Chapter 20

The Quantum Origin of Life: How the Brain Evolved to *Feel Good*

S. Hameroff
The University of Arizona, Tucson, AZ, United States

INTRODUCTION: WHICH CAME FIRST, FEELINGS OR THE BRAIN?

What Drives Conscious Behavior?

According to Darwin's theory of evolution, adaptations through random mutations serve an organism's genes, the fittest genes surviving through reproductive success. However, Darwin's theory renders consciousness epiphenomenal and illusory, leaves apparent gaps in evolution, and has been questioned as its sole guiding force. For example, Kauffman (1993) has invoked principles of self-organization and nonlinear emergence in life and its evolution. But to what end? What is life evolving toward? What's the point?

In psychology and cognitive neuroscience, purposeful conscious behavior is predicated on personal reward, on an animal or human wanting to feel good (or avoid feeling bad). Conscious feelings drive behavior, whether for immediate or delayed gratification, altruism ("it *feels* better to give than to receive"), and/or spiritual peace and contentment. Primacy of feelings has been asserted since Epicurus in ancient Greece, Freud's (1961) "pleasure principle" in psychiatry, and dopamine-mediated "reward" in psychology and neuroscience. Damasio (1999) has emphasized the primacy of emotional feelings, as has Panksepp (1998), and Peil (2014) who suggests they derive from a "deeper authority" which may regulate and guide our behaviors.

In philosophical terms, feelings and conscious awareness are composed of mental features termed qualia, whose essential nature remains a scientific mystery—what it is like to *be* (Nagel, 1974), also known as the hard problem (Chalmers, 1996). We could have been unfeeling zombies, programmed to promote our species, but without qualia and inner experience. But we *do* have them, and we *are* conscious, although how and why remain unknown.

The mainstream view in neuroscience contends consciousness, feelings and qualia emerge from complex computation among many simple brain neurons (Dennett, 1991; Tononi, 2012; Churchland, 2013). Such computational emergence—brain-as-computer—implies consciousness appeared on earth as an adaptation of biological evolution, and may eventually be replicated in silicon. However, these views neglect the question of what *life* is; are based on cartoon-like abstractions of actual neurons; and fail to provide testable predictions, falsifiability, nor any semblance of experimental validation.

These failings have pushed some computationalists toward philosophical panpsychism, the assertion that qualia are properties of matter (Koch, 2012), or of discrete events in an experiential medium (panexperientialism, as proposed by Whitehead, 1929, 1933). Others suggest mental qualities derive from deeper, intrinsic features of the universe, features giving *rise* to qualia, along with matter, charge, spin, and various cosmological parameters (Penrose, 1989; Chalmers, 1996). In these views, qualia-like features preceded life, perhaps encoded in reality, in the structure, or makeup of the universe described as fundamental spacetime geometry. If so, pleasurable qualia may have preceded life, and prompted its origin and evolution to optimize feelings.

However in looking inward in search of qualia, panpsychists and panexperientialists must encounter the mysterious world of quantum mechanics, and specifically the "measurement problem," related to the "collapse of the wave function." At small scales, and the cutoff is seemingly variable, strange laws of quantum physics reign, eg, quantum particles exist in superposition of multiple states or locations simultaneously, described by a quantum wave function. Such superpositions are not seen in our everyday world, as efforts to measure or observe them apparently

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result in collapse to definite states. Why quantum superpositions are not seen is a mystery known as the measurement problem, which seems in some way related to consciousness.

Experiments from the early 20th century appeared to show that conscious observation caused superposition wave functions to collapse to definite states, randomly choosing a particular reality. Consciousness was said to collapse the wave function (attributed to von Neumann, Wigner, Stapp, and Chalmers—see Stapp, 2007—but often termed the Copenhagen interpretation, after the Danish origin of Niels Bohr; see below). The Copenhagen interpretation allowed useful quantum experiments, but placed consciousness outside science, as an extrinsic entity causing collapse. Other interpretations include multiple worlds (Everett, 1957), in which each superposition possibility branches and evolves to form its own universe, resulting in an infinite number of parallel worlds.

Still others stipulate various objective thresholds for quantum state reduction (objective reduction, or OR), one by Sir Roger Penrose (1989, 1994) combining features of the Copenhagen interpretation and multiple worlds, and introducing consciousness into science as an intrinsic feature of the universe. To do so, Penrose characterized superpositions as in the first step in multiple worlds, separations in spacetime geometry, and the structure of the universe. But unlike multiple worlds, spacetime separations, according to Penrose, are unstable, separations continuing only until reaching an objective threshold related to the quantum uncertainty principle, $E_G = h/t$. The magnitude of the superposition is E_G (its gravitational self-energy), h is the Planck–Dirac constant and t the time at which OR self-collapse occurs.

In this approach, whenever superpositions reach threshold, OR events select particular classical states, accompanied by moments of (proto) conscious experience—qualia, basic units of feeling and awareness. The choice of classical states in OR events are influenced by (resonate with) what Penrose termed Platonic values embedded in the fine scale structure of the universe. The qualitative feeling of each quale, ie, good, bad, or otherwise, would depend on resonance and geometry of specific spacetime separations with deeper, Platonic levels of the universe. Most significantly, unlike the Copenhagen interpretation in which consciousness causes collapse, Penrose OR proposes that collapse *causes* consciousness (or that collapse *is* consciousness).

In this regard, Penrose OR is aligned with the process philosophy of Alfred North Whitehead (1929, 1933) who viewed consciousness as a sequence of discrete "occasions of experience." Abner Shimony (1993) suggested Whitehead conscious events, or 'occasions' were equivalent to quantum state reductions, or moments of collapse of the wave function. Generally, Whitehead occasions are "simple, dull and monotonous," and must be "combined," or "organized" into full, rich conscious moments. Similarly, noncognitive, protoconscious qualia occurring with each OR event must be combined, organized, or orchestrated into full rich conscious experience, as described in an iconoclastic theory, orchestrated objective reduction (Orch OR), put forth in the mid-1990s by Sir Roger Penrose and this author (Penrose and Hameroff, 1995; Hameroff and Penrose, 1996a,b, 2014a–c).

Orch OR suggests that conscious awareness and intentional purpose derive from organized (orchestrated) OR events in cytoskeletal structures called microtubules inside brain neurons. Microtubules are self-assembling lattice polymers of the protein tubulin which organize intracellular activities, process information, and vibrate coherently in various related frequencies over a wide spectrum, from terahertz through gigahertz, megahertz, and kilohertz (Sahu et al., 2013a,b, 2014). Orchestration implies that microtubule quantum states are organized through sensory inputs, memory and natural microtubule resonances prior to OR threshold to account for conscious cognition and full, rich conscious experience (Orch OR). Microtubule states selected in Orch OR events in neuronal dendrites and soma can regulate synaptic plasticity and trigger axonal firings to exert causal action and conscious behavior.

Protoconscious OR events occurring throughout the universe would be random and disjointed, metaphorically like isolated sounds and tones, eg, noise, of an orchestra warming up. On the contrary, sequences of Orch OR events would be akin to music, a symphony, jazz, Indian raga, or rock-and-roll classic. Such proposed Orch OR music, vibrations, and resonances in the fine-scale structure of the universe would be self-aware, not needing a listening audience.

However, the notion of functional quantum biology has been viewed skeptically. Technological quantum devices require extreme cold and isolation to avoid disruption by thermal decoherence, and so living systems have been considered too warm, wet, and noisy for functional quantum mechanisms. But plant photosynthesis uses quantum coherence in warm sunlight to produce chemical energy and food (Engel et al., 2007). Photons collected by plants are converted to electron resonance excitations (excitons), and transferred through a protein for conversion to chemical energy, propagating as quantum superposition of all possible pathways through a group of eight chromophores. These chromophores are comprised of nonpolar pi electron resonance clouds, geometrically arrayed nanometers apart, and coupled to coherent vibrations (see below). Buried in nonpolar, hydrophobic (water-aversive) regions, the chromophores constitute a quantum underground, shielded from decoherence, or premature OR via the polar, aqueous environment. Without quantum coherence, food would not be prevalent, and perhaps life could not exist at all.

Useful mechanisms are conserved in evolution. If a potato or asparagus can utilize quantum coherence, our brains, and specifically microtubules, might be expected to do so for cognition and consciousness.

The internal structure of microtubule protein subunits (tubulin) appears analogous to the quantum underground of pi resonance chromophores in plant photosynthesis. Computer models of tubulin structure show pi electron resonance clouds in aromatic amino acid rings of tryptophan, phenylalanine, and tyrosine in clusters and channels (Craddock et al., 2012a). Thus pi resonance regions in both photosynthesis proteins and tubulin in microtubules are buried and arrayed in a (dry) nonpolar solubility region shielded from (wet) polar interactions—a quantum underground. This particular solubility region is precisely where anesthetic gas molecules bind and selectively erase consciousness (the Meyer–Overton correlation—see below), and seems to be the origin of consciousness. Recent studies suggest anesthetics act by dampening terahertz (10^{12} Hz) quantum dipole oscillations in microtubule interiors (Pan et al., 2007; Emerson et al., 2013; Craddock et al., 2015), these rapid oscillations being the inner apex of a spatiotemporal hierarchy leading to electroencephalography (EEG; see Fig. 20.15).

According to Orch OR, quantum states and dipole oscillations in pi resonance clouds in a Meyer–Overton quantum underground within neuronal microtubules are orchestrated by synaptic inputs, memory, and vibrational resonance. This enables superpositions to avoid random, noncognitive interactions, and solely process purposeful and meaningful information. Thus when the $E_G = h/t$ threshold is met in orchestrated conditions, fully conscious Orch OR moments are said to occur, resonating with deeper level Platonic values in spacetime geometry. In pursuit of good feelings, Orch OR connects consciousness to the fine-scale structure of the universe. Over appropriate time scales, Orch OR events optimize pleasurable qualia.

On the biological side, Orch OR is fully consistent with known neuroscience, action of anesthetics and psychoactive drugs; generates testable predictions (some validated, none refuted); has medical and philosophical implications; provides mental states with causal power and intentional awareness; and surpasses other theories of consciousness in terms of evidence and testability. Similar to panpsychism, Orch OR implies that qualia, ie, feelings, preceded life.

It is suggested here that primitive protoconscious feelings occurred via Penrose OR in pi electron resonance clouds of micelle-like structures of dopamine-like molecules in nonpolar regions of the prebiotic primordial soup, the original quantum underground. OR-mediated feelings provided feedback and motivation for self-organizing pi resonance clouds (pi stacks) in the origin and evolution of life, and the brain. Intention and purpose optimized qualia. Life and the brain evolved to feel good.

CONSCIOUSNESS ON THE EDGE BETWEEN QUANTUM AND CLASSICAL WORLDS

In a broad sense, reality is described by two worlds: our familiar material (classical) world predictably follows the laws of Newton, Maxwell, and others. However, at small scales (and the size cutoff is unknown and seemingly variable), strange quantum laws reign. For example, quantum particles exist in multiple locations or states simultaneously, coexisting possibilities known as quantum superposition, represented by a quantum wave function. But we do not see quantum superpositions in our perceived world, reality somehow materializing from quantum possibilities, the wave function appearing to collapse to definite states. How and why this happens remain unknown, seemingly related to measurement and conscious observation, known as the measurement problem in quantum mechanics.

Another quantum feature is coherence, or condensation, in which quantum particles unify as single objects governed by one wave function, for example Bose-Einstein condensates. If any particle is perturbed, others feel it and react, prompting suggestions that quantum coherence supports binding and synchrony of mental and physiological events. A third quantum feature is nonlocal entanglement in which quantum particles remain connected when spatially separated, a bizarre prediction but conclusively demonstrated, and commonly utilized in quantum information technology. Entanglement may include temporal nonlocality, explaining backward time referral of subjective information in the brain, eg, Libet's et al. (1979) sensory experiments, enabling real time conscious control of our actions (Hameroff, 2012).

