arcane area. At a much more mundane level, the process of choosing between alternative forms of behavior or courses of action by means of subjective scenarios of the future looks to also invoke a process that cannot be decided by algorithms. This suggestion is now supported by recent studies showing that in the orbitofrontal region the brain some activity correlates to subjective appreciation rather than the strength of signal, whereas in other parts of the brain not involved with preferences, activity correlates to the strength of this same signal. So while Penrose provides the original inspiration for the idea of an aspect of the universe that could not be derived from a system of calculations, it seems possible to simplify or streamline the original inspiration in a manner that is compatible with recent brain research and not open to the same sort of attacks from logicians and philosophers.

In a similar way, it may be possible to simplify Penrose's proposal of a special type of quantum wave function collapse as the gateway to conscious understanding, seen here as an aspect of fundamental spacetime geometry. Penrose dismissed the randomness of the conventional wave function collapse as irrelevant to the mathematical understanding in which

he was initially interested, and instead proposed a special form of objective wave function collapse, which was neither random nor deterministic, but accessed the fundamental spacetime geometry. His proposal as to wave function collapse is currently the subject of experimental testing although this is a procedure that is likely to take up to a decade.

Again the question is whether it is necessary to go to such lengths. Might there be a way around the apparent randomness that led Penrose to dismiss conventional wave function collapse. Might not the more conventional wave function collapse, or alternatively decoherence equally well provide an access to the fundamental and conscious level of the universe. There are queries as to how random the randomness is. In one form of the famous two slit experiment, single photons arrive at a screen over some extended period of time. The initial photons register on the screen in apparently random position, but as later photons arrive the familiar light and dark bands form. Somehow later photons or perhaps the earlier photons, 'know' where to put themselves. There is a suggestion that this puzzle links to one of the other puzzles of quantum theory, namely entanglement, by which the quantum properties of particles can be altered instantaneously over any distance. In this suggestion, the photons in the two slit experiment are entangled with other distant quanta. Whatever it is that decides the position of these particles in this scheme has no apparent explanation in terms of algorithms or systems of rules for calculating, and this is something that it holds in common with choice by emotional valuation.

But how could such a mechanism related to the fundamentals of distant space arise within our brains. Penrose's collaborator, Stuart Hameroff, proposed a scheme by which quantum coherence arose within individual neurons and then spread throughout neuronal assemblies. Most conscious commentators believe that this theory can be straightforwardly refuted because of the rapid time to collapse or decoherence for quantum states in the conditions of the brain. However, this simplistic approach has in effect been partly refuted by the discovery of functional quantum coherence in biological systems during the last few years, initially in simple organisms subsisting at low temperatures, but most recently at room temperature and in multicellular organisms. Moreover, it is now apparent that the structures of aromatic molecules within the amino acids of individual neurons are similar to those within photosynthetic organisms now known to use quantum coherence. The structures that support quantum states in photosynthetic systems rely on the pi electron clouds discussed in earlier sections and in microtubules the amino acid tryptophan supports the same structure of pi electron clouds which thus look potentially capable of sustaining quantum coherence and entanglement through significant sections of a neuron. The mechanisms by which quantum coherence could subsist in neurons looks here to be within our grasp or understanding.

But as with the original Penrose proposal, Hameroff's scheme may be more ambitious and therefore more open to criticism than it needs to be. Where quantum states have been shown

to be functional they subsist for only femtoseconds or picoseconds, whereas the Hameroff scheme requires quantum coherence to be sustained for an ambitious 25 ms, moreover it has to be sustained over possibly billions of neurons spread across the brain. This lays it open to attack from many angles.

It looks much more feasible to work from the basis of quantum coherence that exists in other biological systems and to look for similar short lived single cell processes in the brain. The known systems of functional quantum states that subsist within individual cells elsewhere in biology look to have the potential to exist within neurons. For this reason, it is thus much more feasible in the absence of countervailing evidence to work on the basis of consciousness arising within individual neurons. This effectively inverts the Hameroff scheme. Rather than neurons feeding into the global gamma synchrony, the synchrony, which is certainly correlated with consciousness, may be a trigger to conscious activity in neurons.

Some studies give credibility to the idea of consciousness in single neurons (**Edwards, 2005, Sevush, 2006**). In addition, experimentation has shown that increased activation in single neurons is correlated to particular percepts. Some neurons are selective in only responding to particular images, and activity in these is correlated to the conscious experience of those images. Of course it isn't as simple as that. With 100 bn neurons in the brain, and perhaps a good percentage of these selecting for particular images, there has to be some way of coordinating their activity.

It is initially puzzling that the same type of experiments that show a correlation between consciousness and individual neurons, also show a correlation between the global gamma synchrony and consciousness. So which of these produces consciousness, the individual neurons or the gamma synchrony? Recent studies suggest that activity in individual neurons correlates with the gamma synchrony when a number of the neuron's neighbors were also active. This agrees with studies showing 'hot spots' of activity in the brain also correlated with consciousness. Here we are perhaps left with the concept that the brain is a gate to the fundamental level of the universe, in the literal sense of a mechanism that allows or prevents entry. All of this may seem very speculative, but against this has to be set the lack of explanation in classical physics for the 'something it is like' or the ability to have choice or preference that we find in consciousness.

Note: In this essay the authors made use of parts of the following texts:

Raggett S. *Quantum Mind. Exploring Quantum Theories of Consciousness.* <http://quantum-mind.co.uk/>

Meijer D K F and Korf J (2013). *Quantum modeling of the mental state: the concept of a cyclic mental workspace.* *Syntropy Journal*, (1), pp 1-41 <http://www.lifeenergyscience.it/english/2013-eng-1-1.pdf>

Meijer D K F (2014). *The Extended Brain: Cyclic Information Flow, in a Quantum Physical Realm.* *NeuroQuantology*, vol. 12, pp 180-200. Abstract: <http://www.neuroquantology.com/index.php/journal/article/view/754>

Goswami, A (2003). *A Quantum Explanation of Sheldrake's Morphic Resonance.* - http://www.stealthskater.com/Documents/Consciousness_32.pdf

Bromberg F (2000). On Goswami's monistic idealism worldview. <http://www.cs.iastate.edu/~bromberg/BrombergPhyl465FinalPaper.pdf>

Hameroff S, Penrose R (2013). *Consciousness in the universe. A review of the 'Orch OR' theory.* *Phys Life Rev.* <http://dx.doi.org/10.1016/j.plrev.2013.08.002>

King CC (2012). *The Cosmology of Conscious Mental States.* Genotype 1.0.0 21-5-13 - 14-8-13

References:

Abbott D [and others] (2008). *Quantum aspects of life.* London: Imperial College Press.

Aharonov Y, Popescu S, Tollaksen J, (2010). *A time-symmetric formulation of quantum mechanics,* *Physics Today*, November, 27-32.

Allefeld C, Atmansacher H, Wackerkanm J, (2009). *Mental states as macrostates emerging from brain electrical dynamics.* *Chaos*; 19 (1) 1-32.

