Chapter 5
The "Quantum Soul": A Scientific Hypothesis

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Abstract The concept of consciousness existing outside the body (e.g. near-death and out-of body experiences, NDE/OBEs, or after death, indicative of a 'soul') is a staple of religious traditions, but shunned by conventional science because of an apparent lack of rational explanation. However conventional science based entirely on classical physics cannot account for normal in-the-brain consciousness. The Penrose-Hameroff 'Orch OR' model is a quantum approach to consciousness, connecting brain processes (microtubule quantum computations inside neurons) to fluctuations in fundamental spacetime geometry, the fine scale structure of the universe. Recent evidence for significant quantum coherence in warm biological systems, scale-free dynamics and end-of-life brain activity support the notion of a quantum basis for consciousness which could conceivably exist independent of biology in various scalar planes in spacetime geometry. Sir Roger Penrose does not necessarily endorse such proposals which relate to his ideas in physics. Based on Orch OR, we offer a scientific hypothesis for a 'quantum soul'.

5.1 Brain, Mind, and Near-Death Experiences

The idea that conscious awareness can exist after bodily death, generally referred to as the "soul," has been inherent in Eastern and Western religions for thousands of years. In some traditions, memories and awareness may be transferred after death to other lifetimes: reincarnation. In addition to beliefs based on religion, innumerable

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subjects have reported conscious awareness seemingly separating from the subject's brain and physical body; this occurs in conjunction with so-called near death experiences (NDEs), most typically in patients who have been resuscitated after cardiac arrest (e.g., van Lommel et al. 2001; Parnia et al. 2007). Such patients describe remarkably consistent phenomenology including visions of a white light, being in a tunnel, feelings of serenity, conversing with deceased loved ones, life review and, in some cases, floating out of the body (out-of-body experiences – OBEs). Frequently, NDE/OBE patients also report a subsequent loss of the fear of death, and tend to be more serene and accepting of life's vicissitudes (Chopra 2006).

Somewhat comparable experiences have been reported in various types of meditative and altered states, as well as traumatic psychological events, or seemingly without cause. A Gallup poll estimated some ten million Americans have reported some form of NDE/OBE (Chopra 2006). The drug ketamine, used as a "dissociative" anesthetic, can produce subjective reports of conscious awareness outside the body (Jansen 2000), as can various other psychoactive drugs. But subjective reports of drug-induced effects are distinctly different from those of NDEs/OBEs (Greyson 1993).

Unable to explain NDEs/OBEs, modern science on the whole ignores and derides such reports as unscientific folly, illusions due to stimulation of particular brain regions (Blanke et al. 2004), or hallucination due to hypoxia (lack of oxygen; Blackmore 1998). But in response one can point out: (1) subjective reports of illusions of body image are quite limited and completely different from NDE/OBE descriptions, (2) hypoxic patients are agitated, not serene, and do not form memory, and (3) modern science cannot explain normal, in-the-brain consciousness.

This last point is critical. NDEs/OBEs are particular types of subjective conscious awareness, in some way akin to our everyday conscious experience (including dreams). How the brain produces consciousness remains unknown.

The prevalent modern scientific approach to consciousness casts the brain as a biological computer, with 100 billion neurons and their axonal firings and synaptic connections acting as information networks of "bit" states and switches. Variability in synaptic strengths mediated by chemical neurotransmitters shapes network activity and enables learning and intelligent functions (Hebb 1949; Crick and Koch 2001; 2004). This "brain-as-computer" view is able to account for complex nonconscious cognitive functions including perception and control of behavior. Such nonconscious cognitive functions are described as "zombie modes," "auto-pilot," or "easy problems" (Koch and Crick 2001; Hodgson 2007; Chalmers 1996). The "easiness" derives from the apparent cause-and-effect between specific computational functions of brain neurons, and actions and behavior which do not involve conscious will or phenomenal experience.

The "hard problem" (Chalmers 1996) is the question of how cognitive processes are accompanied or driven by phenomenal conscious experience. Despite detailed understanding of neuronal firings, synaptic transmissions, neurotransmitter chemistry, and neuronal computation, there is no accounting for conscious experience, the "self," free will or "qualia" – the essence of experienced perceptions. How can the redness, texture, and fragrance of a rose, the experiential world, derive from data streams and electrochemical activity?

The answer according to most views in modern science is that consciousness emerges from a critical (but unspecified) level of neuronal computational complexity. In nonlinear dynamics, new properties do emerge in hierarchical systems, but such systems abound in nature and technology without consciousness. (e.g., weather patterns, the internet). The notion that computational complexity *per se* can account for consciousness may be mere wishful thinking.

The brain-as-neuronal-computer view has three problems.

