Spin-Mediated Consciousness Theory:
An Approach Based On Pan-Protopsychism

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Huping Hu[*]

Biophysics Consulting Group, 25 Lubber Street, Stony Brook, NY 11790

Maoxin Wu

Department of Pathology, Mount Sinai Medical Center, New York, NY 10029-6574

ABSTRACT

As an alternative to our original dualistic approach, we present here our spin-mediated consciousness theory based on pan-protopsychism. We postulate that consciousness is intrinsically connected to quantum mechanical spin since said spin is embedded in the microscopic structure of spacetime and may be more fundamental than spacetime itself. Thus, we theorize that consciousness emerges quantum mechanically from the collective dynamics of "protopsychic" spins under the influence of spacetime dynamics. That is, spin is the "pixel" of mind. The unity of mind is achieved by quantum entanglement of the mind-pixels. Applying these ideas to the particular structures and dynamics of the brain, we postulate that the human mind works as follows: The nuclear spin ensembles ("NSE") in both neural membranes and proteins quantum mechanically process consciousness-related information such that conscious experience emerges from the collapses of entangled quantum states of NSE under the influence of the underlying spacetime dynamics. Said information is communicated to NSE through strong spin-spin couplings by biologically available unpaired electronic spins such as those carried by rapidly diffusing oxygen molecules and neural transmitter nitric oxides that extract information from their diffusing pathways in the brain. In turn, the dynamics of NSE has effects through spin chemistry on the classical neural activities such as action potentials and receptor functions thus influencing the classical neural networks of said brain. Our proposal calls for associative encoding of neural memories in the dynamical structures of neural membranes and proteins. Therefore, according to the present theory: (1) the dynamical nuclear spin ensembles are the "screen" of mind with nuclear spins as its pixels; (2) the neural membranes and proteins are the mind-screen and neural memory hosts; and (3) the fluxes of biologically available unpaired electrons spins are the spin beam for information retrieval, communication and pixel-activation. Together, they form the neural substrates of consciousness. We also present supporting evidence and make important predictions. We stress that our theory is experimentally verifiable with present technologies. Further, experimental realizations of intra-/inter-molecular nuclear spin coherence and entanglement, macroscopic entanglement of spin ensembles and NMR quantum computation, all in room temperatures, strongly suggest the possibility of a spin-mediated mind.

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[*] **Correspondence author:** e-mail: drhu@quantumbrain.org or drhu@att.net
Telephone/Fax: 212-898-1103.

I. Introduction

Experimentally, tremendous progress has been made in neuroscience over the last several decades (see Sakurai, 1999; Srinivasan et al, 1999). Tens of thousands of experiments have been performed and even more papers were written. Theoretically, numerous versions of quantum and non-quantum consciousness theories have been proposed over the recent years (e.g., Beck and Eccles, 1992; Crick, 1994; Donald, 1990; Edelman, 1989; Hameroff and Penrose, 1996; LeDoux, 2002; Penrose, 1989 & 1994; Stapp, 1993; Walker, 2000). But, at this stage almost all are speculative and none is commonly accepted, although progress has also been made (see Goguen, 2002). Philosophically, the age-old debate about consciousness has intensified like a raging fire (e.g., Chalmers, 1996; Churchland, 1993; Freeman, 2001; Searle, 1992). However, despite all these efforts, what is and causes consciousness remains a deep mystery (see Goguen, 2002). In this paper, we propose a novel theory of consciousness with the hope that it would shed some light on these issues.

Spin is a very unique quantum mechanical concept with its own mystery, being often said to have no classical counterpart (see Tomonaga, 1997). Unlike mass and charge that enter a dynamic equation as arbitrary parameters, spin reveals itself through the structure of the relativistic quantum equation for fermions (Dirac, 1928). Thus, it is deeply connected to the microscopic structure of spacetime. Further, because spin uniquely determines the statistical properties of fermions and bosons (Pauli, 1940) – two classes of all known elementary particles, it may be said that spin is "protopsychic" thus makes a particle "conscious" about what quantum statistical rules to follow in a many -body system. Indeed, modern physics leads us right down to the microscopic domain of spacetime where many models of elementary particles and even space-time itself are built with spinors (Budinich, 2001; Penrose, 1960 & 1967) that were first used by Pauli (1927) and Dirac (1928) to describe an electron of spin ½. Therefore, we strongly believe that Nature has utilized quantum mechanical spin in constructing a conscious biological mind.