Amoroso R L (1999). *An Introduction to Noetic Field Theory: The Quantization of Mind.* *Noetic Journal* Vol.2 No.1, 28-39

Arndt M, Juffmann T and Vedral V, (2009). *Quantum physics meets biology,* *HFSP Journal.*

Aspect A, Grangier P and Roger G, (1982). *Experimental realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: a new violation of Bell's inequalities.* *Phys. Rev. Lett.* 48: 91-94.

Atmanspacher, H, Filk T, Römer H, (2004). *Quantum Zeno features of bi-stable perception.* *Biol. Cybern.* 90: 33-40.

- Atmanspacher H**, (2007). *Contextual emergence from physics to cognitive neuroscience*. Journal of Consciousness Studies; 14 (1/2):18-36.
- Atmanspacher H**, (2011). *Quantum Approaches to Consciousness*, The Stanford Encyclopedia of Philosophy (Summer 2011 Edition), Edward N. Zalta (ed.),
- Atmanspacher H**, Primas H, (1977). *The Hidden Side of Wolfgang Pauli: An eminent physicist's extraordinary encounter with depth~psychology*. Journal of Scientific Exploration; 11 (3): 369-386.
- Auletta G**, Ellis GFR and Jaeger L, (2008). *Top-down causation by information control: from a philosophical problem to a scientific research programme*. J. R. Soc. Interface vol. 5, no. 27, 1159-1172.
<http://plato.stanford.edu/archives/sum2011/entries/qt-consciousness/>
- Bandyopadhyay A** (2011). *Direct experimental evidence for quantum states in microtubules and topological invariance*. Abstracts: Toward a Science of Consciousness 2011, Stockholm, Sweden,
<http://www.quantumbionet.org/admin/files/Massimo%20Pregolato%20-%20Rita%20Pizzi%202011.pdf>
- Barrow J D** and Tipler F J (1986). *The Anthropic Cosmological Principle*. Oxford University Press
- Baylor DA**, Lamb TD, Yau KW, (1979). *Responses of retinal rods to single photons*. J Physiol. Mar; 288:613-34.
- Beck C** and Mackey M, (2007). *Measurability of vacuum fluctuations and dark energy*. Physica A 379:101-110, [arXiv:astro-ph/0605418v3](http://arxiv.org/abs/astro-ph/0605418v3)
- Beck F** and Eccles J, (1992). *Quantum aspects of brain activity and the role of consciousness*. Proceedings of the National Academy of Sciences USA ; 89:11357-11361
- Beck F** and Eccles J, (2003). *Quantum Processes in the Brain: A scientific basis of consciousness*. In Osaka N (Ed.), *Neural Basis of Consciousness*. Amsterdam, Philadelphia: John Benjamins.
- Beck F**, (2001). *Quantum brain dynamics and consciousness*. In: The physical nature of consciousness. Ed. P. van Locke Amsterdam Benjamins; pp 83-116.
- Bekenstein J**, (2003). *Information in the holographic universe*. Sci. Am. 289, 58–65.
- Bell J S**, (1966). *On the problem of hidden variables in quantum theory*, Reviews of Modern Physics, 38, p. 447.
- Bergson H**, Paul NM and Palmer WS, (1991). *Matter and Memory*, Zone Books.
- Berkovich S**, (2001). *On the "barcode" functionality of the DNA, or the phenomenon of Life in the physical Universe*. <http://arxiv.org/ftp/physics/papers/0111/0111093.pdf>
- Bernroider G**, Roy S. (2004). *Quantum-Classical Correspondence in the Brain: Scaling, Action Distances and Predictability behind Neural Signals Forma*, 19, 55–68
- Bernroider G**, & Roy, S. (2005). *Quantum entanglement of K⁺ ions, multiple channel states and the role of noise in the brain* International Society for Optical Engineering (SPIE), vol. 5841

- Bernroider, G. & Summhamer, J. (2007)** . *The role of quantum cooperativity in neural signalling* . Quantum Mind 2007 Conference Abstracts
- Bernroider, G. (2003)** – Quantum neurodynamics and the relationship to conscious experience – *Neuroquantology*, 2: 163-168
- Blake T., Dotta B. T., Buckner C. A., Cameron D., Lafrenie R. M., Persinger M. A. (2011)**. *Biophoton emissions from cell cultures: biochemical evidence for the plasma membrane as the primary source*. *Gen. Physiol. Biophys.* 30, 301
- Bode S, He AH, Soon CS, Trampel R, Turner R, et al. (2011)**. *Tracking the Unconscious Generation of Free Decisions Using Ultra-High Field fMRI*. *PLoS ONE* 6(6): e21612. doi:10.1371/journal.pone.0021612
- Bókkon I. (2009)**. *Visual perception and imagery: a new hypothesis*. *Biosystems*, 96, 178, 184.10.1016/j.biosystems.2009.01.005
- Bókkon I., D'Angiulli A. (2009)**. *Emergence and transmission of visual awareness through optical coding in the brain: a redox molecular hypothesis on visual mental imagery*. *Biosci. Hypotheses* 2, 226–232.10.1016/j.bihy.2009.01.009
- Bókkon I., Dai J., Antal I. (2010a)**. *Picture representation during REM dreams: a redox molecular hypothesis*. *Biosystems*100, 79–86.10.1016/j.biosystems.2010.01.005
- Bókkon I., Salari V., Tuszyński J., Antal I. (2010b)**. *Estimation of the number of biophotons involved in the visual perception of a single-object image: biophoton intensity can be considerably higher inside cells than outside*. *J. Photochem. Photobiol. B Biol.* 100, 160–166.10.1016/j.jphotobiol.2010.06.001
- Bohm D, (1990)**. *A new theory of the relationship of mind and matter*. *Philosophical Psychology*.: 3: 271-286.
- Bohm D (1980)**. *Wholeness and the implicate order*, London: Routledge & Kegan Paul
- Bohm D and Hiley B J (1987)**. *An ontological basis for the quantum theory*, *Physics Reports*, 144, pp. 323-348
- Bohm, David & B.J. Hiley, (1993)**: *The undivided universe. An ontological interpretation of quantum theory*. London: Routledge
- Boly M, et al (2011)**. *Preserved feedforward but impaired top-down processes in the vegetative state*. *Science* 13 May 332 (6031): 858-862, DOI: 10.1126/science.1202043
- Bouwmeester D et al. (1997)**. *Experimental quantum teleportation*. *Nature*, 390, pp. 575–579.
- Bromberg F.(2000)** . *On Goswami's monistic idealism worldview*.
<http://www.cs.iastate.edu/~bromberg/BrombergPhyl465FinalPaper.pdf>
- Boyden, E. S, Zhang F, Bamberg E, Nagel G, Deisseroth K (2005)**. "Millisecond-timescale, genetically targeted optical control of neural activity". *Nat. Neurosci* 8 (9): 1263–8. doi:10.1038/nn1525. PMID 16116447.
- Busemeyer J R and Bruza P D (2012)**. *Quantum models of cognition and decision*. Cambridge University Press, Cambridge pp1-403.