1. Because brain synaptic computation correlating with sensory processing often occurs after we have responded to that sensory input (seemingly consciously), the conventional view in modern science is that consciousness occurs after-the-fact, and that conscious control is an illusion, consciousness is merely along for the ride (Dennett 1991; Wegner 2002). Apparently we are, as T.H. Huxley (1893) famously said, "helpless spectators".
2. The best measurable correlate of consciousness (gamma synchrony EEG) does not derive from synaptic computation. Synchronized electroencephalography (EEG) in the gamma range of 30–90 cycles per second (Hertz, "Hz") occurs in various brain regions at different times concomitant with consciousness (Gray and Singer 1989a,b; Engel et al. 1991; Singer 1995; 1999). Gamma synchrony requires networks of neurons interconnected not only by axon-to-dendrite chemical synapses, the basis for recognized neuronal computation, but by dendrite-to-dendrite gap junction electrical synapses (Christie and Westbrook 2006; Dermietzel 1998). One unconventional view is that gap junctions in various neurons open and close, enabling mobile zones of gamma synchrony to move about the brain, mediating consciousness (Hameroff 2006; 2010).
3. As cells, neurons are far more complex than simple switches. Consider the unicellular *Paramecium* which can swim around, find food and mates, avoid obstacles, learn and have sex, all without a single synaptic connection. Artificial intelligence (AI) efforts to simulate brain function have yet to simulate anything as intelligent and nimble. *Paramecium* utilizes intelligent organizational functions of cytoskeletal lattice polymers called microtubules (Sherrington 1953). These same microtubules form the internal structure of brain neurons, regulate synapses and disintegrate in Alzheimer's disease (e.g. Brunden et al. 2011). Microtubule information processing may underlie neuronal function.

Unable to explain consciousness in the brain, conventional science ignores apparent evidence for NDEs/OBEs, rejecting even the possibility of their occurrence. There are, however, unconventional but scientifically valid approaches to consciousness, which may address the three problems described above, and accommodate NDEs/OBEs as well as possible conscious awareness after bodily death. Such approaches explore strata of nature at an even finer scale than the chemical reactions and electrical signals relied upon by neuroscience, seeking convincing answers at the quantum level instead.

5.2 The Quantum World and Fine Scale of the Universe

Quantum theory tells us that physical processes occur in discrete, quantized steps, or levels. The laws that govern the quantum differ strangely from the predictable reality of our everyday "classical" world. At small scales, and sometimes at large scales, the bizarre laws of quantum mechanics reign. For example, atoms and subatomic quantum particles can exist in two or more states or places simultaneously, more like waves than particles, and existing as multiple coexisting possibilities known as *quantum superposition,* governed by a quantum wave function. Another quantum property is "nonlocal entanglement," in which components of a spatially separated system remain unified and connected (Penrose 1989).

Physics circumvents the strangeness of quantum mechanics by strictly dividing the macro/classical and micro/quantum, keeping the two worlds apart. However, consciousness somehow bridges the macro/classical and micro/quantum domains, equivalent to the subject – object split. Consciousness exists precisely on the edge between quantum and classical.

In our conscious experience, we do not see superpositions – coexisting wave-like possibilities. We see objects and particles as material things in specific locations and states. This is partly due to scale. A humpback whale leaps out of the sea whole, despite the fact that the atoms and subatomic particles comprising the whale may occupy uncertain or even multiple positions in the invisible realm of possibilities. But even when small quantum systems are measured or observed they somehow choose definite states.

The issue of why we do not see quantum superpositions in our everyday classical world is known as the "measurement problem," which has led to various interpretations of quantum mechanics. Early experiments by quantum pioneer Niels Bohr and others seemed to show that quantum superpositions, when measured by a machine, stayed as multiple possibilities until a conscious human observed the results. Bohr concluded that conscious observation "collapsed the wave function," that unobserved superpositions persisted until being observed, at which instant they reduced, or collapsed to particular definite states (the choice of states being random). In this approach, consciousness *causes* quantum state reduction, placing consciousness outside science. Erwin Schrödinger objected through his still-famous thought experiment in which the fate of a cat in a box is linked to a quantum superposition. According to the Copenhagen interpretation (so-named after Bohr's Danish origin) Schrödinger's cat is both dead and alive until the box is opened and the cat observed. The thought experiment was intended to ridicule Copenhagen, but the question remains: how large can superpositions become?

Another popular interpretation is the multiple worlds view (Everett 1957) in which superpositions are separations in reality, each possibility evolving its own distinct universe; a multitude of coexisting universes results.

Yet another approach is decoherence in which interaction with classical world erodes quantum states. But decoherence does not address isolated quantum systems. Finally, various types of objective reduction (OR) propose that specific objective thresholds cause quantum state reduction.

One particular OR theory was proposed by British physicist Sir Roger Penrose (1989), who began by addressing the fundamental nature of superposition. He extended Einstein's general theory of relativity, in which matter is essentially space-time curvature, to the Planck scale (10^{-33} cm), the most basic level of the universe. A particle in one state or location would be a specific curvature in space-time geometry, and the same particle in another location would be curvature in the opposite direction, extending downward to the Planck scale. Superposition of both locations can then be seen as simultaneous curvatures in opposite directions, and hence, according to Penrose, a separation, bubble, or blister in the very fabric of reality.