Why do not we see quantum superpositions in our consciously perceived world? This is the measurement problem, and interpretations include:

- The *conscious observer* (*Copenhagen interpretation*). Early quantum experiments seemed to indicate that if a machine measured a quantum system, the results remained in superposition until observed by a human. Proposed by Eugene Wigner, John von Neumann, and more recently Henry Stapp and David Chalmers, the conscious observer approach allowed Niels Bohr (whose Danish origin prompted the Copenhagen interpretation) and others to ignore questions related to the reality of superposition, and pragmatically perform quantum experiments.

But the Copenhagen interpretation led to paradox. Erwin Schrödinger considered implications of an unobserved superposition amplified to macroscopic scale in his still-famous thought experiment known as Schrödinger's cat. Imagine a cat in a box with a vial of poison. Release of the poison is coupled to the state of a quantum superposition. According to Copenhagen, Schrödinger noted, the cat would be both dead and alive until the box is opened and the cat observed by a conscious observer. Copenhagen associated consciousness with collapse, but cast it as a mysterious entity outside science.

- *Decoherence*. This approach suggests that any interaction of a quantum superposition with its classical environment, eg, by thermal interactions, degrades the quantum system. But decoherence does not address isolated superpositions, nor explain how quantum systems can ever be isolated. Moreover, some quantum processes are enhanced by environmental heat and/or noise.
- *Multiple worlds interpretation* (MWI; Everett, 1957). MWI claims each possibility in any superposition evolves without collapse, producing its own reality, resulting in an infinite number of parallel universes. Despite a lack of testability, MWI is extremely popular.
- *Objective reduction* (*OR*). These approaches suggest quantum superpositions evolve by the Schrödinger equation until reaching an objective threshold, at which collapse (reduction) occurs. Among these, Sir Roger Penrose (1989, 1994, 1996) described a specific OR threshold at which wave functions collapse, selecting classical states and producing quantized moments of protoconscious qualia.

Penrose began by addressing superposition—how particles can be in two or more places simultaneously—in terms of Einstein's general relativity in which matter is equivalent to spacetime curvature. That equivalence was famously verified at large scales (eg, distant starlight bending around the sun) by Sir Arthur Eddington in 1919, but Penrose applied it to microscopic scales, eg, tiny particles as tiny spacetime curvatures. Superpositions are then regions of alternate curvatures, separated spacetime (Fig. 20.1).

Spacetime separations would occur also in MWI, each curvature evolving its own universe (Fig. 20.2, left). But in Penrose OR, spacetime separations are unstable, and proposed to self-collapse, or undergo reduction by an objective

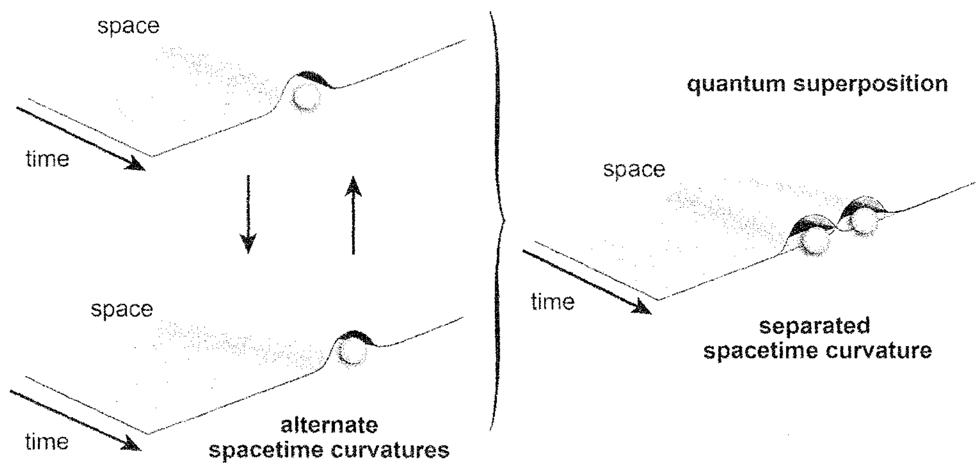

FIGURE 20.1 Spacetime geometry schematized as one spatial and one temporal dimension in which particle location is represented as curvature. (A) Top and bottom show spacetime histories of two alternative particle locations. (B) Quantum superposition of both particle locations as bifurcating spacetime depicted as the union (glued together version) of the two alternative histories. *Adapted from Penrose, R., 1989. The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics. Oxford University Press, Oxford, p. 338.*

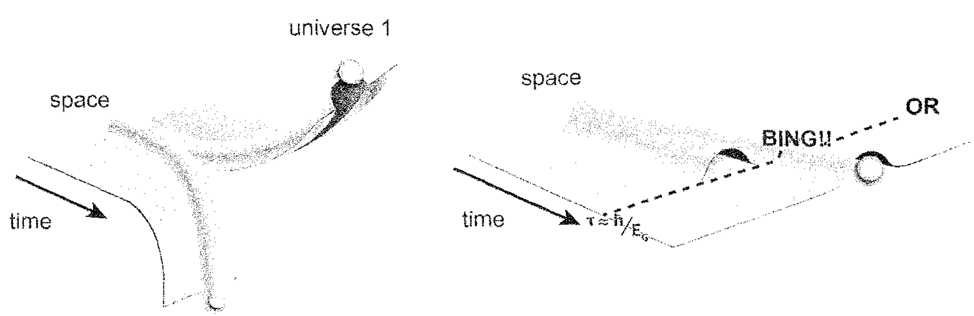

FIGURE 20.2 Two views of the fate of superpositions. Left: Each possibility evolves in its own universe, as per the multiple words interpretation (MWI). Right: Penrose objective reduction (OR); as superposition curvature E reaches threshold (by $E_G = \hbar/\tau$), OR occurs and one particle ceases to exist. The other location/curvature is selected, and becomes classical, accompanied by a moment of conscious experience (BING).

threshold given by $E_G = h/t$, a version of the uncertainty principle. E_G is the gravitational self-energy of the superposition (the energy required to separate a particle, or its equivalent spacetime geometry from itself by separation distance s), h is the Planck–Dirac constant, and t the time at which OR reduction will occur. Each OR self-collapse chooses classical states, and is accompanied by a quantized protoconscious experience—a quale. (A distinction between protoconscious OR moments and fully conscious Orch OR moments will be discussed later.) Thus, consciousness is seen as a process on the edge between quantum and classical worlds.

In the Copenhagen interpretation, postcollapse states selected by conscious observation are chosen randomly, probabilistically (the Born rule, after physicist Max Born). However in Penrose OR the choices (and quality of subjective experience) are influenced by—resonate with—what Penrose called noncomputable Platonic values embedded in the fine scale structure of spacetime geometry. These Platonic values, patterns, or vibrations in the makeup of the universe, may encode qualia, and pertain to mathematics, geometry, ethics, and aesthetics, and the 20 or so dimensionless constants governing the universe. These include the fine structure constant, the mass ratios for all fundamental particles, the gravitational constant and many more, all precise to many decimal points.

If these numbers were slightly different, life and consciousness—at least as we know them—would be impossible. As described in the Anthropic principle (AP), the universe is fine-tuned for consciousness and life. But how and why these key values are so precise are unknown, and approached by several versions of the AP. In strong AP (Barrow and Tipler, 1986), the universe is somehow compelled to harbor and enable consciousness. The weak AP (Carter, 1974) suggests there exist multiple universes, and that only this particular one harbors conscious beings able to ponder the question. The weak AP is often aligned with MWI or multiverse concepts.

Penrose OR avoids the need for MWI and supports strong AP, suggesting that over aeons, dimensionless constants defining the universe evolved and self-organized to optimize life, qualia, and consciousness. How could that have happened? What *is* life?

LIFE IN THE QUANTUM UNDERGROUND

Life has been described in two types of general approaches: functionalism and vitalism. Functionalism characterizes life by its behaviors, including (from Lynn Margulis Sagan, 1995) self-organization, homeostasis, metabolism, growth, adaption, response to stimuli, replication/reproduction, and evolution. Richard Dawkins (1989) focuses on self-replication as life's essential feature, but all these functions occur also in nonbiological computer programs, eg, as artificial life (eg, Langton, 1995), video games, and weather patterns.

Living systems seem to have some unitary quality, akin to oneness, often ascribed to an emergent property of functional processes, much like consciousness is often ascribed to emergence from complex brain computation. In both cases, however, mechanisms, or thresholds for such emergence, are unidentified.

On the other hand, 19th century vitalists saw a unifying energy field, or life force pervading living systems—élan vital. As molecular biology developed, reductionists pushed vitalism from favor, the notion of a life force becoming taboo. But 19th-century vitalism was based either on electromagnetism, or on forces outside science, as quantum mechanics had yet to be discovered. In his famous book *What is Life?*, Erwin Schrödinger (1935) suggested life's unitary oneness derived from quantum coherence in biomolecular lattices which were aperiodic crystals.

Others agreed. Nobel laureate Albert Szent-Gyorgyi (1960) saw the essence of life in coordinated submolecular quantum electron movements in nonpolar regions of biological systems. Russian physicists Phillipe and Albert Pullman (Pullman and Pullman, 1963) attributed life to quantum behavior of electrons in pi resonance clouds, and biophysicist Herbert Frohlich (1968, 1970, 1975) described the essential unifying feature of living systems as quantum coherent dipoles in nonpolar regions in geometrically constrained proteins (eg, membrane proteins and cytoskeleton).

How could quantum coherence relate to cognition and consciousness? The concept of a quantum computer was introduced by Richard Feynman (1986), Paul Benioff (1982), and David Deutsch (1985), who showed how superpositions, eg, of both 1 *and* 0 bit states could act as quantum bits, or qubits, entangle and collapse/reduce to classical bits of either 1 *or* 0. But technological qubits require isolation and extreme cold to avoid decoherence, thermal disruption of seemingly delicate quantum superpositions (or premature OR in the Penrose approach). Consequently, living systems have been considered too warm, wet, and noisy for functional quantum mechanisms. However, photosynthesis proteins utilize quantum coherence, and microtubules and their component protein tubulin have quantum resonances in terahertz, gigahertz, megahertz, and kilohertz at ambient temperatures (Sahu et al., 2013a,b, 2014). But how can quantum systems self-organize, avoid decoherence, and govern biology in a warm and seemingly chaotic microenvironment?

The answer may be found in a simple truth: oil and water do not mix.

Consider a solubility phase perspective on the makeup of biological organisms. Rather than viewing living creatures as composites of tissues, cells, molecules, and atoms, they may be viewed instead as sets of various solubility phases, ie, regions with different and distinct solvent characteristics, where particular molecules may bind and dissolve. Pharmacologists use solubility to determine where drugs bind in the body, an essential factor being degree of polarity, ie, how highly charged are the drug molecule (solute) and its environment (solvent).

Water, blood, and bodily fluids are polar solvents in which electrically charged solute molecules, eg, most drugs and hormones, bind and dissolve by hydrogen bonds and other polar interactions. In such microenvironments, quantum superpositioned charges will rapidly bind and entangle with others, increasing E_G to quickly reach OR threshold by $E_G = h/t$. OR events in such polar media, occurring ubiquitously, would be random, and accompanied merely by noncognitive, isolated moments of protoconscious experience (like dull, monotonous, and repetitious Whitehead occasions). Polar microenvironments are inhospitable to quantum superpositions.

However, the body and brain also include nonpolar, oil-like solubility phases, composed largely of benzene-like pi resonance clouds in aromatic rings which coalesce in nonpolar regions spatially segregated from polar ones (eg, oil and water do not mix!). Nonpolar groups bury themselves within protein, lipids, and nucleic acid molecules (eg, the pi stack in DNA), are friendly to quantum superpositions, and are the medium—the quantum underground—in which anesthetics specifically act to erase consciousness (see later in this chapter). Nonpolar regions are essential to organic chemistry, which starts with carbon.

Carbon atoms each have four electrons to bond with other atoms, eg, hydrogens and other carbons to form hydrocarbon chains called alkanes, with the general formula C_nH_{2n+2} where n is the number of carbons and length of the chain (Fig. 20.3). Carbons can also share two electrons, a double bond or pi resonance bond, and hydrocarbon chains with a single double bond are called alkenes, with the general formula C_nH_{2n}. Pi resonance implies a free electron (from carbon's outermost pi orbital) shared between carbon atoms, either oscillating between the two (molecular orbital theory), or delocalized, ie, in quantum superposition within a pi electron resonance cloud covering both carbons (resonance theory).