- Carter P J** (2014a). Quantum Spacetime and Consciousness, <http://vixra.org/pdf/1312.0208v2.pdf>
- Carter P J** (2014 b). Imaginary Physics. <http://vixra.org/pdf/1210.0124v3.pdf>
- Chalmers D J.** (2000). *Facing Up to the Problem of Consciousness*. <http://consc.net/papers/facing.pdf>
- Chaudhury S, Smith A, Anderson B, Ghose S, Jessen P** (2009). *Quantum signatures of chaos in a kicked top*, Nature 461 768-771.
- Chin A.W., Prior J., Rosenbach R., Caycedo-Soler F., Huelga S.F., Plenio M.B** (2013). *The role of non-equilibrium vibrational structures in electronic coherence and recoherence in pigment-protein complexes*. Nat Phys, 9 pp. 113-118
- Cho A.** (2011). *Furtive Approach Rolls Back the Limits of Quantum Uncertainty*, Science 333 690-3.
- Clarke C J S** (2001). *Consciousness and non-hierarchical physics in: The physical nature of consciousness*, Ed Philip van Looke, pub. Jon Benjamins Publishing, 2001, pp 191-217
- Clarke, C J S** (1995). *The non-locality of mind'*, JCS 2 231-240
- Clarke, C J S** (2000). *Construction and reality: reflections on philosophy and spiritual/psychotic experience*. in *Psychosis and Spirituality: Exploring the New Frontier* ed I Clarke, Whurr, London
- Clayton and Davies, P** (2006). *Re-emergence of Emergence*, Oxford University Press
- Cramer J** (1988). *An Overview of the Transactional Interpretation*. International Journal of Theoretical Physics 27, 227.
- Cramer J** (2005) *A Farewell to Copenhagen?*, Analog, December.
- Davia CJ** (2010) *Life, Catalysis and Excitable Media: Dynamic Systems Approach to Metabolism and Cognition in: The Emerging Physics of Consciousness*, (ed J.A. Tuszynski), Springer Berlin pp 255-292,
- Davies P and Gregersen N H** (2010). *Information and the Nature of Reality: From Physics to Metaphysics*. Cambridge:Cambridge University Press.
- Davies P C W** (2004). *Quantum fluctuations and life*. Available on: arXiv:quant-ph/0403017
- Del Giudice, E. et al** (2002). *Effects of weak magnetic fields on ions* . Bioelectromagnetics, 23, 522-530
- Del Giudice, E., Doglia, S. Milani, M. & Vitiello, G.** (1988). *Electromagnetic interactions in living matter*. In Fröhlich, H. ed. *Biological Coherence and Response*
- Dennett D** (2007). *Consciousness Explained* . <http://pages.uoregon.edu/donovan/writings/Chapter%20summary.pdf>
- Deutsch D** (1997). *The Fabric of Reality*, London: Allen Lane
- Di Biase F** (2009a). *A Holoinformational Model of Consciousness*. Quantum Biosystems, 3, 207-220.

- Di Biase F** (2009b). *Quantum-holographic informational consciousness*. NeuroQuantology, Vol 7 pp 657-664.
- Dixon, P. B., Starling, D. J., Jordan, A. N., & Howell, J. C.** (2009). *Ultrasensitive beam deflection measurement via interferometric weak value amplification*. Physical review letters, 102(17),173601
- Donald J A** *Evidence supporting information processing in animals –, with references to David Deutch, T. Kanade and others.* http://w2.eff.org/Net_culture/Consciousness/quantum_info_process.paper
- Dotta B. T., Persinger M. A.** (2011). *Increased photon emissions from the right but not the left hemisphere while imagining white light in the dark: The potential connection between consciousness and cerebral light*. JCER2, 1463–1473.
- Dotta B. T., Saroka K. S., Persinger M. A.** (2012). *Increased photon emission from the head while imagining light in the dark is correlated with changes in electroencephalographic power: Support for Bókkon's Biophoton Hypothesis*. Neurosci. Lett. 513, 151–154.10.1016/j.neulet.2012.02.021
- Duncan W L** (2010). *The Quantum Universe: An Information Systems Perspective*. <http://critical-path.itgo.com/Articlesanscover.html>
- Dyer, M.G.** (1994). *Quantum physics and consciousness, creativity, computers: A commentary on Goswami's quantum-based theory of consciousness and free will*. The Journal of Mind and Behavior, **15**, 265-290.
- Edelman GM, Tononi G** (2000). *The universe of consciousness. How matter becomes imagination*. Basic Books New York
- Edwards J.** (2005). *Is consciousness only a property of individual cells?* J Consciousness Studies; 12: 429-457.
- Edwards J,** (2008). *Are our spaces made of words?* Journal of Consciousness Studies, 15, No. 1, , pp. 63-83
- Edwards P** (1967). *Panpsychism*, in: Paul Edwards (ed.) The Encyclopedia of Philosophy, vol. 5.
- Ellis G F R** (2005). *Physics and the real world*. <http://www.mth.uct.ac.za/~ellis/realworld.pdf>
- Emerson Daniel J, Weiser BP, J, Z. Liao, O Taratula, A Fiamengo, X. Wang, K Sugasawa, Smith A B., III, Eckenhoff R G, and D Mochowski** (2013). *Direct Modulation of Microtubule Stability Contributes to Anthracene General Anesthesia*. J Am Chem Soc. Apr 10, 2013; 135(14): 5389–5398 doi: [10.1021/ja311171u](https://doi.org/10.1021/ja311171u)
- Engel GS, Calhoun TR, Read EL, Ahn TK, Mancal T, Cheng YC, Blankenship RE, Fleming GR** (2007). *Evidence for wavelike energy transfer through quantum coherence in photosynthetic systems*. Nature, 446: 782-786.
- Feferman, S** (1996). *Penrose's Gödelian argument*. <http://math.stanford.edu/~feferman/papers/penrose.pdf>
- Flanagan BJ** (2007) . *On the unification of Mind and Matter*. NeuroQuantology, Vol 5, Issue 4, Page 331-345
- Freeman, W J, and Vitiello G** (2008). *Dissipation and spontaneous symmetry breaking in brain dynamics*. Journal of Physics A 41, 304042.

- Freeman**, W J and Vitiello, G. (2006). "Nonlinear brain dynamics as macroscopic manifestation of underlying many-body field dynamics". *Physics of Life Reviews* 3(2), 93–118.
- Fröhlich** H (1968). *Long Range Coherence and Energy Storage in Biological Systems*. *Int. J. Quantum Chem*; 2: 641-649.
- Fröhlich**, H (1970). *Long-range coherence and the actions of enzymes*. *Nature*, 228, 1093
- Fröhlich**, H (1975). *Dielectric properties of biological materials*. *Neuron*, 20, pp. 847-54
- Fröhlich**, H. (1985) *Physics Letters*, 110A 48
- Gauger** E, Rieper, E., Morton J.J.L., Benjamin S.C., Vedral V. (2011). *Sustained quantum coherence and entanglement in the avian compass*. *Phys Rev Lett*. 2011 Jan 28;106(4):040503.
<http://www.ncbi.nlm.nih.gov/pubmed/21405313>
- Geissler**, H (1992) . *New magic numbers in mental activity*. In: Eds. Geisler, H. et al – *Cognition, Information Processing and Psychophysics*
- Geissler**, H. et al (1999). *Ultra-precise quantal timing – Perception and Psychophysics*, 6, pp. 707-26
- Genovese M (2010)**. *Interpretations of Quantum Mechanics and the measurement problem*
<http://arxiv.org/abs/1002.0990v1>
- Georgiev**, D. (2003). *Electronic and magnetic fields inside neurons* .
<http://cogprints.org/3190/1/solitons.pdf>
- Georgiev**, D. (2004). *Bose-Einstein condensation of tunneling photons in the brain cortex as a mechanism of conscious action*. <http://cogprints.org/3539/1/tunnelling.pdf>
- Germine** M (2007). *The Holographic Principle Theory of Mind*.
<http://goertzel.org/dynapsyc/2007/holomind.htm>
- Geroch**, R., and Hartle, J.B. (1986) *Computability and physical theories*. *Foundations of Physics* 16:533.
- Gleiser** M (2004), *The three origins: cosmos, life, and mind*, In: *Science and ultimate reality*, J.D. Barrow, P.C.W. Davies, and C.L. Harper (eds.), Cambridge: Cambridge University Press, pages 637-653.
- Globus**, G (1995). *Postmodern Brain*. John Benjamins
- Goodman**, E et al (1995). *Effects of electromagnetic fields on molecules and cells*. *Int. Rev. Cytol.*, 158, pp. 279-339