If such space-time separations were to continue and evolve, the universe would bifurcate, leading to parallel universes as described in the multiple worlds view supported by many physicists and cosmologists including Stephen Hawking (Hawking and Mlodinow 2010). But Penrose has suggested that such space-time separations are unstable and will reduce, or collapse to one particular state or location at a particular time due to an objective threshold intrinsic to the fine structure of the universe, like infinitesimally tiny soap bubbles bursting one facet or another, shaping and creating a new reality. Penrose also suggests that each OR, or self-collapse – essentially a ripple or quantized annealing in fundamental space-time geometry – results in a moment of conscious experience.

This is in direct contradistinction to the Copenhagen interpretation in which consciousness is outside science, externally *causing* reduction by observation. In Penrose OR, consciousness *IS* reduction (a particular type of reduction). Thus Penrose OR is the only worldview incorporating consciousness into the universe.

Penrose OR differs in another important way from Copenhagen and decoherence in which particular classical states are selected randomly from among superpositioned possibilities. The selections in Penrose OR are not random, but influenced by information embedded in fundamental space-time geometry, information Penrose characterized as Platonic values (Penrose 1989).

The Greek philosopher Plato described an abstract world of pure form, mathematical truth, and ethical and aesthetic values. Penrose suggests such Platonic values, along with precursors of physical laws, constants, forces, and consciousness, literally exist as patterns in fundamental space-time, encoded in Planck scale geometry.

Physics tells us the universe is as it is, and thus able to support life and consciousness, because 20 or more physical constants and the laws they dictate take on very specific values. If any of these varied even slightly, we would not be here, so the precise values and our presence in the universe are apparently a coincidence of staggeringly low probability, akin to wining the cosmic lottery. The "anthropic principle" addresses the question of why these values are what they are, and has several interpretations (e.g., Davies 2006). The most common is tautological – that we are in the particular universe which has these specific values simply because it *has* those values. If it did not, we would not be here. For many physicists and philosophers, the tautological answer is related to the multiple worldviews, that this universe with consciousness is one in a multitude of universes, the others having different physical constants and lacking life and consciousness.

This is the view espoused by Hawking and Mlodinow in their book *Grand Design* (Hawking and Mlodinow 2010) in which they assert "M-theory" (a derivative of string theory) with a near-infinite number of parallel universes, all others devoid of consciousness.

Penrose suggests another possibility which avoids the need for multiple universes. Values for physical constants defining our universe may be encoded in the fine structure of the universe itself, along with mathematical truth, Platonic values, and precursors of mass, spin, charge, and consciousness. The roots of consciousness may thus extend to the most basic level of the universe. Penrose has also proposed that our universe is serial, that the Big Bang was preceded by a previous iteration, and before that another one and so on (Penrose 2010). Unlike the idea of parallel universes which is untested (and likely untestable), the Penrose proposal for serial universes is supported by evidence from the cosmic microwave background radiation (Gurzadyan and Penrose 2010). Perhaps physical constants, conscious precursors, and Platonic values embedded in the fine structure of the universe mutate and evolve with each cosmological cycle.

What *is* the fine structure of the universe? The material world is composed of atoms and subatomic particles. But atoms ($\sim10^{-8}$ cm) are mostly empty space, as is the space between atoms. If we go down in scale from atoms, eventually we reach the basement level of reality, Planck scale geometry at 10^{-33} cm, with coarseness, irregularity, and information.

Descriptions of Planck scale geometry include string theory and loop quantum gravity. String theory, in which Planck scale strings vibrate at specific frequencies correlating with fundamental particles, has several problems. It lacks background geometry (e.g., in which the strings vibrate) and requires multiple untestable dimensions (Penrose 2004).

Another approach, loop quantum gravity depicts space-time geometry as quantized into volume pixels, Planck scale polygons whose edges may be considered as irreducible spin whose lengths also vary but average 10^{-33} cm. Planck volumes evolve and change with time, conveying information as a 3-dimensional spider web of spin. Somehow, space-time geometry is also nonlocal, as revealed by entanglement experiments (Nadeau and Kafatos 2001), and perhaps holographic (e.g., Susskind 1994). Could Planck scale information affect biology?

Recent evidence suggests that Planck scale information may repeat at increasing scales in space-time geometry, reaching to the scale of biological systems. The British-German GEO 600 gravity wave detector near Hanover, Germany has consistently recorded fractal-like noise which apparently emanates from Planck scale fluctuations, repeating every few orders of magnitude in size and frequency from Planck length and time (10^{-33} cm; 10^{-43} s) to biomolecular size and time (10^{-8} cm; 10^{-2} s, Hogan 2008; Chown 2009). At some point (or actually at some complex edge, or surface) in this hierarchy of scale, the microscopic quantum world transitions to the classical world. If this transition is due to Penrose OR, consciousness occurs as a process on this edge between quantum and classical worlds.