Nineteenth century chemists were puzzled by the structure of benzene, an oily, flammable hydrocarbon with the formula C_6H_6, fitting neither alkanes nor alkenes. Then the German chemist Kekule had a dream about snakes of varying lengths, which he later recognized as alkanes and alkenes. One longer snake in Kekule's dream swallowed its

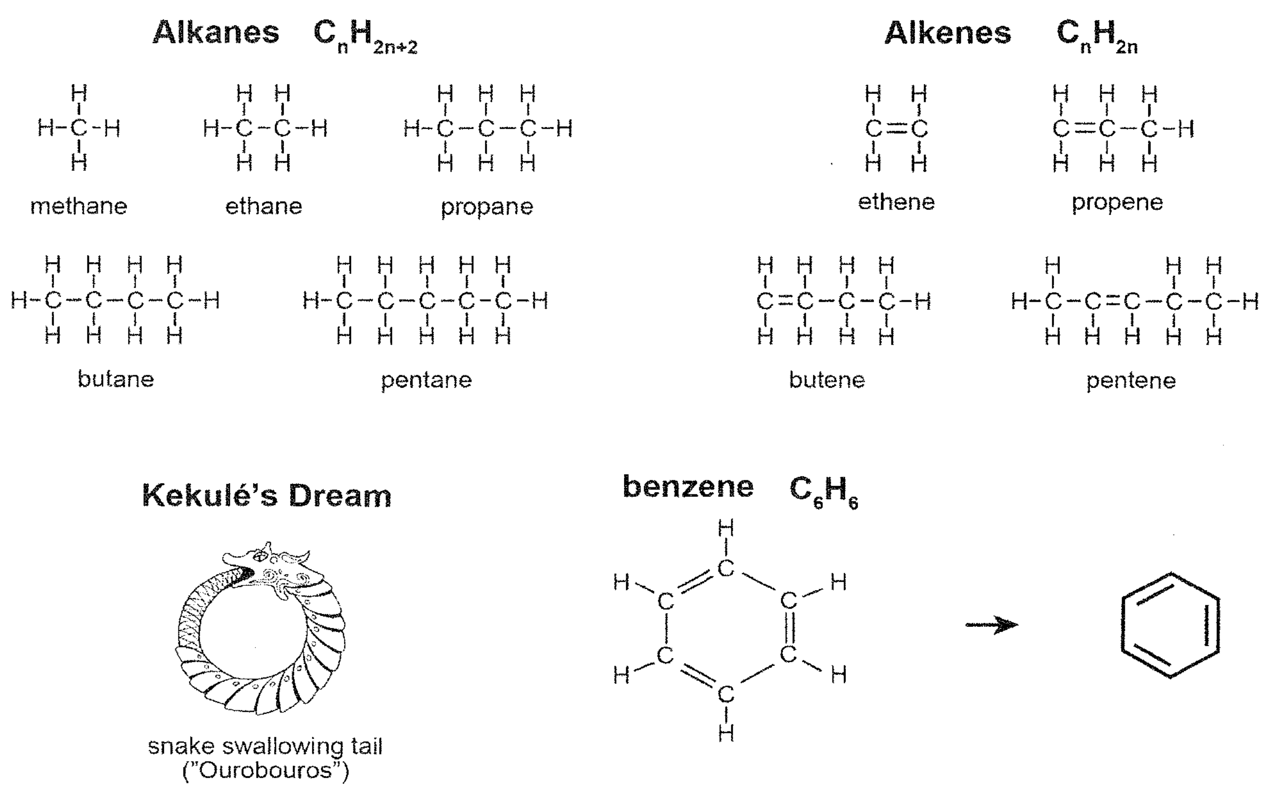

FIGURE 20.3 Carbon atoms can each form four covalent bonds, eg, with other carbons or hydrogens. Alkanes (top left) are a series of hydrocarbons with the general formula C_nH_{2n+2}. Alkenes (top right) are hydrocarbons with one carbon–carbon (pi resonance) double bond, and the general formula C_nH_{2n}. However, benzene had the formula C_6H_6 and was nonpolar and water-insoluble. Kekule's dream (lower left) suggested a ring structure which turned out to be correct with three carbon–carbon pi resonance double bonds. This is often represented as a hexagon with three extra bonds/lines (lower right).

tail, forming a ring (like the mythical Ouroboros). Kekule concluded it was benzene, C_6H_6, a hexagonal ring with three carbon–carbon pi electron resonance bonds.

Benzene's three pi resonance electrons are not confined to specific carbons, but delocalize and align in electron cloud dipoles which couple by van der Waals forces (or spin coupling), oscillate, and form superpositions (Fig. 20.4).

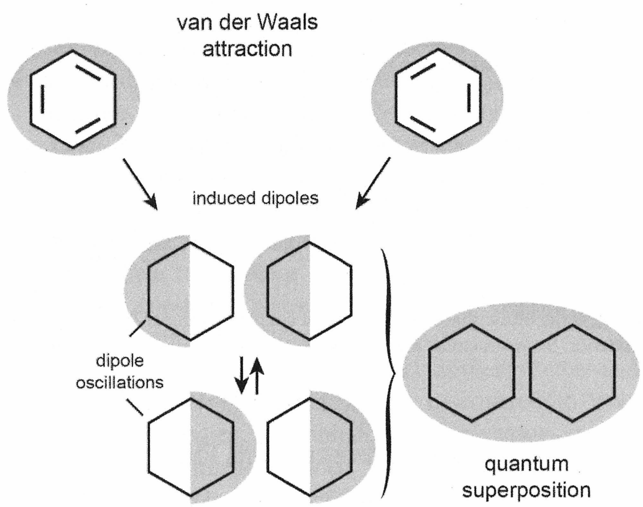

FIGURE 20.4 Electron resonance cloud dipoles of adjacent benzene (phenyl) rings can couple at precisely the proper separation distance (van der Waals radius), oscillate, and exist in superposition of both dipole orientations. Natural resonant frequencies for such rings are in terahertz (10^{12} Hz).

Pi resonance clouds are the basis for organic chemistry. Replacing hydrogens in benzene makes an attachable phenyl ring which, along with indole (6 + 5) rings are called aromatic because of generally sweet, pleasant smells. Adding one or more charged, polar ends to aromatic rings makes amphipathic biomolecules, nonpolar on one end, polar on another. They include aromatic amino acids phenylalanine, tyrosine and tryptophan, and psychoactive dopamine, serotonin,lysergic acid diethylamide, dimethyltryptamine, etc. (Fig. 20.5). When these bind to membrane receptors (or microtubules), nonpolar groups insert into nonpolar interior regions, and their charged, polar ends stick outward toward the exterior, forming a micelle structure. In bulk form, benzene is flammable and oily, but when geometrically constrained, eg, in flat sheets as graphene, or cylindrical fullerene nanotubes, pi electron resonance clouds couple in extended cooperative systems with interesting quantum properties (Figs. 20.6 and 20.7).

Though electrically neutral and nonpolar, pi electron resonance clouds are polarizable, and, when adjacent (at the angstrom-level van der Waals radius) attract and couple by induced quantum dipoles (van der Waals London forces, quadrupoles, magnetic dipoles). Such coupling is enhanced

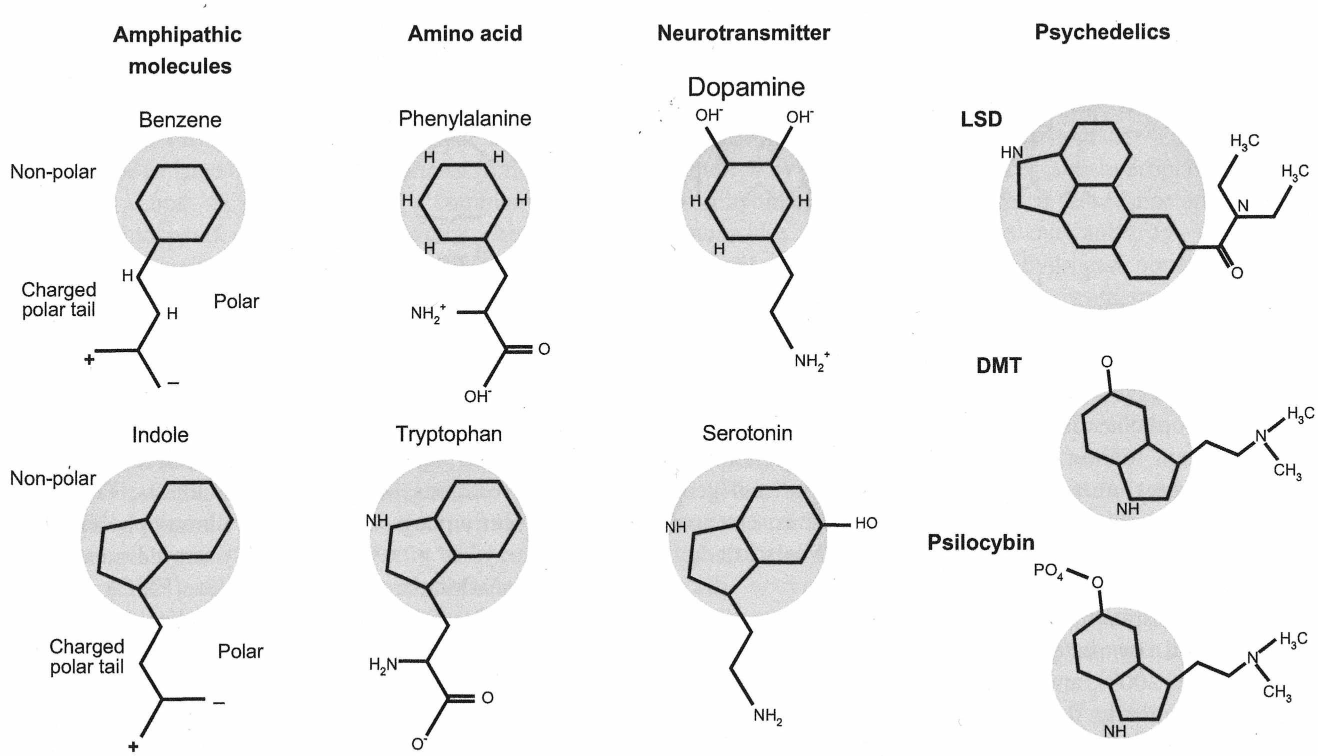

FIGURE 20.5 Amphipathic biomolecules have a nonpolar head composed of pi electron resonance clouds (gray) of phenyl (benzene) and indole aromatic rings, and tails with polar, charged ends. Virtually all psychoactive molecules are amphipathic including neurotransmitters and psychedelic drugs.

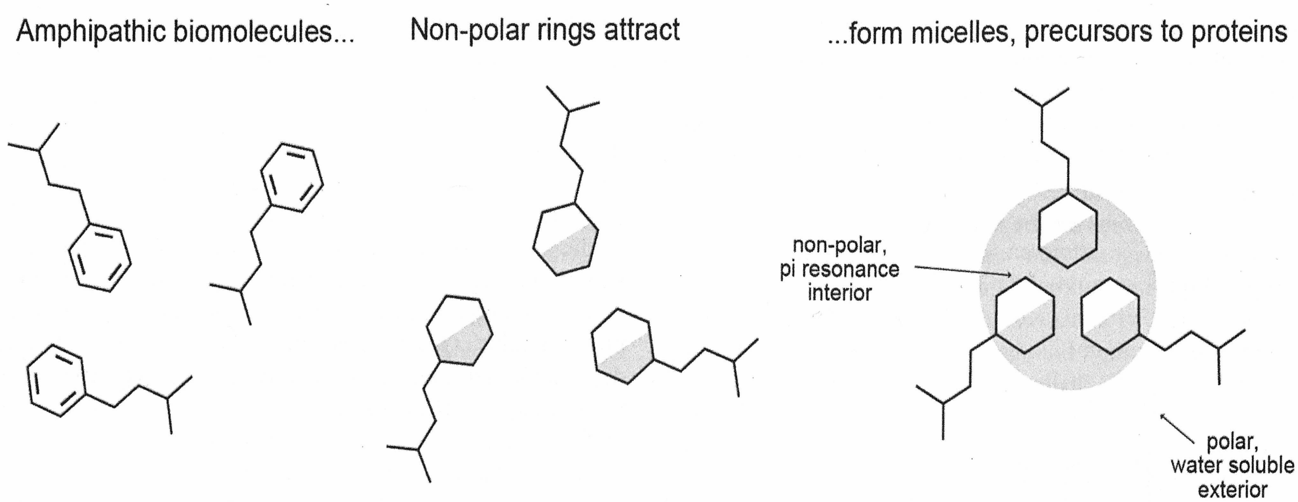

FIGURE 20.6 A simplified view of the origin of life. Amphipathic molecules (eg, in the primordial soup) attract and couple by van der Waals dipoles in a micelle (as suggested by Oparin) with a nonpolar interior and water-soluble exterior. Such structures are precursors to protein folding and formation of lipid membranes and nucleic acids (Fig. 20.7).