Görnitz T (2012). *Quantum Theory as Universal Theory of Structures – Essentially from Cosmos to Consciousness*, Advances in Quantum Theory, Prof. Ion Cotaescu (Ed.), ISBN: 978-953-51-0087-4, InTech, Available from: <http://www.intechopen.com/books/advances-in-quantum-theory/quantum-theory-as-universaltheory-of-structures-essential-from-cosmos-to-consciousness>

Goswami, A. (1989), *The idealistic interpretation of quantum mechanics*. Physics Essays, 2,385-400.

Goswami, A. (1990). *Consciousness in Quantum Physics and The Mind-Body Problem*.

The Journal of Mind and Behavior, winter 1990, **11**, 1, p. 75-96.

Goswami A. (1993). *The Self-aware Universe. How consciousness creates the material world*. New York: Tarcher/Putnam.

Goswami, A (2003). *A Quantum Explanation of Sheldrake's Morphic Resonance*.
http://www.stealthskater.com/Documents/Consciousness_32.pdf

Gray and Singer, (1989). *Oscillatory responses in cat visual cortex exhibit inter-columnar synchronization which reflects global stimulus properties*. *Nature* **338**, 334 - 337 (23 March 1989); doi:10.1038/338334a0

Greene B (2004). *The Fabric of the Cosmos. About the Search for the Theory of Everything*, The Spectrum, Utrecht.

Griffin D R (1997). *Parapsychology, Philosophy, and Spirituality: A Postmodern Exploration*, (SUNY Series in Constructive Postmodern Thought), State University of New York Press.

Grof S, (1987). *Beyond the Brain; Birth, Death and Transcendence in Psychotherapy*, New York: State University of New York Press.

Gurzadyan VG, Penrose R (2010). *Concentric circles in WMAP data may provide evidence of violent pre-Big-Bang activity*. [arXiv:1011.3706](https://arxiv.org/abs/1011.3706) [astro-ph.CO].

Hagan, S., Hameroff, S.R., Tuszynski, J.A., (2002). *Quantum computation in brain microtubules: Decoherence and biological feasibility*. Phys. Rev. E. 65, 061901.

Hagelin JS (1987). *Is Consciousness the Unified Field? A Field Theorist's Perspective*.
<http://www.mum.edu/pdf/msvs/v01/hagelin.pdf> .

Hameroff, SR, and Penrose, R (1996). *"Conscious Events as Orchestrated Spacetime Selections"*, Journal of Consciousness Studies, 3(1): 36-53.

Hameroff SR, (2007). *The brain is both a neurocomputer and quantum computer*. Cognitive Science; 31: 1035-1045.

Hameroff S, Penrose R (2011) *Consciousness in the Universe: Neuroscience, Quantum Space-Time Geometry and Orch OR Theory*, In: *Cosmology of Consciousness: Quantum Physics & Neuroscience of Mind*, pp 51- 102, Cosmology Science Publishers, Cambridge

Hameroff S, Penrose R. (2013). *Consciousness in the universe. A review of the 'Orch OR' theory*

Phys Life Rev <http://dx.doi.org/10.1016/j.plrev.2013.08.002>

Hamill OP, Marty A, Neher E, Sakmann B., Sigworth FJ (1981). *Improved patch-clamp techniques for high resolution current recording from cells and cell-free membrane patches*. Pflügers Arch, 391: 85-100

Hartmann L, Düer W and Briegel, HJ (2006). *Steady state entanglement in open and noisy quantum systems at high temperature*. Physical Review A 74, 052304

Hawking S W and Mlodinow, L. (2010). *The Grand Design*. New York: Bantam Press.

Hawking S. (1988). *A Brief History of Time*. Bantam Dell Publishing Group.

Hayes, D., Griffith G.B., Engel G.S (2013). *Engineering coherence among excited states in synthetic heterodimer systems*. Science, 340 (6139) pp. 1431-1434

Heimburg, T, Jackson, AD (2005). *On soliton propagation in biomembranes and nerves*" Proc. Natl. Acad. Sci. U.S.A. **102** (2): 9790. h

Henry RC (2005). *The Mental Universe*, Nature, 436(7): 29.

Hildner R, Brinks, D, Nieder J.B, Cogdell R.J., van Hulst N.F. (2013). *Quantum coherent energy transfer over varying pathways in single light harvesting complexes*. Science, 340, 1448-51

Hiley BJ and Pylkkänen P (2005). *Can Mind affect Matter via Active Information?* Mind & Matter, 3: 7-27.

Hiley, B. (2001). *The Bohm Interpretation and the Mind Matter Relationship*. In Dubois, D. Ed. Computing Anticipatory Systems

Hosten O. (2011). *How to catch a wave*, Nature 474 170-1.

Hosten O., Kwiat P. (2008), *Observation of the Spin Hall Effect of Light via Weak Measurements*, Science 319 787-790.

Holland, P. (1988) *Causal interpretation of Fermi fields* . Phys. Lett., 128A, pp. 9-18

Holland P (1996). *Quantum back-reaction and the particle law of motion*.
http://users.ox.ac.uk/~gree0579/index_files/back-reaction.pdf

Hu H and Wu M (2010). *Current landscape and future direction of theoretical and experimental quantum brain/mind/consciousness research*, J. Consc. Exploitation & Research 1, 888-897..

Hu H and Wu M (2004). *Possible roles of neural electron spin networks in memory and consciousness*. Cogprints ID 3544, see also NeuroQuantology, 2006: 5-16.

Jahn RG and Dunne B J (2004). *Sensors, Filters, and the Source of Reality*. Journal of Scientific Exploration, 18(4): 547-570.

Jahn RG and Dunne B J (2007). *A modular model of mind/matter manifestations*. Explore, 3:311-24, reprinted from J. Scientific. Exploration, 2001

Jensen CS, Rasmussen HB, Misonou H. (2011). *Neuronal trafficking of voltage-gated potassium channels*. Mol Cell Neurosci; 48: 288-297.