This notion that consciousness is in some way intrinsic to the universe is comparable to purely subjective views on consciousness going back thousands of years in India. The Vedic tradition and ancient sacred texts derive their name from the Sanskrit word *Veda,* for knowledge. The most philosophical branch of Veda is Vedanta – literally, "the end of the Vedas." In Vedanta, consciousness is everything, and manifests, or creates reality. In this view (taken by one of us, DC, differing slightly from the argument presented in this paper), consciousness is both subject and object, both quantum and classical. Consciousness is all there is (Chopra 2001).

Penrose OR (and Penrose-Hameroff Orch OR) maintains the classical world exists on its own. Consciousness is a process on the edge between quantum and classical worlds, the process consisting of discrete, quantized ripples in the fine scale structure of the universe, transitions between subject and object.

5.3 Quantum Consciousness: Orchestrated Objective Reduction ("Orch OR")

The Penrose-Hameroff theory of "orchestrated objective reduction" ("Orch OR") proposes that consciousness depends on quantum computations in structures called microtubules *inside* brain neurons, occurring concomitantly with and supporting neuronal-level synaptic computation (Penrose and Hameroff 1995; Hameroff and Penrose 1996a,b; Hameroff 1998a,b; Hameroff et al. 2002).

Microtubules are cylindrical polymers of the protein "tubulin," and major components of the cell cytoskeleton which self-assembles to configure intracellular architecture, create and regulate synapses, and communicate between membrane structures and genes in the cell nucleus. In addition to bone-like support, microtubules and other cytoskeletal components seem to act as the cell's nervous system, its "on-board computer," continually reshaping and differentiating. In microtubule lattices, states of individual tubulins are proposed to act as "bit" states, as in classical computers and molecular automata (Hameroff and Watt 1982; Rasmussen et al. 1990). Microtubule-level processing raises the capacity for neuronal information processing immensely. Rather than a few (synaptic) bits per neuron per second, 10^8 tubulins per neuron switching coherently in megahertz (10^6 Hz) give potentially 10^{14} operations, or bits per second per neuron.

But increased information processing alone does not solve all problems regarding consciousness in the brain. Penrose Hameroff Orch OR further proposes tubulins can be quantum bits, or "qubits" in microtubule quantum computers, and that such quantum computations connect conscious brain functions to the most basic level of the universe.

This opens the door to consciousness being nonlocal, and in some cases possibly untethered to body and brain. These speculations are based on ideas in physics put forth by Sir Roger Penrose. It should be stated clearly that Sir Roger does not necessarily endorse the further speculations developed here, and generally avoids connections between science, religion, and spirituality.

Penrose defined OR self-collapse of superpositions (due to separations in space-time geometry) and moments of consciousness by $E=\hbar/t$. E is the gravitational self-energy of an object (or its equivalent space-time geometry) separated from itself. $\hbar$ is Planck's constant (over 2π) and t is the time at which OR occurs. E may be calculated based on factors including (1) the object's mass, (2) the level at which the object separates from itself, i.e., its entire mass, individual atoms, atomic nuclei, or subatomic particles, and (3) the spatial separation distance, how far the object, or its space-time geometry separates from itself. If a superposition of self-energy E evolves and avoids decoherence to reach time t, an OR moment of consciousness occurs.

Because of the inverse relation, the larger the mass and spatial separation E, the briefer the time t at which OR conscious moments occur. Superpositions E must avoid decoherence (i.e., the quantum system must be isolated from the classical environment) until time t is reached. Hence, the conditions for Penrose OR and conscious moments are fairly stringent.

Penrose and Hameroff suggest such conditions have evolved in the brain, specifically in microtubules inside brain neurons, and that microtubules perform quantum computations which are "orchestrated" by synaptic inputs and neurophysiology, isolated from decoherence, and terminated by Penrose OR, hence orchestrated objective reduction, "Orch OR." Microtubule quantum superpositions E are proposed to extend and entangle from neuron to neuron through gap junctions (which mediate gamma synchrony), enabling selective brain-wide quantum coherence among microtubules. Decoherence is suggested to be avoided through coherent pumping, actin gelation, ordered water and topological resonances. OR events also entail backward time effects, consistent with evidence for backward referral of conscious experience in the brain (Libet 1979). Entanglement with the future may enable real-time conscious action, and rescue consciousness from the unfortunate role of epiphenomenal illusion (Hameroff 2007).

Orch OR has been criticized since its inception in 1995, mainly because laboratory-built technological quantum computers require extreme cold to avoid decoherence by thermal vibrations, and the brain operates at warm biological temperatures (e.g., Tegmark 2000; Hagan et al. 2001). However, in the past 5 years numerous experiments have shown warm temperature quantum coherence in proteins involved in photosynthesis, ion channels, and other biomolecules (Engel et al. 2007). Dr. Anirban Bandyopadhyay (2010) at the National Institute of Materials Sciences in Tsukuba, Japan has preliminary evidence for quantum coherence, topological quantum conductance, and decoherence times of one-tenth millisecond or longer in individual microtubules at warm temperatures. For Orch OR and quantum biology, the future is fairly bright. Can Orch OR account for NDEs/OBEs and conceivably an after-life?