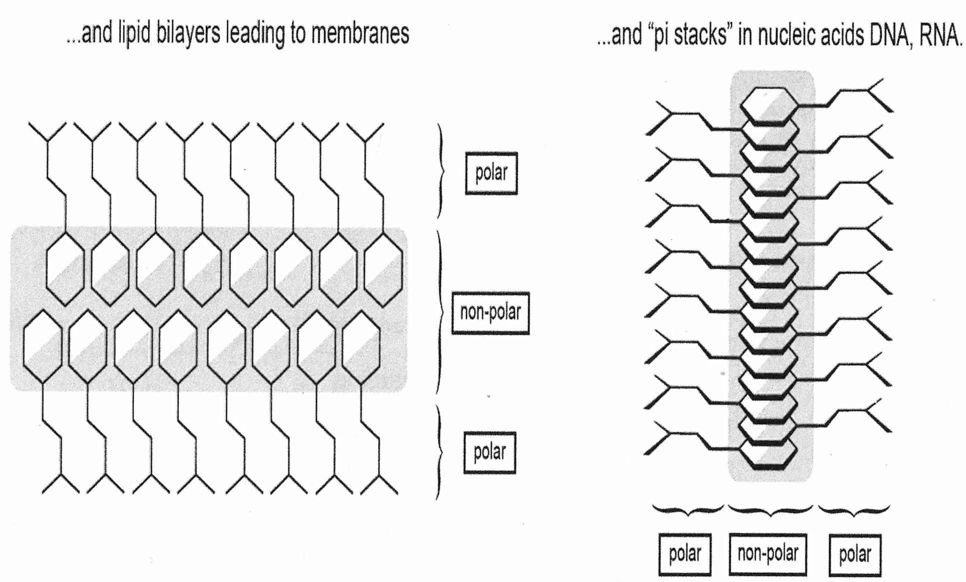

FIGURE 20.7 Amphipathic molecules form lipid bilayer (left) and nucleic acids DNA and RNA by similar mechanism, with nonpolar, water-excluding pi resonance quantum interiors, and polar, charged exteriors soluble in water.

by the hydrophobic effect (oil and water do not mix), which drives protein folding and results in pi stacking in which resonance rings are arrayed at specific spacings and geometric orientations. At the van der Waals radius, electron clouds can couple and oscillate by van der Waals London forces and excitons.

Quantum spin transfer through pi resonance clouds is enhanced by increased temperature (Ouyang and Awschalom, 2003), and pi resonance clouds are optically active and able to fluoresce, ie, absorb photons which induce excited electron states, and then emit lower energy photons when the excited states drop to lower states. This quantum-level energy can also be efficiently transferred nonradiatively between excited resonance clouds separated by up to 2 nm by Förster resonance electron transfer (FRET), or excitons. In plant photosynthesis, FRET-like excitons occur among seven or eight chromophores (more complex arrays of pi resonance rings) arrayed nanometers apart in Fenna-Matthews-Olson complex (FMO) proteins. Photons from the sun are collected in an adjacent molecule, converted to electronic energy, and transferred through FMO to a third molecule for conversion to chemical energy and food. The electronic energy transfer occurs through all chromophores simultaneously—a quantum superposition resulting in optimal efficiency. Life on earth depends on quantum coherence in photosynthesis proteins.

Tubulin proteins comprising microtubules (discussed later in Section: Microtubules and Sex in the Primordial Soup) each have eight tryptophan indole rings arrayed in a geometry strikingly similar to that in FMO photosynthesis proteins. Using molecular modeling, Craddock et al. (2014, 2015) showed FRET-like excitons passing through tubulin among eight tryptophan pi resonance clouds, driven by ambient energy, and blocked by anesthetics which bind naturally in nonpolar regions.

Interiors of DNA and membranes have similar arrays and stacks of pi resonance clouds and nonpolar regions. Taken together, a quantum-friendly, nonpolar solubility phase of pi electron resonance—a quantum underground—is shielded inside biomolecules, distributed throughout living systems, and hospitable to quantum superposition. Compelling evidence from anesthesia research directly links consciousness to this quantum underground.

In the mid-19th century, gases, such as diethyl ether and nitrous oxide ("laughing gas") were discovered to have anesthetic properties, ie, inhaling these gases caused humans and animals to lose consciousness, or some observable correlate, eg, mice falling over, or salamanders not moving in response to stimulation. When the anesthetic gas was exhaled away, the subjects and animals woke up, snapping back to consciousness, essentially unchanged. Potencies were determined for each anesthetic, ie, the gas concentration at which half of a group of mice, or salamanders, will roll over, and half remain upright. Amazingly, each gas acted at the same concentration in all animals, identical concentrations anesthetizing a mouse, salamander, or human. By the turn of the 20th century, dozens of anesthetic gases had been discovered, curiously with various different types of chemical structures, eg, ethers, halogenated hydrocarbons, nitrous oxide, and the inert gas xenon. Scientists sought a common molecular property, independent of structure, which correlated with anesthetic potency. The answer was solubility in an oil-like, nonpolar solubility region, in a quantum underground of pi resonance clouds.

Working separately, Hans Meyer (1901) and Ernst Overton (1901) ranked anesthetic potency for many anesthetics in various animal models, and tested anesthetic solubility in different types of solvents, each finding the same result. Over many orders of magnitude, among many chemically disparate structures, potency of all anesthetics for all animals correlated near perfectly with their solubility in a particular nonpolar medium, characterized by a low Hildebrand coefficient lambda (15.2−19.3 SI Units), closely resembling olive oil and benzene (Hameroff, 2006). The Meyer–Overton correlation shows that anesthetics act (by quantum London dipole dispersion forces), in nonpolar regions involving pi electron resonance clouds. As anesthesia is fairly selective (eg, sparing nonconscious brain activities which continue during anesthesia), consciousness apparently originates in pi resonance cloud regions in the quantum underground.

If so, the environment-hosting consciousness—the Meyer–Overton quantum underground—may have hosted the origin of life.

A general consensus is that life on earth began in a prebiotic primordial soup, proposed independently in the 1920s by the Russian biologist Alexander Oparin and British geneticist J.B.S. Haldane. The soup refers to a simmering mix from which life's biomolecular building blocks could have emerged three to four billion years ago, the requirements being an oxygen-poor atmosphere (now known to have been the case at that time), sea water, an energy source (eg, sunlight, heat, radiation, thermal vents, lightning), and necessary chemical components. In a famous experiment in the 1950s, chemistry graduate student Stanley Miller and his professor Harold Urey (Miller and Urey, 1959) simulated the primordial soup with methane, ammonia, hydrogen, and electric sparks for lightning. They found amphipathic molecules having both polar and nonpolar components, including pi resonance rings. These were apparently the seeds of life. But then what happened?

Richard Dawkins (1986, 1989) suggests molecular self-replicators carried life until genes and evolution were in place (cf, Dennett, 1995). RNA molecules, with stacks of nonpolar pi resonance clouds as central cores, may have acted as self-replicators. But if so, how and why did amphipathic replicators become functional and interactive?

Oparin had suggested amphipathic molecules formed micelles in which nonpolar parts of the molecules, eg, aromatic pi resonance rings, stick together in the micelle interior by van der Waals forces and hydrophobic effects (oil avoiding water). Polar ends of these same amphipathic molecules would then radiate outward from the central nonpolar confluence, forming hydrogen bonds with surrounding water. This process can result in water-soluble, spheroidal micelles, precursors to proteins and nucleic acids which are non-polar on the inside, and polar on the outside (Figs. 20.6–20.9). Oparin suggested micelles gained functions and began to organize, evolve, and function as protocells. But why would they?

Micelles have self-organized in laboratory experiments and are considered by some to be primitive forms of artificial life (Rasmussen, 2010). In some cases, optically active components are included in the nonpolar (quantum-friendly) interior (Rasmussen, 2010; Tamulis and Grigalavicius, 2014), enabling quantum entanglement between adjacent micelles.

Electric and magnetic dipoles of pi resonance clouds oscillate in terahertz (10^{12} Hz) in the infrared region of the optical spectrum. As the earth cooled, terahertz radiation in thermal noise could have driven pi stack oscillations in

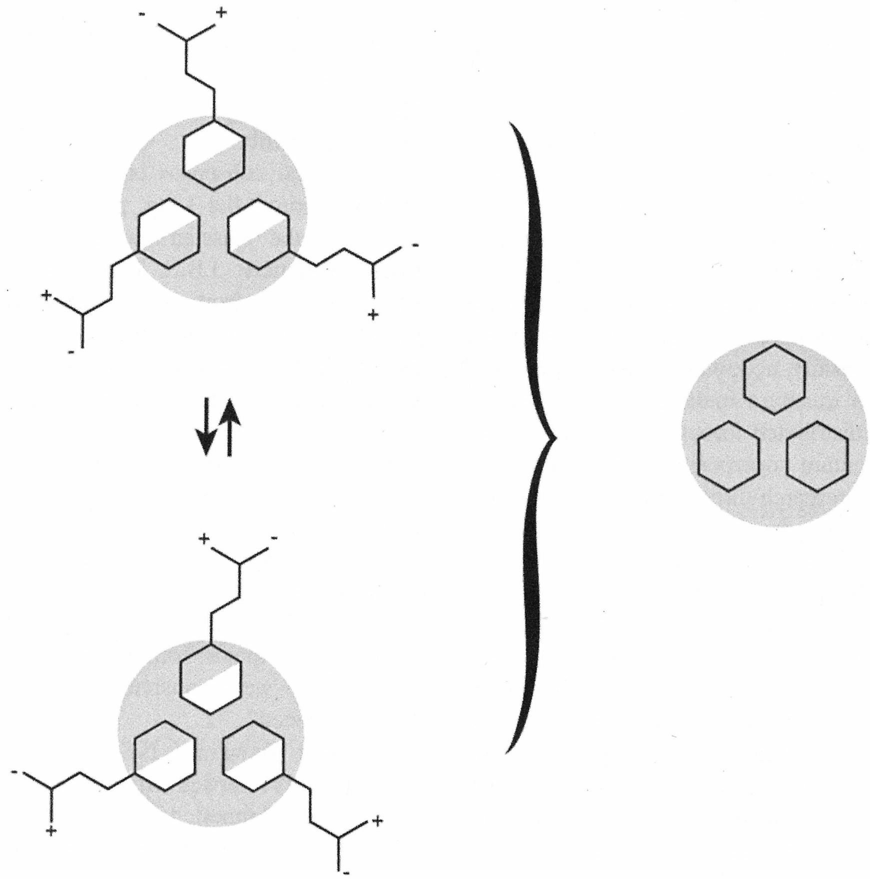

FIGURE 20.8 Simplified micelle qubit (only three amphipathic molecules are shown as opposed to hundreds or thousands). Left: Dipoles in nonpolar interior of Oparin micelle oscillate, eg, in terahertz. Right: Dipoles exist in quantum superposition of both possible states. Taken together the micelle is proposed to function as a quantum bit, or qubit.