- Jiang, Y.** MacKinnon, R. et al (2003) . *The principle of gating charge movement in a voltage-dependent K⁺ channel* , Nature, 423, pp. 42-8
- Jiang, Y.,** MacKinnon, R. et al (2003) – X ray structure of a voltage-dependent K⁺ channel – Nature, 423, pp. 42-8
- Jibu, M & Yasue, K.** (1992). *A physical picture of Umezawa's quantum brain dynamics*. In: Cybernetics and Systems Research, ed. R. Trappl World Scientific
- Jibu, M & Yasue, K.** (1993). *Introduction to quantum brain dynamics*. In: Nature , Cognition and System ed, Carvallo, M. Kluwer Academic
- Jibu, M.** et al (1997). *Evanescent photon and cellular vision* . Biosystems, Vol. 42, Issue 1, March 1997, Pages 65–73. <http://www.sciencedirect.com/science/article/pii/S0303264797016869>
- Jibu, M.,** Hagan, S., Hameroff, S. Pribram, K. & Yasue, K. (1994). *Quantum coherence in microtubules*. Biosystems 32, 195-209
- Jung, CG** and Pauli W (1955). *The Interpretation of Nature and the Psyche*. New York, Bollinger.
- Kafatos M** (2009). *Cosmos and Quantum: Frontiers from the Future*. J. Cosmol. Vol. 3, pp 511- 528
- Kafatos, M,** Tanzi R E, and Chopra D (2011). *How Consciousness Becomes the Physical Universe*. Journal of Cosmology, Vol. 14, pp 1-11
- Kaivarainen A.** (2005). *Hierarchic model of consciousness*. NeuroQuantology, Issue 3, 180-219
- Kak S** (2009). *The Universe, Quantum Physics and Consciousness*. J.Cosmol. Vol.3, pp 500-510
- Kauffman SA** (2008). *Reinventing the Sacred: A New View of Science, Reason, and Religion*. New York: Basic Books.
- Kauffman SA** (2012). *Is there a ""poised realm between quantum and classical worlds?*
http://stuartkauffman.com/index_25_1612352741.pdf
- Khrennikov, A.** (1999) . *Classical and quantum mechanics on information spaces* . Found. Phys., 29, pp. 1065-98
- Khrennikov, A.** (2002) . *On cognitive experiments to test quantum-like behaviour of mind*. Rep. Växjö University: Math. Nat. Sc. Tech., N7
- Khrennikov, A.** (2003) . *Quantum-like formalism for cognitive measurements* . Biosystems, 70, pp. 211-33
- Khrennikov, A.** (2004) . *Information dynamics in cognitive etc. phenomena*. Fundamental Theories of Physics: Berlin-Heidelberg: Springer
- Khrennikov A.** (2006). *Quantum-like brain* . BioSystems, 84 (3), pp. 225-41
- King CC.** (1989). *Dual-Time Supercausality*, Physics Essays, 2(2): 128-151.

- King CC.** (2003). *Chaos, Quantum-transactions and Consciousness*, *NeuroQuantology*, 1(1): 129-162.
- King CC.** (2011). *The Central Enigma of Consciousness*, *Nature Precedings*, 2008 JCER.
- King CC.** (2012). *The Cosmology of Conscious Mental States*. Genotype 1.0.0 21-5-13 - 14-8-13
- King CC.** (2014). *Space, Time and Consciousness*. <http://www.dhushara.com/stc/ct.htm>
- King U** (1996). *Spirit of Fire: The Life and Vision of Teilhard de Chardin*. Maryknoll, NY: Orbis. Knopf Doubleday Publishing Group (Random House).
- Koch C and Hepp K (2006)**. *Concept Quantum mechanics in the brain*. *Nature* 440, 611 (30 March), doi:10.1038/440611a
- Kocsis, S., Braverman, B., Ravets, S., Stevens, M. J., Mirin, R. P., Shalm, L. K., & Steinberg, A. M.** (2011). *Observing the average trajectories of single photons in a two-slit interferometer*. *Science*, 332(6034), 1170-1173.
- Kumar M** (2009). *Quantum. Einstein, Bohr and the Great Debate about the Physics*, Amsterdam: Macmillan.
- Kurzweil R.** (2005). *The Singularity is Near. When Humans Transcend Biology*. Viking.
- László E** (2004). *Cosmic vision. The dawn of the integral theory of everything*. Rochester, Inner Traditions International
- László, E.** (2007). *The Akashic Field*. New York: Dutton
- Lehmann D., Strik W. K., Henggeler B., Koenig T., Koukkou M.** (1998). *Brain electric microstates and momentary conscious mind states as building blocks of spontaneous thinking: I. Visual imagery and abstract thoughts*. *Int. J. Psychophysiol.* 291-11.
- Li, J and Paraoanu, GS** (2009). *Generation and propagation of entanglement in driven coupled-qubit systems*. *New Journal of Physics* 11, 113020.
- Lima, S Q and Miesenböck G** (2005). *Remote control of behavior through genetically targeted photostimulation of neurons*. *Cell* 121 (1): 141-52. doi:10.1016/j.cell.2005.02.004. PMID 15820685
- Libet B.** (2006). *Reflections on the interaction of the mind and brain*. *Prog Neurobiol.* 78(3-5): 322-326. Life. Perseus Press: Boston, MA
- Linde A** (2003). *Inflation, Quantum Cosmology, and the Anthropic Principle, in Science and Ultimate Reality: From Quantum to Cosmos, honoring John Wheeler's 90th birthday*. Barrow JD, Davies PCW and Harper CL eds. Cambridge University Press.
- Lloyd S** (2011). *Quantum coherence in biological systems*. *J. Phys.: Conf. Ser.* 302, 012037 *Journal of Physics: Conference Series* **302** (2011) 012037 doi:10.1088/1742-6596/302/1/012037
- Lockwood, M.** (1989). *Mind, Brain & the Quantum* - Blackwell ISBN 0-631-18031-1
- Lundeen J. S., Steinberg A. M.** (2009). *Experimental Joint Weak Measurement on a Photon Pair as a Probe of Hardy's Paradox*. *Physical review letters*, 102 020404.

Lundeen J.S., Sutherland B., Patel A., Stewart C, Bamber C. (2011). *Direct measurement of the quantum wave function*, Nature 474 188-191.

Luo, L.. Lu J (2011). Temperature dependence of protein folding deduced from quantum transition
<http://arxiv.org/abs/1102.3748>

Mandelbrot BB (1977). *The Fractal Geometry of Nature*. New York: Freeman.

Marcer PJ and Schempp W (1997). *Model of the Neuron Working by Quantum Holography*, Informatica 21: 519-534

Marshall I (1989). *Consciousness and Bose-Einstein condensates* *New Ideas in Psychology*, 7: 73-83.

Martin F, Carminati F, Carminati G G (2013). Quantum information theory to unconscious and consciousness. *NeuroQuantology*, 12: 16-33

Matsuno K (1999). *Cell motility as an entangled quantum coherence*. *BioSystems* 51, 15-19.

Matsuno K. and Paton RC (2000). *Is there a biology of quantum information?* *BioSystems* 55: 39-46.