5.4 Orch OR, NDEs, and Altered States

Orch OR assumes consciousness typically occurs in the human brain at around 40 Hz, i.e., 40 conscious moments per second, corresponding with gamma synchrony EEG, the best measurable correlate of consciousness. For $t = 25$ ms (1/40 s), by

$E = \hbar/t$, E corresponds with nanograms of superpositioned tubulins (~10^{11} tubulins) distributed in microtubules in thousands of gap junction-connected neurons (and glia), still a very, very small fraction of the brain (total ~10^{20} tubulins, 100 billion neurons).

In principle, OR and Orch OR (and thus conscious moments) can occur at any scale, in any type of medium, as long as superpositions avoid decoherence. Thus $E = \hbar/t$ predicts a full spectrum of possible conscious moments, much like the electromagnetic spectrum for photons. Large superpositions E will reach threshold quickly (and have more intense experiences) while small superpositions E will require longer times and have weak experiences (intensity proportional to E). For example, a single superpositioned electron (small E, long t), if isolated from environmental decoherence would reach threshold only after ten million years, and have an extremely low intensity moment of consciousness. Larger superpositions (large E, small t) will reach threshold quickly and have higher intensity consciousness. But decoherence must be avoided until time t and OR occurs. Higher levels of consciousness would involve larger E (more tubulins, more neurons and a higher portion of the brain), and shorter t, thus higher frequencies.

Vedic meditation, contemplation, and self-reflection exploring consciousness has led to descriptions of expanded states of consciousness or enlightenment involving 14 different levels, "astral planes," or "lokas." Lokas are portrayed as distinct worlds, realms, or planes of existence which differ from the 3-dimensional world of our everyday waking experience. Vedic texts say each plane or experienced reality has a characteristic frequency range, and is accessed or reached when it is matched by the frequency of the subject's conscious awareness (Chopra 2001).

Tibetan monks reach 80 Hz gamma synchrony during meditation (Lutz et al. 2004) presumably an enhanced, altered state, with twice as many conscious events per second, each at higher intensity. Magneto-encephalography has recorded coherent signals in the range of a kilohertz (1,000 Hz) from human brain (Papadelis et al. 2009), and higher frequency effects (megahertz, gigahertz, terahertz) have been measured in microtubules inside neurons (Bandyopadhyay 2010). Could consciousness shift levels to higher frequencies and greater brain involvement in altered and enhanced states?

Electrical signals occur in the brain in a self-similar way at different spatial and temporal scales, scale-free dynamics (He et al. 2010). This is also called pink noise, proportional to $1/f^{\alpha}$, where f is frequency and α is the separations in scale (e.g., spatial and temporal orders of magnitude) at which the information repeats, similar to a fractal or hologram.

Fractal or holographic-like structure also occurs in "small world" and "large world" networks of neurons, nested hierarchies of networks within networks within networks. And inside neurons are cytoskeletal networks including microtubules which may also process information. Scale-free dynamics occurs both temporally and structurally in the brain, in layers or information processing systems with both bottom–up and top–down relationships.

In altered states, the process of consciousness may shift to different planes, or scales in the brain, with higher frequencies (smaller t), greater intensity, and larger

E in terms of number of involved microtubules, neurons, and volume of brain capacity. Consciousness occurring by $E = h/t$ normally at 40 Hz (each conscious moment involving roughly one millionth of brain microtubules) could transition to higher frequencies at, say 10 kHz, megahertz, gigahertz, and terahertz levels. These would involve greater and greater proportions of brain neurons and microtubules. These levels would involve, respectively, 1/10,000th, 1/100th, and, for gigahertz consciousness, the entire brain.

Thus altered states of consciousness may involve transcendence to deeper, more intense levels of experience, deeper levels of reality, e.g., consistent with Vedic astral planes or lokas, and enlightenment reached by meditation and spiritual practices. Such enhanced, altered states need not involve alternative dimensions or universes, but rather deeper, more fine scale geometry in nonlocal holographic-like levels or scales in this one universe.

As the Beatles said (Lennon and McCartney 1968): "The deeper you go, the higher you fly, The higher you fly, the deeper you go."

At any frequency, Orch OR consciousness in the brain is occurring in fundamental space-time geometry, localized to brain neuronal microtubules and driven by metabolic processes. When the blood stops flowing, energy and oxygen depleted and microtubules inactivated or destroyed (e.g., NDE/OBE, death), it is conceivable that the quantum information which constitutes consciousness could shift to deeper planes and continue to exist purely in space-time geometry, outside the brain, distributed nonlocally. Movement of consciousness to deeper planes could account for NDEs/OBEs, as well as, conceivably, a soul apart from the body.

5.5 End-of-Life Brain Activity

Gamma synchrony EEG brain activity is known to correlate with normal consciousness. Monitors able to measure and detect gamma synchrony and other correlates of consciousness have been developed for use during anesthesia to provide an indicator of depth of anesthesia and prevent intraoperative awareness, i.e., to avoid patients being conscious when they are supposed to be anesthetized and unconscious. For example the "BIS" monitor (Aspect Medical Systems, Newton MA) records and processes frontal EEG to produce a digital "bispectral index," or BIS number on a scale of 0–100. A BIS number of 0 equals EEG silence, and 80–100 is the expected value in a fully awake, conscious adult with gamma synchrony. A BIS number maintained between 40 and 60 is recommended for general anesthesia. The "SEDline" monitor (Hospira, Lake Forest, IL) also records frontal EEG and produces a comparable 0–100 index.