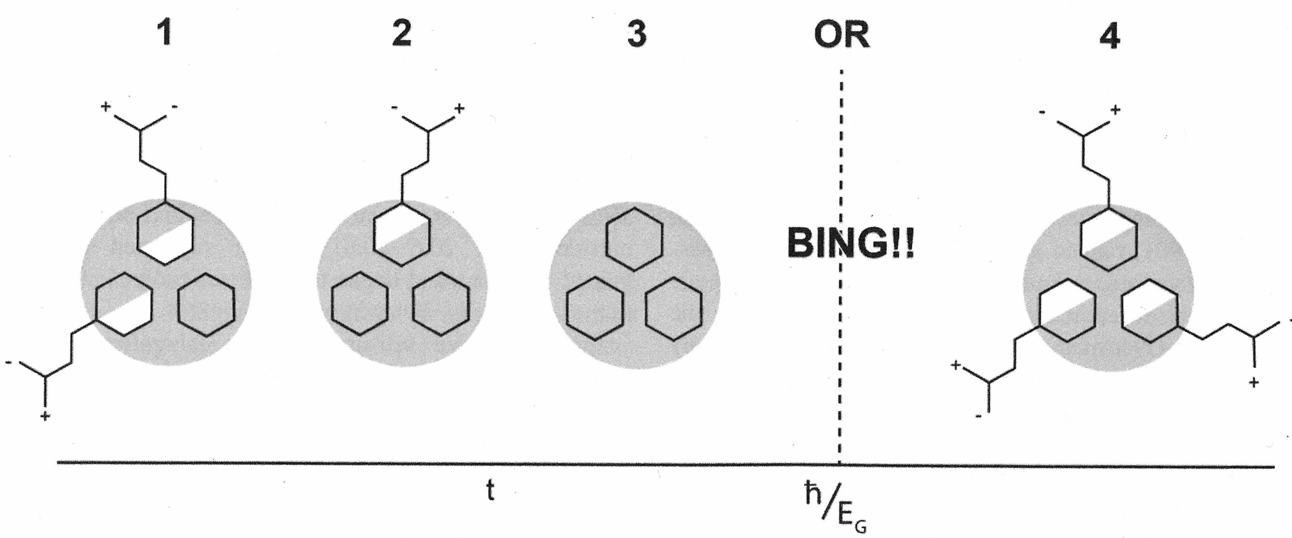

FIGURE 20.9 A simplified version of a protoconscious OR moment in the primordial soup. Three amphipathic molecules coalesce by nonpolar van der Waals attractions (polar tails disengage) and entangle in superposition to reach threshold for OR self-collapse at time $t = h/E_G$. A quale, protoconscious moment, or primitive feeling (BING) occurs. However, simple micelles as depicted here would rapidly entangle with the polar environment and undergo OR/decoherence to result in protoconscious moments with random qualia lacking cognition or meaning. Much larger micelles, eg, with many more pi resonance clouds forming a protected quantum underground would be required.

primitive micelles which became essential features of life. Vattay et al. (2015) have shown that pi resonance clouds are arrayed at precisely critical distances from each other in proteins to be at the edge between quantum and classical behaviors, ie, the separation distance at which mechanical vibrations can bring the groups into, and out of, quantum coherent superposition. Graphene (a planar layer of pi resonance rings) acts as a terahertz antenna, transferring up to 100 terabits per second. But the question remains why micelles or other structures based on pi resonance clouds with quantum properties would purposefully self-organize. There were no genes, no mutation-based evolution, no reward, no feedback, no creatures to survive. What was the motivation, the fitness function toward which life evolved? Was there a spark of life? If so, what could it be? A possible, logical answer is feelings, eg, pleasurable qualia occurring by Penrose OR.

Superpositions with electric charge in a polar, aqueous medium, eg, on micelle exteriors, would rapidly entangle by charge interactions to reach OR threshold with strictly random inputs. Such OR events would culminate in fleeting, noncognitive, protoconscious moments—quantum noise, in a musical metaphor. However, in nonpolar confluences of pi electron resonance clouds, shielded and precisely arrayed in the quantum underground, superpositioned dipoles could entangle collectively, oscillate coherently, and couple to biomolecular mechanical resonances—a coherent dance of quantum dipoles.

Superposition and coherence of just a few pi stack rings (small E_G) would require a long time t to reach threshold (by $t = E_G/h$). Polar interactions would likely intervene to contribute randomness, resulting in partially coherent moments of protoconscious experience (Fig. 20.9). With larger pi stacks protected in nonpolar quantum underground interiors of biomolecules and micelle-like structures, resonance with Platonic vibrations in spacetime geometry could occur so that associated protoconscious qualia would begin to have primitive feelings and emotions. The intensity and quality of such feelings, eg, pleasure, would depend on particular geometry of the pi stack (Fig. 20.9).

From Epicurus in ancient Greece to Freud's pleasure principle, and more recently Panksepp, Peil, and Damasio, feelings and emotions are considered primary in human and animal awareness and behavior, exemplified by dopaminergic reward pathways. But the essential nature of emotions, their subjective feel, remains a mystery. Why do good feelings feel good? Plato believed value, meaning, and pleasure to reside in the "form of the good," implying inherent geometry. Penrose attributed Platonic forms and values to fundamental spacetime geometry, extending to the Planck scale. Biology is based on organic chemistry, in turn based on pi electron resonance clouds of phenyl, or benzene rings. Dopamine, the pleasure molecule, is a prototypical amphipathic pi resonance phenyl ring molecule, presumably present in the primordial soup. Perhaps OR events, in particular pi resonance geometries, resonate more deeply with Plato's form of the good; encoded as vibrations in the structure of the universe, these events having feelings of greater pleasure. Such positive qualia—"good vibrations"—could have been the feedback fitness function by which life developed, with natural selection and survival of the fittest serving to optimize feelings. Feeling good by pleasurable OR could have been the spark of life by resonating with Platonic values embedded in the structure of the universe. Did biology then evolve to orchestrate OR, to turn quantum noise into conscious music, to "strike up the band?" To feel good? How could that have happened?

OR is naturally causal, choosing among different possibilities, a requisite for intentional purpose. In a nonpolar environment (the quantum underground) adjacent pi resonance rings, attracted by van der Waals London force dipoles and quadrupoles tend to align in one of two stable orientations, separated by the van der Waals radius. The two stable orientations are the "T," in which one ring hangs perpendicular from the middle of the second ring, and the offset parallel (OP) orientation, in which two rings are parallel in one plane, and offset.

OR events from various configurations would result in specific superpositions of pi resonance clouds and particular rudimentary mental experiences. Thus, arrangements of pi stack orientations can be a code for qualia. Adjacent pi resonance rings may be arrayed as T or P, so a stack of three rings would have four possible arrangements, P—P, T—T, T—P, and P—T. When superposition and OR results by $E_G = h/t$ among these rings, particular qualia (eg, good, bad) would occur. For example, P—P might have pleasurable feelings, and T—T unpleasurable ones. With causal effects of OR outcomes influenced by feedback, three-dimensional pi stacks could then rearrange in orientation sequences (including helical, branching, and different ring types) to optimize and orchestrate OR-mediated feelings and qualia. Over time and replication cycles, recurrent feedback could optimize pi stack geometry for pleasurable conscious feelings whose particular pi-stack orientations would best resonate with Platonic values in spacetime geometry.

Micelle-like structures, RNA, membranes, and other structures in the primordial soup could self-organize their pi stacks to optimize OR qualia. But pleasure, and ability to causally affect the physical world to further increase pleasure, would soon become limited. Better organization, memory, motility, communication, and reproduction were required to feel even better. Self-assembling intelligent polymers were the answer.

Enter microtubules.

MICROTUBULES AND SEX IN THE PRIMORDIAL SOUP

Interiors of all animal cells are organized and shaped by the cytoskeleton, a dynamic scaffolding of protein lattice polymers. These self-organizing structures include microtubules, microtubule-associated proteins (MAPs), actin, and intermediate filaments, all anchored by the centriole, a pair of microtubule-based mega-cylinders in the cell center (centrosome), just outside the nucleus. Plant cells also have microtubules and centrioles, and prokaryotes and archaebacteria have similar, but slightly different protein structures. All living cells are organized by microtubules or closely related structures.

Microtubules (MTs) are cylindrical polymers 25 nm (nm $= 10^{-9}$ m) in diameter, comprised usually of 13 longitudinal protofilaments, each a chain of the protein dimer tubulin. Composed of alpha and beta monomers with net dipoles, tubulins give microtubules net dipoles. Tubulins self-assemble and arrange in MTs in two types of twisted hexagonal lattices (A-lattice and B-lattice) such that helical pathways along contiguous tubulins in the A-lattice repeat every three, five, and eight rows on any protofilament (the Fibonacci series). Within microtubules, each tubulin may differ from its neighbors by genetic variability, posttranslational modifications, phosphorylation states, binding of ligands, and MAPs, and transient dipole orientation (Hameroff, 1987; Garham et al., 2015). With many tubulins per cell, eg, 10^9 tubulins per neuron, information capacity in a mosaic-like MT is enormous. Epigenetic information is encoded in microtubule-based centrioles (Balestra et al., 2015).

Due to their organizational roles, lattice structure and coherent dynamics, microtubules have been suggested to actively process information since Sherrington (1951) described them as the cell's nervous system. Descriptions of MTs as computer-like devices (Hameroff and Watt, 1982; Hameroff, 1987; Rasmussen et al., 1990) viewed individual tubulins as bit-like information units in Boolean switching matrices, or cellular (molecular) automata played on microtubule lattices. Simulation of tubulin dipoles interacting with neighbor dipoles and synchronized by Fröhlich coherence showed rapid information integration and learning (microtubule automata; Smith et al., 1984; Rasmussen et al., 1990; Fig. 20.10).

Microtubules in neurons seemed particularly suited for memory and some form of computation. In cell division (mitosis), MTs disassemble and then reassemble as mitotic spindles, anchored by centrioles, which separate chromosomes, establish daughter cell polarity, and rearrange for cellular structure and function. However, neurons do not divide once they are formed, and so neuronal microtubules can remain assembled, providing a stable medium for memory encoding.

Microtubules in neuronal soma and dendrites are unique in other ways. In axons, and all nonneuronal cells throughout biology, microtubules are arrayed radially, like spokes in a wheel, extending continuously from the hub-like centriole outward toward the cell membrane, all with the same polarity. However, microtubules in dendrites and cell bodies/soma are short, interrupted and arrayed in mixed polarity networks interconnected by MAPs, and stabilized by MAP-capping proteins. Interrupted dendritic-somatic microtubules are poorly suited for structural support, but ideal for memory encoding and information processing (Rasmussen et al., 1990).

The standard explanation for memory encoding in neuroscience is synaptic plasticity, ie, sensitivities at particular synapses guiding activity through neuronal networks. However, synaptic proteins are transient and

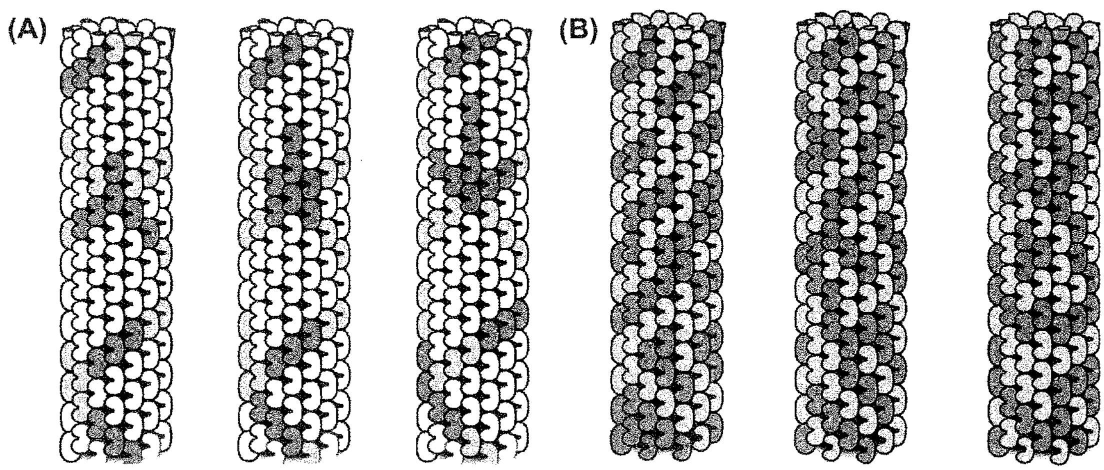

FIGURE 20.10 Three time-steps (eg, at 10 MHz) of a microtubule automaton which is classical. Tubulin subunit dipole states (light gray, dark gray) represent information. (A) Spin currents interact and compute along spiral lattice pathways. For example (upper, middle in each microtubule) two upward-traveling spin waves intersect, generating a new vertical spin wave (a "glider gun" in cellular automata). (B) A general microtubule automata process. *With permission from Hameroff, S., Penrose, R., 2014a. Consciousness in the universe: a review of the 'Orch OR' theory. Physics of Life Reviews 11 (1), 39–79.*

recycled over hours to days, and yet memories can last lifetimes. Craddock et al. (2012b) showed how synaptic information in the form of calcium ion influx activates the hexagonal enzyme calcium-calmodulin-kinase II (CaMKII), which can then encode up to 6 bits of information on microtubules by phosphorylation (Fig. 20.11).