McFadden J (2001). *Quantum Biology*. Norton, New York

McFadden J and Al-Khali (2001). *A quantum mechanical model of adaptive mutation*. *Biosystems* 50, 203-211.
http://www.surrey.ac.uk/qe/pdfs/mcfadden_and_al-khalili.pdf

McGinn C (1999). *The Mysterious Flame: Conscious Minds in a Material World*, New York: Basic Books.

Meijer D K F and Korf J (2013). *Quantum modeling of the mental state: the concept of a cyclic mental workspace*. *Syntropy Journal*, (1), pp 1-41

Meijer D KF (2012). *The Information Universe. On the missing link in concepts on the architecture of reality*. *Syntropy Journal*, 1, pp 1-64

Meijer D K F(2013b). *Immortality: Myth or becoming Reality ?* *Syntropy Journal*,; (3), pp 166-203.
<http://www.lifeenergyscience.it/english/2013-eng-3-04.pdf>

Meijer D K F. Information: what do you mean ? *Syntropy Journal*, 2013 a; (3), pp 1-49.
<http://www.lifeenergyscience.it/english/2013-eng-3-01.pdf>

Meijer D. K. F. (2014). *The Extended Brain: Cyclic Information Flow, in a Quantum Physical Realm*. *NeuroQuantology*, vol. 12, pp 180-200. Abstract:
<http://www.neuroquantology.com/index.php/journal/article/view/754>

Melkikh A V 2013). Biological complexity, quantum coherent states and the problem of efficient transmission of information inside a cell. *BioSystems*; 111: 190-8

Melkikh A V (2013). Quantum field theory solves the problem of the collapse of the wave function.;
<http://arxiv.org/abs/1311.0205>

Menini A., Picco C., Firestain S. (1995). *Quantal-like current fluctuations induced by odorants in olfactory receptor cells*. *Nature* 373, 435 - 437 (02 February); doi:10.1038/373435a0

Merali Z. (2010). *Back From the Future*, Discover Magazine August 26

Minkowski H (1952). In: Lorentz HA, Einstein A, Minkowski H and Weyl H, (1952). *The Principle of Relativity: A Collection of Original Memoirs on the Special and General theory of Relativity*. New York: Dover

Mitchell ED and **Staretz R** (2011). *The quantum hologram and the nature of consciousness*. *Journal of Cosmology* 14:1-35..

Murphy N (2011). *Avoiding Neurobiological Reductionism: the role of downward causation in complex systems*, in *Moral Behavior and Free Will. A Neurological and Philosophical Approach*, eds Juan José Sanguinetti, Ariberto Acerbi, José Angel Lombo

Murphy, N. and **W.R. Stoeger, SJ.** (eds.). (2007). *Evolution and Emergence: Systems, Organisms, Persons*, Oxford: Oxford University Press.

Nagel T (2012). *Minds and Cosmos. Why the materialist neo-darwinian conception of nature is almost certainly false*. Oxford Univ. Press. New York.

Nicolescu B (1992). "Levels of Complexity and Levels of Reality", in *The Emergence of Complexity in Mathematics, Physics, Chemistry, and Biology*, Proceedings of the Plenary Session of the Pontifical 28

Academy of Sciences, 27–31 October 1992. See also in 2011:
<http://bdigital.ufp.pt/bitstream/10284/2392/3/119-130.pdf>

Ouyang, M., **Awschalom D D** (2003): *Coherent Spin Transfer Between Molecularly Bridged Quantum Dots*. *Science*, Vol. 301 no. 5636, pp. 1074-1078. DOI: 10.1126/science.1086963

Pauli W. (1994): *Writings on Physics and Philosophy*, ed. by C.P. Enz and K. von Meyenn. Springer, Berlin.

Penrose R (2004). *Twistor Theory*: <http://universe-review.ca/R15-19-twistor.htm>

Penrose R (2006). *Before the Big Bang: An Outrageous New Perspective and its Implications for Particle Physics*". Proceedings of the EPAC 2006, Edinburgh, Scotland: 2759–2762

Penrose R (2010). *Cycles of Time. An Extraordinary New View of the Universe*. London: Bodley Head.

Penrose, R. (1994). *Shadows of the Mind*. Oxford University Press

Penrose R. (1989). *The Emperor 's New Mind*. Oxford University Press: 1-275.

Penrose, Roger (2004). *The Road to Reality. A Complete Guide to the Laws of the Universe*, Jonathan Cape, London

Pereira A (2003): *The quantum mind/classical problem*. *NeuroQuantology*, 1: 94- 118.

Pereira A, Furlan FA (2007). *Biomolecular Information, Brain Activity And Cognitive Function*. In: ARBS Annual Rev Of Biomdical Sciences, 9: 12-29.

- Persinger M** Dotta, B, Saroka K & Scott M, (2013). *Congruence of energies for cerebral photon emissions, quantative EEG activities and ~5 nT changes in the proximal geomagnetic field support spin-based hypothesis of consciousness*. Journal of Consciousness Exploration and Research, February vol. 4, issue 1, pp. 1-24
- Pessa E** and Vitiello G (2003). "Quantum noise, entanglement and chaos in the quantum field theory of mind/brain states". *Mind and Matter* 1: 59-79.
- Pezzulo G**, Barsalou LW, Cangelosi A, Fischer MH, McRae K, Spivey MJ. (2011). *The mechanics of embodiment: a dialog on embodiment and computational modeling*. *Front Psychol.* 2011; Philosophical Approach (eds Juan José Sanguinetti, Ariberto Acerbi, José Angel Lombo)
- Piaget, J.** (1956). *The general problem of the psychobiological development of the child*. *Discussions on Child Development*, 1956, 4, 3-27.
- Pizzi, R**, Fantasia A, Gelain F, Rosetti D, Vescovi A (2004). In: *Quantum Information and Computation II*. *Proceedings of SPIE 5436*, (ed.) Donkor, E.
- Popper K.R** and Eccles J C. (1977). *The self and its brain*. Springer International. Berlin, Heidelberg, London, New York.; pp 3-566.
- Pothos EM** Busemayer J. R. (2011). *Formalizing heuristics in decision-making: a quantum probability perspective*. *Front Psychology* ; 2: 289. doi : 10.3389/fpsyg.2011.1100289
- Pribram K** (1991). *Brain and perception: holonomy and structure in figural processing*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Pribram K H** and EH Carlton, (1986). *Holonomic brain theory in imaging and object perception*. *Acta Psychologica*: 63: 175-180..
- Primas H** (2003). *Time entanglement between mind and matter*. *Mind and Matter*, 1: 81-119.
- Primas H** (2009). *Complementarity of mind and matter*. in: *Recasting Reality*, Berlin. Springer, 171-209
- Pusey MF**, Barret J and Rudolph T (2012). *On the reality of the quantum state*. *Nature Physics*, 8, pp 475-478. <http://lanl.arxiv.org/abs/1111.3328>
- Radín DI** and Nelson R (2006). *Entangled Minds. Extrasensory experiences in the quantum reality*. New York: Simon & Schuster
- Radín, Dean.** (1997). *The Conscious Universe. The Scientific Truth of Psychic Phenomena*. New York: HarperEdge.
- Raichle, M.** (1998). The neural correlates of consciousness. *Phil. Trans. Royal Soc London B*, 353, pp. 1889-901
- Reiter G.F.**, Kolesnikov A.I., Paddison S.J., Platzman P.M., Moravsky A.P., Adams M.A et al (2011). *Evidence of a new quantum state of nano-confined water*. <http://arxiv.org/abs/1101.4994>
- Rieper, E.** Anders J., Vedral V (2011). *Quantum entanglement between the electron clouds of nucleic acids in DNA*. <http://arxiv.org/abs/1006.4053>
- Ricciardi, L.M.**, and Umezawa, H. (1967). *Brain and physics of many-body problems*. *Kybernetik* 4, 44-48.