In recent years, these monitors have been applied outside of anesthesiology, e.g., to dying patients at or near the moment of death, revealing startling end-of-life brain activity.

In a study reported in the *Journal of Palliative Medicine*, Chawla et al. (2009) reported on seven critically ill patients from whom life support (medications, machine ventilation) was being withdrawn, allowing them to die peacefully. As per protocol, they were monitored with a BIS or SEDline brain monitor during the process of dying. While on life support the patients were neurologically intact but heavily sedated, with BIS or SEDline numbers near 40 or higher. Following withdrawal, the BIS/SEDline generally decreased to below 20 after several minutes, at about the time cardiac death occurred. This was marked by lack of measurable arterial blood pressure or functional heartbeat. Then, in all seven patients postcardiac death, there was a burst of activity as indicated by abrupt rise of the BIS or SEDline to between 60 and (in most cases) 80 or higher. After a period of such activity ranging from 90 s to 20 min, the activity dropped abruptly to near zero.

The SEDline number is derived from a proprietary algorithm which includes EEG data. In one patient, raw SEDline data was analyzed and revealed the burst of postcardiac death brain activity to include gamma synchrony, an indicator of conscious awareness. Chawla et al. raise the possibility that the measured postcardiac death brain activity might correlate with NDEs/OBEs. Of course the patients died, so we have no confirmation that such experiences occurred.

In another study published in the journal *Anesthesia and Analgesia*, Auyong et al. (2010) described three brain-injured patients from whom medical and ventilatory support were withdrawn prior to "postcardiac death" organ donation (Csete 2010) These patients were hopelessly brain-damaged, but technically not brain dead. Their families consented to withdrawal of support and organ donation. Such patients are allowed to die "naturally" after withdrawal of support, their bodies then quickly taken to surgery for organ donation.

The three patients in the Auyong et al. study prior to withdrawal of support had BIS numbers of 40 or lower, with one near zero. Soon after withdrawal, near the time of cardiac death, the BIS number dwindled downward and then spiked to approximately 80 in all three cases, and remained there for 30–90 s. The number then abruptly returned to near zero, followed thereafter by declaration of death and organ donation. Various sources of artifact for the end-of-life brain activity were considered and excluded.

Obviously we cannot say whether the end-of-life brain activity is indeed related to NDEs/OBEs, or even possibly the soul leaving the body. Nor do we know how commonly it occurs (ten out of ten in the two studies cited). Those issues aside, the mystery remains as to how brain activity occurs in metabolically dead tissue, receiving no blood flow or oxygen, and lacking mechanisms to remove toxic metabolites.

Some describe the end-of-life brain activity as nonfunctional, generalized neuronal depolarization. Chawla et al. suggested excess extracellular potassium could cause "last gasp" neuronal spasms of activity throughout the brain. Another suggested cause is calcium-induced programmed neuronal death by apoptosis. But such explanations seem unable to account for globally organized coherent synchrony during the end-of-life brain activity.

If end-of-life brain activity does correlate with conscious NDE/OBE phenomenology and/or the soul leaving the body, we still face the question of how/why conscious activity, or even synchronized activity of any sort is occurring in the nearly dead brain. But there are logical possibilities.

Energy requirements for consciousness may be small compared to nonconscious brain functions, especially if consciousness occurs primarily in dendrites and cell bodies rather than axonal firings. Neuronal hypoxia and acidosis would disable sodium-potassium ATPase pumps, preventing axonal action potentials, but temporarily sparing lower energy dendritic activity. Consciousness as a low energy quantum process might transiently flourish if energy-dependent decoherence-causing mechanisms were impaired, resulting in a transient burst of enhanced consciousness.

In the Orch OR context, consciousness occurs as a process at the level of fundamental space-time geometry. When the brain is under duress, it is conceivable quantum information processes constituting consciousness dissipate to the nonlocal universe at large. A dualist perspective, in which a separate, as yet undefined spiritual information field constitutes awareness outside the body, may not be necessary. An afterlife, an actual soul-as-quantum information leaving the body and persisting as entangled fluctuations in multiple scales, or planes in quantum space-time geometry, may be scientifically possible.

5.6 Conclusion: The Quantum Soul

Conventional science and philosophy attempt to base consciousness strictly on classical physics, rejecting the possibility of quantum nonlocality in consciousness, including persistence outside the body as indicated by NDEs/OBEs, religious lore, and anecdotal memories suggesting reincarnation. But evidence in recent years links biological functions to quantum processes, raising the likelihood that consciousness depends on nonlocal quantum effects in the brain. That in turn suggests that the "hard problem" of the nature of conscious experience requires a worldview in which consciousness or its precursors are irreducible components of reality, fundamental space-time geometry at the Planck scale. Max Planck (1931) was clear-sighted when he said, "I regard consciousness as fundamental. We cannot get behind consciousness." Vedic and other spiritual traditions have similar assumptions; consciousness and knowledge are intrinsic to the universe.