Synaptic proteins are synthesized in neuronal cell bodies/soma, and transported to synapses by dynein and kinesin motor proteins traveling along microtubule tracks. In interrupted dendritic-somatic microtubules, motor proteins must jump from microtubule to microtubule, and choose particular pathways at synaptic branch points to deliver synaptic cargo. Delivery is guided by specific placement of tau on microtubule lattices as "traffic signals" or address code (Dixit et al., 2008), getting the right cargo to specific synapses, serving memory and cognition. Displacement of tau from microtubules results in neurofibrillary tangles, microtubule instability, and the cognitive dysfunction in Alzheimer's disease. CaMKII may encode tau binding on microtubule lattices following synaptic calcium influx (Craddock et al., 2012b). Dendritic-somatic microtubules are likely and convenient sites for memory encoding, cognition, and consciousness.

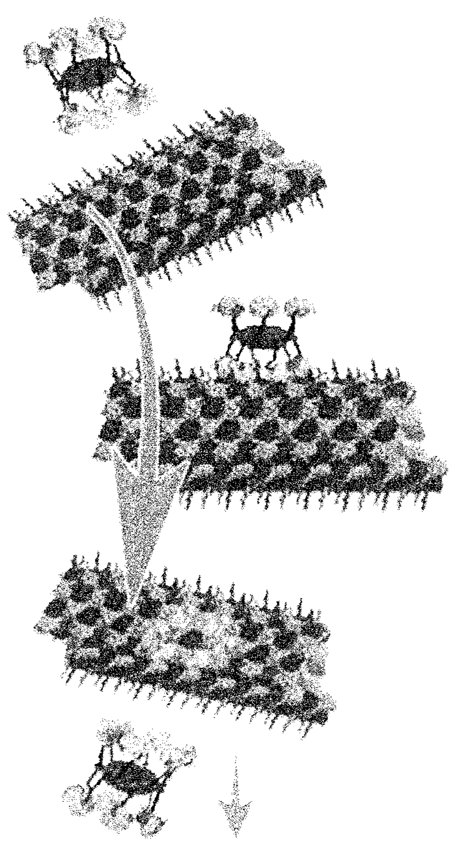

FIGURE 20.11 Calcium-calmodulin-kinase II (CaMKII), a hexagonal holoenzyme activated by synaptic calcium influx extends six leg-like kinase domains above and below an association domain. The six kinase domains precisely match hexagonal size and geometry in both A-lattice and B-lattice microtubules. *With permission from Travis.*

Microtubule-based processing implies a huge increase in cellular and brain-wide information capacity. For example, artificial intelligence (AI) proponents (including advocates of the Singularity) aim to emulate the brain in computers, and estimate brain capacity as 10^{11} neurons, each with 10^3 synaptic connections firing, or being excited up to 100 times per second (10^2 Hz), giving a capacity of 10^{16} operations per second for the brain. But inside each of those neurons are microtubules with 10^9 tubulins/neuron capable of switching at 10^7 Hz (Sahu et al., 2013a,b, 2014), for 10^{16} operations per second per *neuron*, and 10^{27} ops/s for the brain. Microtubule information processing would push the AI/Singularity goal for brain equivalence in computers far into the future, and can account for memory. But increased capacity per se does not address the hard problem of consciousness, of subjective feelings, of qualia. The only specific scientific mechanisms for qualia, feelings, and subjective conscious experience which has ever been proposed is Penrose OR.

In the mid-1990s, Sir Roger Penrose and I began to suggest that microtubules could act as quantum computers whose superpositioned qubits would halt, or terminate to classical states by quantum state reduction—"collapse of the wave function," according to Penrose OR. Such events would have cognitive representation and meaning by virtue of microtubule information processing, unify or bind percepts by entanglement, and have phenomenal experience, or qualia, at each moment of OR. Through information processing, memory, and natural resonances, brain microtubules would orchestrate OR events into full, rich conscious moments (Orch OR). Metaphorically, random, meaningless OR notes, sounds, and noise qualia become meaningful music.

The qubit for Orch OR microtubule quantum computing was originally suggested to utilize superposition of alternate states of individual tubulins, interacting with surrounding neighboring tubulins in hexagonal cellular automata. When the atomic structure of tubulin became known through crystallography in 1998 (Nogales et al., 1998), clusters and channels of pi electron resonance clouds of aromatic amino acids became apparent (Fig. 20.12). Quantum transfer of electronic excitations and dipole resonance among arrays of pi resonance clouds were proposed to occur within tubulin, and also between and among neighboring tubulins in helical pathways in microtubule lattices, eg, the five-start and eight-start helices of the Fibonacci sequences in microtubule A-lattices. Accordingly, net dipole orientations along helical pathways were proposed to act as Orch OR qubits, along the lines of topological quantum computing.

The Orch OR proposal in the mid-1990s prompted skeptical criticism, largely based on decoherence, the notion that thermal vibrations would disrupt seemingly delicate quantum processes. Laboratory efforts to build

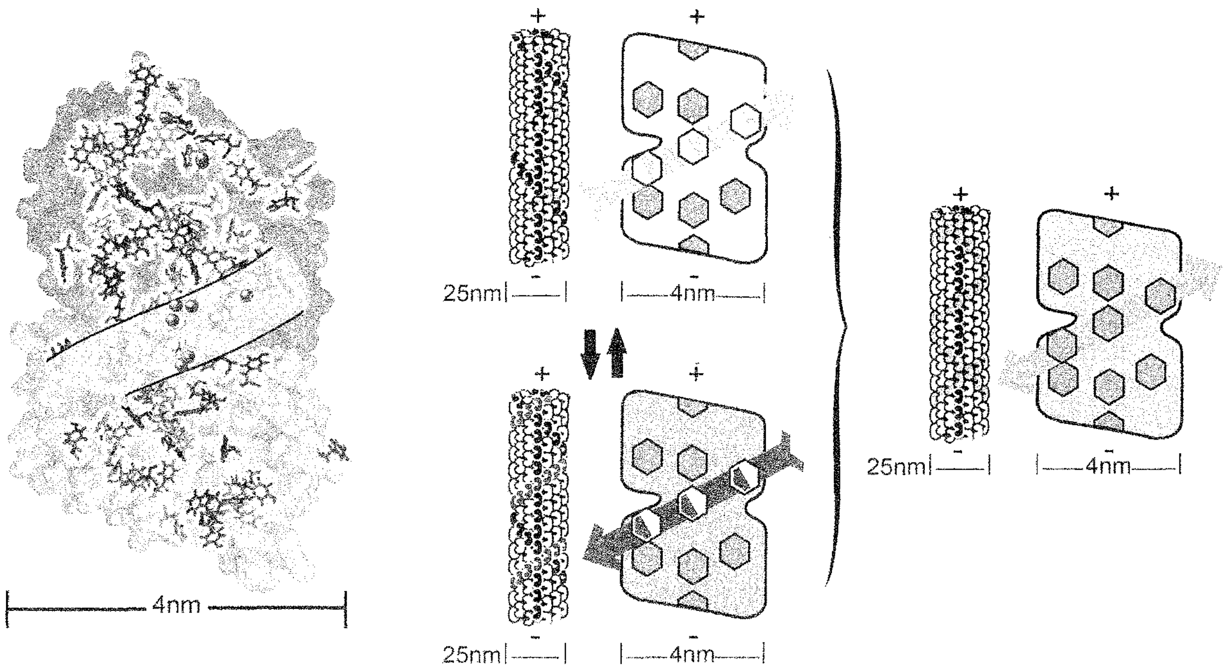

FIGURE 20.12 At left is the protein tubulin showing aromatic amino acid pi resonance clouds (tryptophan, phenlylalanine, tyrosine) and sites of binding of anesthetic halothane (spheres). Band indicates nonpolar cluster of aromatic rings (quantum channel or quantum underground) with anesthetic binding sites aligned along five-start helix in microtubule lattice. Right: Dipole qubit in microtubule in Orch OR theory, with quantum dipole states oscillating, and forming quantum superposition of alternate states along five-start helical pathway in tubulin and microtubules. Dipoles may be electric or magnetic, eg, related to electronic (and/or nuclear) spin. Similar qubit pathways may occur along eight-start pathways or other pathways.

quantum computers were conducted near absolute zero temperature, and the brain (and biology in general) were considered too warm, wet, and noisy. However, beginning in 2007 (Engel et al., 2007), quantum coherence in plant photosynthesis at ambient temperatures was discovered, and found to depend on nonpolar (ie, dry, not wet) pi resonance groups, and coupling to coherent mechanical vibrations. As suggested by Frohlich (1968, 1970, 1975), thermal vibrations pumped the quantum coherent states, rather than disrupted them. Subsequently, Anirban Bandyopadhyay's group (Sahu et al., 2013a,b, 2014) found resonances in individual microtubules, and bundles of microtubules in self-similar patterns occurring every two to three orders of magnitude in terahertz, gigahertz, megahertz, and kilohertz frequency ranges (Fig. 20.13). Conductances in microtubules at these frequencies were determined to be quantum in nature because conductances through entire microtubules were greater (resistances lower) than through individual tubulin proteins. A picture emerges of microtubules as multiscalar biological quantum resonators.

The evolution of tubulin and microtubules is puzzling. Why would tubulin, a single protein, evolve as a cog in a machine, one brick in a skyscraper yet to be realized? According to conventional evolutionary theory, the feedback fitness function for tubulin would depend on higher order microtubule activities not yet present. Proponents of intelligent design cite microtubules and their composites cilia and centrioles as structures which are difficult to explain through natural selection. They may have a valid objection, but lack a scientific alternative.

How *did* tubulin and microtubules (or their prokaryotic and archaebacteria counterpart proteins) evolve? Consider a possible scenario in the primordial soup. Pumped by ambient terahertz radiation, pi resonance rings on amphipathic molecules coalesced, coupled, and oscillated in nonpolar micelle interiors. Van der Waals forces provided separation between rings at quantum critical distances (Vattay et al., 2015). As micelles incorporated more pi resonance clouds (eg, clusters of three or four rings), entangled quantum superpositions extended in an expanding quantum underground. The resultant increasing "E_G" in each $E_G = h/t$ OR event became, with feedback and developing over time, more purely coherent so that subjective protoconscious OR qualia became more cognitive and intense, good or bad. Good feelings ensued from more energetically favorable pi stack geometry which resonated with Platonic values.

Here is a possible scenario. As the number of coupled coherent rings and E_G grew, intensity and quality of good feelings also grew, providing feedback to pi stack geometry, eg, flipping T and OP configurations within each micelle's quantum underground, optimizing qualia and experience.