- Romijn, H.** (1997). *About the origin of consciousness*. Proceedings Kon. Akad, 100, pp. 181-267
- Romijn H.** (2002). *Are virtual photons the elementary carriers of consciousness?*
Journal of Consciousness Studies 9 (1):61-81 (2002)
- Rosa LP, Faber J.** (2004). *Quantum models of the mind: are they compatible with environmental decoherence.* Phys Rev E Stat Nonlin Soft Matter Phys. Sep;70(3 Pt 1):031902
- Sahu S, Ghosh S, Ghosh B, et al** (2013a). *Atomic water channel controlling remarkable properties of a single brain microtubule: correlating single protein to its supramolecular assembly.* Biosensors and Bioelectronics.;47:141-148
- Sahu S, Ghosh S, Hirata K, Fujita D, Bandyopadhyay** (2013 b). *Multi-level memory-switching properties of a single brain microtubule.* Applied Physics Letters. 102(12) : 4 pages.123701
- Sakai & Miyashita, (1994).** *Neuronal tuning to learned complex forms in vision.* Neuroreport, 5, 829
- Salari V, Tuszynski, M. Rahnama, G. Bernroider.** *Plausibility of Quantum Coherent States in Biological Systems* <http://arxiv.org/ftp/arxiv/papers/1012/1012.3879.pdf>
- Sarfatti J** (2011). *Retrocausality and Signal Nonlocality in Consciousness and Cosmology.* Journal of Cosmology, 14: 3-33.
- Scaruffi P** (2006). *The nature of consciousness.* <http://www.scaruffi.com/nature/consc3.html>
- Scaruffi P** (2001). *A simple theory of consciousness,* <http://www.scaruffi.com/science/sweden.html>
- Schacter et al** (1998). *Memory, consciousness and neuroimaging.* Phil. Trans Royal Soc. London, 353, pp. 1861-78
- Schafer L** (2009). *Quantum Reality and Evolution Theory.* Journal of Cosmology 3: 547-557.
- Schempp W** (2003). *Replication and transcription processes in the molecular biology of gene expressions: control paradigms of the DNA quantum holographic information channel in nanobiotechnology.* BioSystems 68: 119-145.
- Schrödinger E** (1959). *Mind and Matter.* Cambridge: University Press.
- Schrödinger E,** (1986). *What is Life?* 1944. Pribram and Carlton
- Schwartz JM, Stapp HP, Beauregard M.** (2004). *Quantum physics in neuroscience and psychology: a neurophysical model of mind-brain interaction.* Philosophical Transactions R Soc B; 1598: 1-19.
- Searle J R,** (1992). *The rediscovery of mind.* MIT Press Cambridge, Mass 0-262-19321-3, 978-0-262-69154-3270 pp
- Searle JR,** (2000). *Consciousness.* Ann Rev Neurosci 23: 557-578.
- Searle JR,** (2007). *Dualism Revisited.* J Physiology (Paris) 101: 168-178
- Sevush S.** (2006). *Single-neuron theory of consciousness.* J Theoretical Biology, 238, 704-725

- Sheldrake R** (2012). *The Science Delusion. Freeing the spirit of inquiry*. Coronet/Hodder&Stoughton. London.
- Sheldrake R.** (2005). *Morphic Resonance and Morphic Fields An Introduction* <http://www.sheldrake.org/research/morphic-resonance/introduction>, also in J. Noetic Sci. 4, 2010 <http://noetic.org/noetic/issue-four-november-2010/morphic-fields-and-morphic-resonance/>
- Shimony A.** (2005). "Quantum Mechanics and the Philosophy of Alfred North Whitehead (review)." Transactions of the Charles S. Peirce Society: A Quarterly Journal in American Philosophy 41.3 714-723.
- Sirag S P.** *Consciousness, a hyperspace view.* <http://www.williamjames.com/Theory/Consciousness.pdf>
- Skarda CA, Freeman WJ** (1987). *How brains make chaos in order to make sense of the world.* Behavioral and Brain Sciences, 10:161-195.
- Skrbina D** (2005). *Panpsychism in the West*, MIT Press, Cambridge, MA.
- Smolin L** (2004). *Atoms of Space and Time.* Scientific. Am. Febr: 43-52.
- Smythies, J.** (2003) . *Space, time & consciousness* . Journal of Consciousness Studies, 10, (3), pp. 47-56.
- Soon CS, Brass M, Heinze HJ, Haynes JD** (2008). *Unconscious determinants of free decisions in the human brain.* Nat Neurosci 11: 543–545.
- Spinoza B** (1677/1985). *Ethics, in The Collected Works of Spinoza*, Princeton: Princeton.
- Spivey M J** (2007). *The continuity of mind.* New York Oxford University Press . pp
- Stapp H P** (2009). *Mind, Matter and Quantum Mechanics*, Berlin-Heidelberg: Springer-Verlag.
- Stapp, Henry P.** (1998a) . *Pragmatic approach to consciousness In:s Brain and Values* ed. Karl Pribram
- Stapp, HP** (2012). Reply to a critic: *Mind efforts, quantum zeno effect and environmental decoherence.* NeuroQuantology,10: 601-605
- Stuart CIJM, Takahashi Y, Umezawa H.** (1978). *On the stability and non-local properties of memory.* Journ. of Theor Biol 71: 605-618.
- Steck D.** (2009). *Passage through chaos*, Nature 461 736-7.
- Sudbury T** (1997). *The Fastest Way From A to B*, Nature, 390, 11th December, 551-552.
- Sun Y., Wang C., Dai J.** (2010). *Biophotons as neural communication signals demonstrated by in situ biophoton autography.* Photochem. Photobiol. Sci. 9, 315–322.10.1039/b9pp00125e
- Susskind L** (1994). *The world as a hologram.* arXiv.org > hep-th > arXiv:hep-th/9409089v2.
- Sutcliffe, M. & Scrutton, N.** (2000) .*Enzyme catalysis* .Trends in biochemical science, 25, pp. 40

Yasue, K. (1988). *Wave cybernetics*. Physical Review A38, 2671-2673

Tarlaci S (2010). *A Historical View of the Relation between Quantum Mechanics and the Brain*. NeuroQuantology, 8: 120-136

't Hooft G (2001). *The Holographic Principle. Basics and Highlights*; in Fundamental Physics The Subnuclear Series, Vol. 37; Zuchichi, A., Ed.; World Scientific Singapore; pp 72-100. ETTTERS
PUBLISHED ONLINE: 14 NOVEMBER 2010 |

Tegmark M (2000). *Importance of quantum decoherence in brain processes*. Phys Rev E Stat Phys Plasmas Fluids Relat Interdiscip Topics, 61: 4194-4206.