How did they get there? Physicist Paola Zizzi has proposed that the period of rapid inflation during the very early Big Bang was characterized by superposition of multiple possible universes. By $E=\hbar/t$, Zizzi (2004) has calculated that the end of inflation and selection of this universe was caused by a cosmic conscious moment at a particular instant during the Big Bang (the "Big Wow"). Perhaps the possible universes were related to a previous universe, as Penrose (2010) has proposed in "Cycles of Time," our universe mutating and evolving with each rebirth[1].

The Penrose-Hameroff Orch OR model of consciousness proposes a connection between quantum brain processes and fundamental space-time geometry. In this study we consider Orch OR in the context of anecdotal reports of NDE/OBE experiences as well as circumstantial evidence for afterlife, reincarnation, and the potential

[1] Although this proposal does not include inflation.

for quantum consciousness in space-time geometry. We conclude the concept of a "quantum soul" is scientifically plausible.

The "quantum soul" implies consciousness in the brain as described by Orch OR, as well as nonlocal features including:

1. Interconnectedness via entanglement among living beings and the universe
2. Contact with cosmic wisdom/Platonic values embedded as quantum information in fundamental space-time geometry
3. Consciousness as patterns in nonlocal fractal/holographic-like space-time geometry, able to exist at deeper planes and scales independent of biology

We present a secular, scientific approach consistent with all religions and known science. With the advent of quantum biology, nonlocality in consciousness must be taken seriously, potentially building a bridge between science and spirituality.

References

Auyong, D. B., Klein, S. M., Gan, T. J., Roche, A. M., Olson, D. W., & Habib, A. S. (2010). Processed electroencephalogram during donation after cardiac death. *Anesthesia and Analgesia, 110*(5), 1428–1432.

Bandyopadhyay, A. (2010). *Direct experimental evidence for quantum states in microtubules and topological invariance*. Toward a Science of Consciousness 2011 Abstracts. Retrieved, from http://www.consciousness.arizona.edu (manuscript in preparation).

Blackmore, S. J. (1998). Experiences of anoxia: Do reflex anoxic seizures resemble near-death experiences? *Journal of Near Death Studies, 17*, 111–120.

Blanke, O., Landis, T., Spinelli, L., & Seeck, M. (2004). Out-of-body experience and autoscopy of neurological origin. *Brain, 127*(2), 243–258.

Brunden, K. R., Yao, Y., Potuzak, J. S., Ferrer, N. I., Ballatore, C., James, M. J., et al. (2011). The characterization of microtubule-stabilizing drugs as possible therapeutic agents for Alzheimer's disease and related tauopathies. *Pharmacological Research, 63*(4), 341–351.

Chalmers, D. J. (1996). *The conscious mind – in search of a fundamental theory*. New York: Oxford University Press.

Chawla, L. S., Akst, S., Junker, C., Jacobes, B., & Seneff, M. G. (2009). Surges of electroencephalogram activity at the time of death: A case study. *Journal of Palliative Medicine, 12*(12), 1095–1100.

Chopra, D. (2001). *How to know god: The soul's journey into the mystery of mysteries* New york, NY. Running Press Book Publishers.

Chopra, D. (2006). *Life after death – the burden of proof*. New York: Three Rivers Press.

Chown, M. (2009). Our world may be a giant hologram. *NewScientist*. Retrieved, from http://www.newscientist.com/article/mg20126911.300.2010-04-19

Christie, J. M., & Westbrook, G. L. (2006). Lateral excitation within the olfactory bulb. *Journal of Neuroscience., 26*(8), 2269–2277.

Crick, F. C., & Koch, C. (2001). A framework for consciousness. *Nature Neuroscience, 6*, 119–126.

Csete, M. (2010). Donation after cardiac death and the anesthesiologist. *Anesthesia and Analgesia, 5*, 1253–1254.

Davies, P. (2006). *The Goldilocks enigma*. London: Allen Lane.

Dennett, D. C. (1991). *Consciousness explained*. Boston: Little, Brown.

Dermietzel, R. (1998). Gap junction wiring: A 'new' principle in cell-to-cell communication in the nervous system? *Brain Research Reviews, 26*(2–3), 176–183.

Engel, G. S., Calhoun, T. R., Read, E. L., Ahn, T.-K., Mancal, T., Cheng, Y.-C., et al. (2007). Evidence for wavelike energy transfer through quantum coherence in photosynthetic systems. *Nature, 446*, 782–786.

Gray, C. M., & Singer, W. (1989a). Stimulus-specific neuronal oscillations in orientation columns of cat visual cortex. *Proceedings of the National Academy of Sciences USA* (Vol. 86, pp. 1698–1702). USA.