Rudimentary mental states exerted causal power, arranging pi resonance clouds within micelles which became

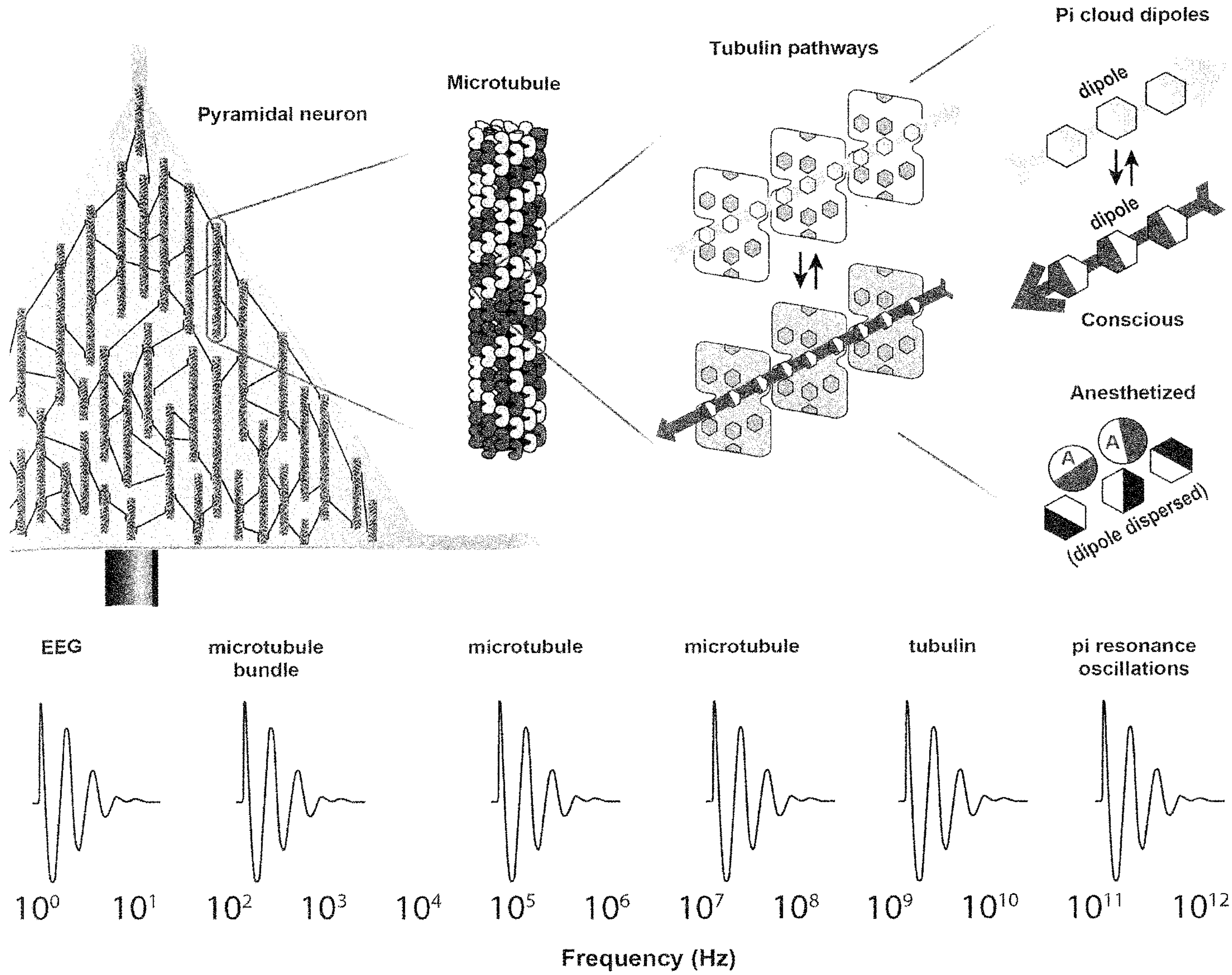

FIGURE 20.13 Brain multiscalar hierarchy. Top row shows structure (left to right) pyramidal neuron cell body with interior microtubules, a single microtubule, tubulin pathways through pi resonance clouds along which dipole oscillations, resonance transfers, and/or spin currents occur (top) pi cloud dipole oscillations (bottom) anesthetics dispersing dipoles. (Bottom) Dynamics at frequency ranges matching structure in top row (Sahu et al., 2013a,b, 2014, Craddock et al., 2015).

proteins, membranes, and nucleic acids. With repetitive feedback, clusters of pi resonance clouds optimized their geometry for pleasurable qualia as particular sequences of T and OP arrangements, coupling with other clusters by FRET and excitons, and absorbing and resonating with ambient terahertz, ultraviolet and cosmic microwave radiation. This all served to further optimize OR-mediated pleasure by pi cloud geometry.

But then what happened? Tubulins aligned by charge interactions and entropy, forming lattice patches with pi resonance clouds extending from one tubulin to its neighbor, increasing OR-mediated pleasure. Cooperative information exchange developed a logic based on hexagonal geometry of tubulin patches which rolled into cylinders, stabilized by ultra-violet absorption and megahertz mechanical resonances, reinforcing pi stack coherence, developing a hexagonal-based information code, ramping up OR pleasure even more. The microtubule was born.

Neighboring microtubules became interconnected by MAPs forming networks of coupled resonators. Coherent lattice vibrations enabled stable quantum coherence, as Fröhlich predicted in the 1970s. Mixed polarity networks were most conducive to cooperative resonance, leading to orchestrated OR events, interference beats, and faster, richer, and more intense moments of conscious experience. At much higher frequencies and smaller scale, these processes connect to fundamental spacetime geometry (Fig. 20.14).

Microtubules fused into doublets and triplets, further ramping up OR pleasure. These then aligned into mega-cylinders of nine doublets/triplets called cilia, centrioles,

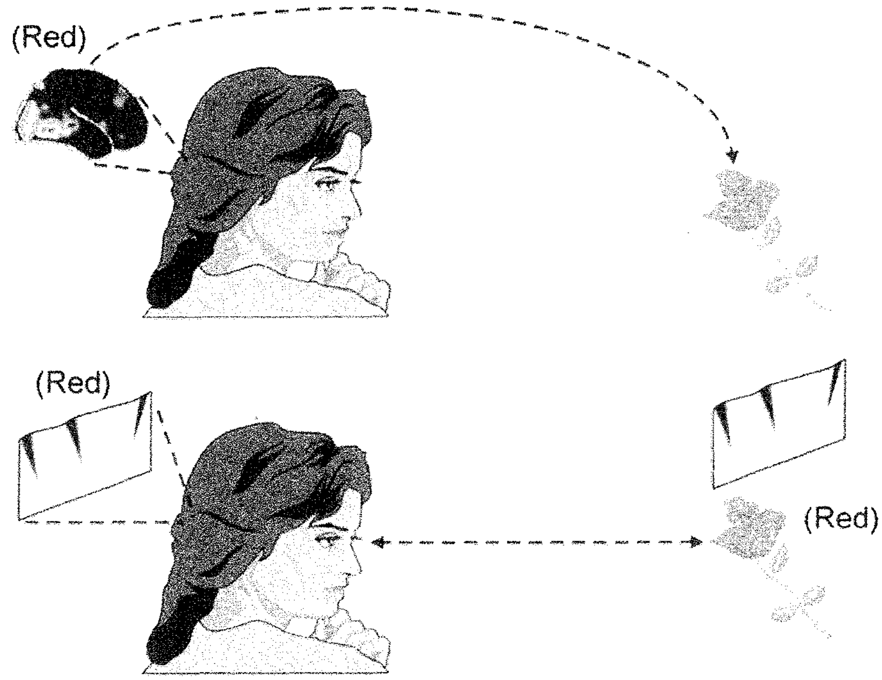

FIGURE 20.14 (Top) Conventional views characterize the redness of a rose as a particular pattern of brain activity. (Bottom) The Orch OR theory suggests redness is a particular pattern of curvature in fundamental spacetime geometry.

and flagella. Membrane-covered cilia and flagella acted as sensors, as well as motor-like oars and whip-like propellers, able to bend, move, and exert causal effects in their environment (the same mechanism moves synaptic cargo through brain neurons).

Centrioles, the focal point of the cytoskeleton inside cells, are two mega-cylinders arrayed in a mysterious perpendicular alignment, each with a helical twist. Centrioles organize and anchor mitotic cell division, the first step being to spawn another mega-cylinder, rotating perpendicularly. The original pair then separates, the daughter centrioles twisting through cytoplasm, leading spindles and chromosomes to perfect alignment and daughter cell destiny. Perpendicular rotational spawning allows centriolar information (as states of tubulin) to be transferred to subsequent generations without genes, epigenetic Lamarckian inheritance (Balestra et al., 2015).

Cilia, centriole, and flagellar composites of microtubules also gained new mechanical vibrations, further promoting quantum resonances, and became able to detect photons. Biologist Guenter Albrecht-Buehler (1992) isolated fragments of cells containing the centriole, cytoplasm, and enough cytoskeleton to move around, without nucleus or DNA. He then shone infrared light at the fragments which invariably turned and moved toward the light source. He meticulously showed it was the centriole mega-cylinders, 150-nm inner diameter and ~700 nm in length, perfectly sized for optical wavelengths, which received and responded to the photons (Fig. 20.15). Primitive visual systems consist of ciliated ectoderm which, along with centrioles and flagella, may capture and detect photons, pumping FRET-like excitons and promoting OR pleasure qualia.

With membrane coats and metabolic machinery, solar-powered flagella became motile spirochetes, slithering through the primordial soup in search of nutrients and photons, catching rays and feeling good. OR pleasure jumped exponentially. Musically, vibrational resonance brought harmony, range, and tunes.

By then, simple immobile prokaryotic cells had also emerged with microtubule-like structures (FtsZ proteins), lacking movement and internal compartmentalization, their DNA and metabolic enzymes floating freely in watery interiors. According to biologist Lynn Margulis-Sagan (1995), prokaryotes underwent a series of symbiotic mergers to produce the eukaryotic animal cell, our ancestor. She proposed prokaryotes ingested mitochondria from another species, providing chemical energy in the form of ATP, mitochondria remaining on as sheltered intracellular organelles. Margulis-Sagan also suggested prokaryotes ingested, or were invaded by spirochetes—motile flagellates, much like sperm penetrating an ovum. The invading flagellates became symbiotic with their hosts, forming the cytoskeleton, eg, cilia, centrioles, flagella, and microtubules. Eukaryotic animal cells were able to sense their environment, move nimbly, and interact with other organisms (Fig. 20.16). As genes developed, cells became able to undergo mitosis. The cytoskeleton may have also brought intelligence, consciousness, and sexual reproduction.

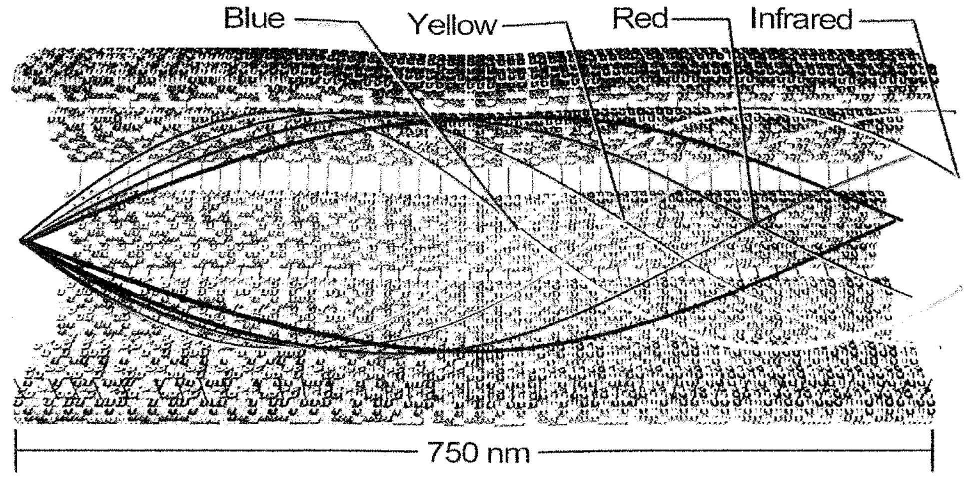

FIGURE 20.15 Inside of centriole/cilia structure shows five (of nine) microtubule triplets. Wavelengths of visible and infrared photons match interior cavity as waveguide/resonator. Centrioles and cilia are able to detect photons.