Tegmark M (2008). *The mathematical universe*. Found. Phys. 38:101-150, [arXiv:0704.0646](https://arxiv.org/abs/0704.0646) [gr-qc]

Thompson I (2000). *Dualism: a Causal Correspondence Theory*.

<http://www.newdualism.org/papers/I.Thompson/qmc1h.html>

Tipler F (1995). *The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead*. New York: Anchor Ultimate Reality, Cambridge: Cambridge University Pres.

Tononi G and Koch C (2008). *The Neural Correlates of Consciousness. An Update*. Ann. N.Y. Acad. Sci. 1124: 239-261

Trueblood JS Busemeyer J.R. (2012). *A quantum probability model of causal reasoning*. Front. Psychology 3: 138. doi: 10.3389/fpsyg. 2012.00138.

Turenout M, Hagoort P, Brown CM (1998). *Brain activity during speaking: from syntax to phonology in 40 milliseconds*. Science.; 280: 572-574

Tsai, H.C.; Zhang, F.; Adamantidis, A.; Stuber, G. D. et al. (2009). "Phasic firing in dopaminergic neurons is sufficient for behavioral conditioning". Science 324 (5930): 1080-4. Bibcode 2009Sci...324.1080T. doi:10.1126/science.1168878. PMID 19389999.

Turin L. (1996). *A spectroscopic mechanism for primary olfactory reception*. Chem Senses, 21 (6) pp. 773-791

Tuszynski JA. and Woolf N (2010) *The Path Ahead*. Introductory chapter of: The Emerging Physics of Consciousness. Springer verlag http://www.newdualism.org/books/Tuszynski/Tuszynski-EPC-1_2006.pdf

Tuszynski JA. and Woolf N (2010). The Emerging Physics of Consciousness. Springer verlag

Ullman S (1991). *Sequence seeking and counter streams: A model for information processing in the cortex*. MIT artificial intelligence laboratory. <http://dspace.mit.edu/bitstream/handle/1721.1/6574/AIM-1311.pdf?sequence=2>

Umezawa H (1993). *Advanced Field Theory. Micro, Macro and Thermal physics*. New York: The American Institute of Physics Press.

Utts J and B D Josephson (1996). *THE PARANORMAL: THE EVIDENCE AND ITS IMPLICATIONS FOR CONSCIOUSNESS*. <http://www.tcm.phy.cam.ac.uk/~bdj10/psi/tucson.html>

Life (Perseus, 2000), 368 pp, ISBN 0-7382-0436-6.

Vannini A, Di Corpo U (2008). *Quantum Models of Consciousness*. Quantum Biosystems; 1(2): 165-184.

Varela, F.J. (1995). Resonant cell assemblies: a new approach to cognitive function and neural synchrony, *Biological Research* 28:81-95.

Varela, FJ.; Thompson, E; Rosch, Elean (1991). *The embodied mind: Cognitive science and human experience*. MIT Press, Cambridge, MA, USA..

Vattay G, Kauffman S, Niiranen S (2012). *Quantum biology on the edge of quantum chaos*. arXiv:1202.6433 (or arXiv:1202.6433v1)

Vedral V (2012). *Information and physics*. Information, 3, 219-223

Vedral V (2010). *Decoding Reality*, University Oxford Press, Oxford, U.K.

Verlinde EP (2011). *On the Origin of Gravity and the Laws of Newton*. JHEP 04, 29.

Verlinde EP (2011). *On the Origin of Gravity and the Laws of Newton*. JHEP 04, 29

Vitiello G (2001). *My Double Unveiled. The Dissipative Quantum Model of Brain*. Advances in Consciousness Research, 32, Amsterdam: John Benjamins.

Vitiello G (2001). *My Double Unveiled. The Dissipative Quantum Model of Brain*. Advances in Consciousness Research, 32, Amsterdam: John Benjamins.

Vitiello, G. (1995). "Dissipation and memory capacity in the quantum brain model". *International Journal of Modern Physics B* 9, 973–989.

Vitiello, G. (1995). *Dissipation and memory capacity in the quantum brain model*. *International Journal of Modern Physics B* 9, 973–989.

Von Neumann J (1963). *Collected Works of John von Neumann*, Taub, A. H., ed., Pergamon Press.

Walker EH (2000). *The Physics of Consciousness: The Quantum Mind and the Meaning of the*

Wheeler J.A. (1990). *Information, physics, quantum: the search for links. Complexity, Entropy and the Physics of Information*. Zurek, W.H., Ed.; Addison-Wesley, Redwood City, 3–28.

Wheeler JA, (2002). *Quotation from: Does the Universe Exist if We're Not Looking?* Discover Magazine. Physics & Math / Cosmology June.

Wheeler, J. A.; Feynman, R. P. (1949). "Classical Electrodynamics in Terms of Direct Interparticle Action". *Reviews of Modern Physics* 21 (3): 425–4332. doi:10.1103/RevModPhys.21.425

Whitehead C.W.A. (1961). *The Relevance of Whitehead*, Chapter 1, London: Allen and Unwin.

Wigner, E P, (1992). *As told to Szanton, Andrew The Recollections of Eugene P. Wigner*. Plenum. ISBN 0-306-44326-0.

Wolf FA (2008). *Is the Mind of God Found in Quantum Field Theory?*
<http://www.fredalanwolf.com/myarticles/Quantum%20Field%20Theory.pdf>

Wolf FA (1996). *The Spiritual Universe. How Quantum Physics Proves the Existence of the Soul*. New York: Simon & Schuster.

Woolf NJ, Hameroff SR (2001) A quantum approach to visual consciousness.
 Trends Cogn Sciences 5: 472-478

Yasue K and Jibu M (1995). *Quantum brain dynamics and consciousness*, John Benjamins

Wigner, E. P. (1960). "The unreasonable effectiveness of mathematics in the natural sciences. Richard Courant lecture in mathematical sciences delivered at New York University, May 11, 1959". *Communications on Pure and Applied Mathematics* **13**: 1-14.

Zeilinger A (1999). *A Foundational Principle for Quantum Mechanics*. *Foundations of Physics* 29 (4), 63-143.

Zeilinger A (2000). *Quantum Teleportation*. *Scientific Am.* Febr. 8-16. Update 2003:
<http://www.univie.ac.at/qfp/publications3/pdf/2003-24.pdf>

Zeki & Bartels (1998). *The autonomy of the visual systems and the modularity of conscious vision*. *Philos Trans R Soc Lond B Biol Sci.* 1998 November 29; 353(1377): 1911-1914.
<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1692424/>

Zohar D, Marshall I.N. (1990). *The quantum self*, human nature and consciousness defined by the new physics

DKFM and SR, 12-3- 2014

Internetsites: Consciousness in general

Thomas (basic quantum theory): <http://www.ipod.org.uk/reality/>

Course in Consciousness/Sobbotca: <http://faculty.virginia.edu/consciousness/>

Course in Consciousness/ Scaruffi: <http://www.scaruffi.com/nature/index.html>

Website Mind Papers: <http://consc.net/mindpapers>

Website consciousness: <http://consc.net/online/8.8b>

Integral consciousness., http://en.wikipedia.org/wiki/Integral_thought

Websites Chalmers., <http://consc.net/papers/moving.html>