Gray, C. M., & Singer, W. (1989b). Stimulus-specific neuronal oscillations in orientation columns of cat visual cortex. *Proceedings of the National Academy of Sciences USA* (Vol. 86, pp. 1698–1702). USA.

Greyson, B. (1993). Varieties of near-death experience. *Psychiatry, 56*(4), 390–399.

Gurzadyan, V. G., & Penrose, R. (2010). *Concentric circles in WMAP data may provide evidence of violent pre-Big-Bang activity*. arXiv:1011.3706.

Hameroff, S. (1998a). Quantum computation in brain microtubules? The Penrose Hameroff "Orch OR" model of consciousness. *Philosophical Transactions of the Royal Society of London Series A, 356*, 1869–1896.

Hameroff, S. (1998b). Quantum computation in brain microtubules – the Penrose-Hameroff "Orch OR" model of consciousness. *Philosophical Transactions of the Royal Society of London Series A, 356*, 1869–1896.

Hameroff, S. (2006). Consciousness, neurobiology and quantum mechanics: The case for a connection. In Tuszyuski J (Ed.), *The emerging physics of consciousness*. New York: Springer.

Hameroff, S. (2007). The brain is both neurocomputer and quantum computer. *Cognitive Science, 31*, 1035–1045.

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

Hameroff, S. R., & Penrose, R. (1996a). Orchestrated reduction of quantum coherence in brain microtubules: A model for consciousness. In S. R. Hameroff, A. Kaszniak, & A. C. Scott (Eds.), *Toward a science of consciousness the first Tucson discussions and debates* (pp. 507–540). Cambridge: MIT Press. Also published in Mathematics and Computers in Simulation (1996) 40:453–480.

Hameroff, S. R., & Penrose, R. (1996b). Conscious events as orchestrated spacetimeselections. *Journal of Consciousness Studies, 3*(1), 36–53.

Hawking, S., & Mlodinow, L. (2010). *Grand design*. New York: Bantam.

Hebb, D. O. (1949). *Organization of behavior: A neuropsychological theory*. New Yourk: Wiley.

Hodgson, D. (2007). Making our own luck. *Ratio, 20*, 278–292.

Hogan, C. J. (2008). Measurement of quantum fluctuations in geometry. *Physical Review D, 77*(10), 104031. doi: 10.1103/PhysRevD.77.104031.arXiv:0712.3419

Huxley, T. H. (1893). Method and results: Essays.

Jansen, K. L. (2000). A review of the nonmedical use of ketamine: Use, users and consequences. *Journal of Psychoactive Drugs, 32*(4), 419–433.

Koch, C. (2004). *The quest for consciousness: A neurobiological approach*. Englewood: Roberts and Company.

Koch, C., & Crick, F. (2001). The zombie within. *Nature, 411*, 893.

Lennon, J., & McCartney, P. (1968). *Everybody's got something to hide except for me and my monkey*. White Album. Sony /ATV Music, Nashville,TN.

Lutz, A., Greischar, L. L., Rawlings, N. B., Ricard, M., & Davidson, R. J. (2004). Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *The Proceedings of the National Academy of Sciences USA, 101*(46), 16369–16373.

Nadeau, R., & Kafatos, M. (2001). *The non-local universe: The new physics and matters of the mind*. Oxford: Oxford University Press.

Papadelis, C., Poghosyan, V., Fenwick, P. B., & Ioannides, A. A. (2009). MEG's ability to localise accurately weak transiently neural sources. *Clinical Neurophysiology, 120*(11), 1958–1970.

Parnia, S., Spearpoint, K., & Fenwick, P. B. (2007). Near death experiences, cognitive function and psychological outcomes of surviving cardiac arrest. *Resuscitation, 74*(2), 215–221.

Penrose, R. (2004). *The road to reality: A complete guide to the laws of the universe*. London: Vintage Books.

Penrose, R. (2010). *Cycles of time: An extraordinary new view of the universe*. London: The Bodley Head.

Penrose, R., & Hameroff, S. R. (1995). Gaps, what gaps? Reply to Grush and Churchland. *Journal of Consciousness Studies, 2*(2), 99–112.

Planck, M. (1931). The observer, London, Januvary 29, 1931.

Singer, W. (1999). Neuronal synchrony: A versatile code for the definition of relations. *Neuron, 24*, 111–125.

Singer, W., & Gray, C. M. (1995). Visual feature integration and the temporal correlation hypothesis. *Annual Review of Neuroscience, 18*, 555–586.

Susskind, L. (1994). *The world as a hologram*. Retrieved, from http://arxiv.org/abs/hep-th/9409089

van Lommel, P., van Wees, R., Meyers, V., & Elfferich, I. (2001). Near-death experience in survivors of cardiac arrest: A prospective study in The Netherlands. *Lancet, 358*(9298), 2039–2045.

Wegner, D. M. (2002). *The illusion of conscious will*. Cambridge: MIT Press.

Zizzi, P. A. (2004). *Emergent consciousness: From the early universe to our mind*. Retrieved, from http://arxiv.org/abs/gr-qc/0007006