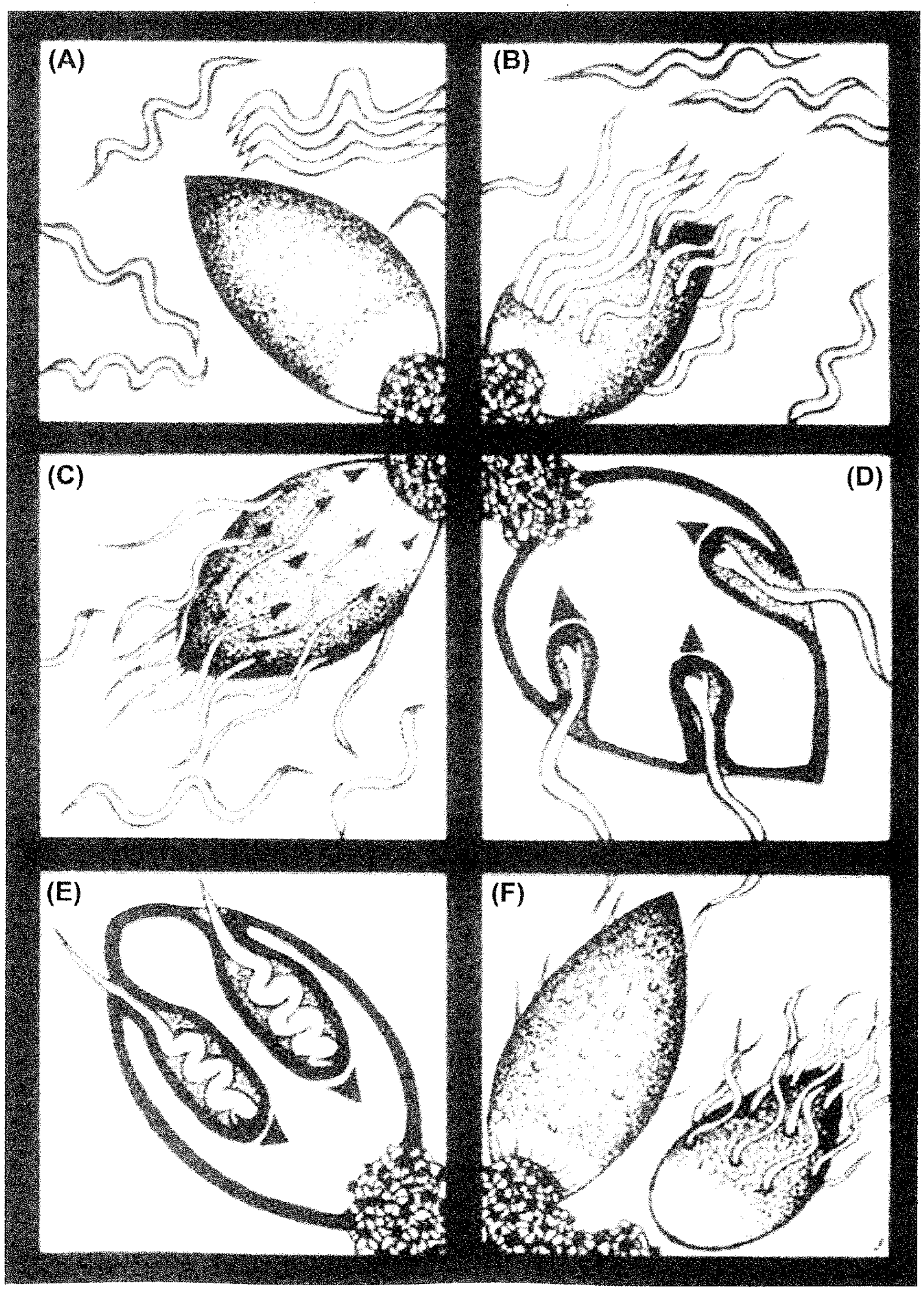

FIGURE 20.16 Symbiotic ingestion of/invasion by motile spirochetes into a primitive prokaryotic bacterium, resulting in the first eukaryotic cell. The spirochete's filamentous proteins became, according to Margulis-Sagan's endosymbiotic theory, the centrioles and cytoskeleton of eukaryotic cells, providing movement and organization of cytoplasm. *From Hameroff, S., 1987. Ultimate Computing-biomolecular Consciousness and Nanotechnology. Elsevier, Amsterdam by Paul Jablonka.*

Prokaryotes reproduce by simple division and budding to form spores. Spirochetes undergo longitudinal fission, separating along parallel microtubule doublets. With the onset of genetic material, sexual reproduction would eventually enable evolution, gene mixing, species diversification, and adaptability. But how did it start? Evolutionary biologists are unable to explain the origin of sexual reproduction and gender.

Graham Bell (1982) says "Sex is the queen of problems in evolutionary biology." Richard Dawkins' (1989) trademark "selfish gene" view finds sex "counter-productive, throwing away half one's genes with every reproduction." Ironically, Dawkins lists the origin of sex as one of three remaining mysteries in evolution, along with consciousness, and differentiation, the mechanism by which "genes influence bodies." All three mysteries can be explained through microtubules.

In *The Cooperative Gene*, Mark Ridley (2008) writes "Evolutionary biologists are much teased for their obsession with why sex exists. People like to ask, in an amused way, 'isn't it obvious?' Joking apart, it is far from obvious.... Sex is a puzzle that has not yet been solved; no one knows why it exists".

It *is* obvious. Sex feels good. Sex and sexual reproduction might have started through endosymbiosis, driven by the quest for OR pleasure. Flagellated spirochetes were likely the most agile and clever of creatures, marauders of the soup. Sedentary prokaryotes were inviting targets. In a manner analogous to sperm fertilizing eggs, spirochetes wriggled through cell walls to reach bacterial interiors, finding energy (eg, for dynein motors) and a stable, protected environment. Pi cloud arrays in host cell proteins coupled their E_G with that of flagellar microtubules, the mutual superpositions avoiding random distractions from the polar environment and allowing orchestration. OR threshold was approached more gradually, harmonically, with orchestrated pi stack coherent contributions. When threshold was finally reached by $E_G = h/t$, climactic and pleasurable Orch OR moments occurred. Sex was born.

At first, spirochetal invasions might have been temporary and predatory—one night stands. But spirochetal microtubules began to unpack, disassemble, and rearrange through quantum dipole coupling with host protein pi stacks. Microtubules moved in, further optimizing Orch OR resonance and mutual benefit and pleasure. The symbiosis took hold. Mitosis by centrioles and microtubule spindles separated chromosomes into perfectly paired matches, combining genes from each parent, promoting diversification and adaptation. These evolutionary processes have continued through the present day.

Microtubules radially arranged around centrioles, tethered by actin proteins in tensegrity structures in cell interiors. Rigid cell walls were replaced by flexible membranes. Megacylinder extensions in cilia, flagella, and axonemes enabled external sensing, agile locomotion, and adaptive interactions with other cells and the outside world. Within cell cytoplasm, centrioles and microtubules fostered mitosis, gene mixing, mutations (influenced by Penrose OR—mediated Platonic influences in DNA pi stacks) and evolution, all in pursuit of more and more pleasurable qualia. Cells began to communicate, compete and/or cooperate, guided by feedback toward feeling good.

Cells joined through adhesion molecules and gap junctions, resulting in multicellular organisms. Specialization occurred through differentiation via gene expression through cytoskeletal proteins. In some types of cells, the cytoskeleton became asymmetric and elongated, taking on signaling and management roles as axonemes and neurons. Neurons and other cells fused by gap junctions, and chemical signaling ensued at synapses between axons, and dendrites and soma within which microtubules became uniquely arranged in mixed polarity networks, optimal for integration, recurrent information processing, interference beats, and orchestration of OR-mediated feelings. Neurons formed networks, E_G grew larger, t grew shorter and conscious experiences became more and more intense. At E_G of roughly 10^{11} tubulins in ~ 300 neurons or axonemes in simple worms and urchins, t became brief enough to avoid random interactions, prompting, perhaps, the Cambrian evolutionary explosion (Hameroff, 1998). The brain evolved in pursuit of pleasure, and in the musical metaphor, the band began to play.

CONCLUSION: DID "QUANTUM FEELINGS" SPARK THE ORIGIN AND EVOLUTION OF LIFE?

Darwin's theory of evolution through natural selection is a pillar of modern science, but it is incomplete. Natural selection fails to address the origin of life, the nature of consciousness, and presumed incremental changes in evolution cannot fully explain life's molecular machinery. Something is missing.

In modern times Darwin's theory is taken to imply (eg, Richard Dawkins' "selfish gene") that behavior of living organisms serves to promote genetic survival through reproductive success. But behavior in humans and animals is driven by conscious feelings (eg, Epicurean delight, Freud's pleasure principle, dopaminergic reward, avoidance of pain). The subjective nature of conscious feelings (phenomenal experience, or qualia in philosophical terms) has yet to be explained scientifically, theorists appealing to either higher order emergence, or lower level panpsychism, the latter suggesting qualia are intrinsic features of matter, or deeper levels of reality. These deeper levels somehow give rise not only to qualia, but also to matter, as well as electrical charge, magnetic spin, and the various constants and parameters which govern the universe. In approaching these deeper levels another mystery arises, that of quantum mechanics and collapse of the wave function.

At small scales, particles exist in multiple states or locations simultaneously—quantum superposition, described by a quantum wave function. Yet such superpositions are not seen in our consciously observed world, and the reason may have something to do with consciousness itself.

One longstanding view is that the act of conscious observation causes superposition to reduce, or collapse, to classical states, that consciousness causes collapse of the wave function. However, this view, termed the Copenhagen interpretation after the Danish origin of Neils Bohr, its early proponent, fails to consider the underlying reality of superposition, and puts consciousness outside science. But rather than consciousness causing collapse, as in the Copenhagen interpretation, Sir Roger Penrose has taken the opposite approach, suggesting that collapse causes consciousness (or *is* consciousness), a process in fundamental spacetime geometry, the fine scale structure of the universe, each OR event a qualia moment of subjective experience. Such events would be occurring ubiquitously in microscopic electrically charged environments throughout the universe, quickly reaching threshold and undergoing OR with random, meaningless, and disjointed protoconscious qualia. However, such primitive experiences could include pleasurable feelings or painful ones.

If so, OR events and qualia were occurring when life began, eg, in earth's primordial soup billions of years ago. Biomolecular self-organization could have been driven by optimizing pleasurable OR qualia, and avoiding painful ones. Were pleasurable qualia the spark of life driving evolution? Do they continue to be so?

In the early universe, and continuing to the present time, OR events would generally occur in electrically charged, polar environments like water or most forms of matter. There, quantum states quickly entangle and react chemically to reach OR threshold (decoherence), producing random, noncognitive protoconscious qualia which would come and go without a trace. However, also present in the early universe, eg, in the primordial soup from which life began, were nonpolar, uncharged oil-like environments of pi electron resonance clouds. When properly arrayed in nonpolar regions, pi electron resonance clouds are quantum-friendly, enabling superpositions to avoid random entanglements, and be orchestrated (Orch OR) in appropriate structural lattices with resonance, memory, and inputs. Orch OR events, eg, in microtubules inside brain neurons, could then culminate in meaningful, rich conscious moments.

Quantum friendly nonpolar regions pervade biology, buried within cores of microtubules and nearly all biomolecules, shielded from polar, aqueous interactions, and defined by a solubility parameter akin to olive oil. The Meyer—Overton correlation shows such nonpolar sites, eg, composed of aromatic amino acid pi electron resonance clouds in protein interiors, to be the sites where anesthetics act to selectively erase consciousness. The Meyer—Overton quantum underground appears to host consciousness in the brain, and may have enabled the origin of life.

It is suggested here that life originated billions of years ago to optimize OR-mediated qualia in nonpolar molecules in the primordial soup. Pi electron resonance clouds in dopamine-like amphipathic molecules coalesced in geometric pi-stacks, forming micelle-like proto-cells, RNA, membranes, and simple proteins with quantum-friendly regions for OR events. Positive pleasurable feelings, and avoidance of negative ones, are suggested to have provided feedback for self-organizing pi stack geometries optimal for pleasure. Absorption of ambient terahertz, gigahertz, and megahertz radiation help promote resonance, larger micelle structures, microtubules, cilia, centrioles, flagella, eukaryotic cells, and eventually the brain, in pursuit of feelings, resonating with the fine-scale structure of the universe.

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