Indeed, proton nuclear spin ½ is the most abundant unpaired nuclear spin to be found in neural membranes and proteins. Nothing else even comes close. Both magnetic resonance imaging (MRI) and functional MRI (fMRI) are based on the abundance of proton nuclear spin in human body. Neural membranes play vital roles in the normal functions of a conscious brain. They transmit neural signals through propagating action potentials formed by the collective actions of voltage-regulated ion channels on the membranes. They maintain a delicate environment for the proper functions of neural receptors and serve as barriers, carriers and filters for the proper metabolic life of a neuron. Their major molecular components are phospholipids, proteins and cholesterols. Each phospholipid molecule contains on its lipid chains a cluster of more than 60 nuclear spin ½, one in each hydrogen atom attached to the chain. Neural proteins include membrane proteins such as ion channels and neural transmitter receptors, structural proteins such as microtubules inside the dendrites, and many enzymes such as ATP-ase and nitric oxide (NO) synthase. All these proteins play respectively very important roles in normal neural functions. Each of them contains a larger cluster of proton spin ½ intra-molecularly coupled as a network of spins.

Very importantly, we believe that the mechanism of anesthetic action is closely related to the inner workings of consciousness. But how general anesthetics work is itself a 150-year old mystery (see Cantor, 1997; Hu and Wu, 2001; Koubi, 2000). Besides unconsciousness, general anesthesia is marked by the overall depressed cerebral metabolic functions and accompanied sometimes by hypoxia and acidosis (see Berthoud and Reilly, 1992; Fiset et al, 1999; Hempel *et al*, 1975). As will be discussed in more details later, we have already proposed within the framework of conventional neuroscience that anesthetic perturbations of oxygen pathways in both neural membranes and proteins are possibly involved in general anesthesia (Hu and Wu, 2001).

Oxygen molecule (O_2) contains two unpaired valence electrons thus is strongly paramagnetic and at the same time chemically reactive as a bi-radical. It is capable of producing a large fluctuating magnetic field along its diffusing pathway thus serves as a natural contrast agent in MRI (see Morris, 1986). The existence of unpaired electrons in stable molecules is very rare indeed. O_2 is the only paramagnetic molecule to be found in large quantities in the brain besides certain metal elements found in proteins. In addition, O_2 is an essential component for energy production in the central nervous system. One of the most immediate purposes of our respiratory and circulatory systems is to deliver O_2 to the brain (see Magistretti *et al*, 2002).

O_2 and NO, the latter being a unstable free radical with one unpaired electronic spin and a recently discovered small neural transmitter, are well known in spin chemistry - a field focused on the study of free-radical mediated chemical reactions where very small magnetic energies can change non-equilibrium spin conversion process (e.g., Hayashi, 2002; Nagakura, 1998). Thus O_2 and NO may serve as "spin-catalysts" in consciousness-related neural biochemical reactions such as those dual path reactions initiated/driven by free radicals (e.g., Minaev, 1996).

II. Nature of Spin

As already mentioned above, spin is deeply connected to the microscopic structure of spacetime as reflected by the Dirac equation for fermions (Dirac, 1928). Indeed, Penrose (1960 & 1967) had considered early on that spin might be more fundamental than spacetime and invented spinor and twistor algebras for a combinatorial description of spacetime geometry. Bohm and Hiley (1984) generalized the twistor idea to Clifford algebra as a possible basis for describing Bohm's implicit order. Recently various spin foams have been formulated as extensions to Penrose (1960)'s spin networks for the purpose of constructing a consistent theory of quantum gravity (e.g., Baez, 1998; Smolin, 2001). According to Baez (1998), spin networks provide a language for describing the quantum geometry of space and spin foams attempt to extend this language to describe the quantum geometry of spacetime. Thus, in the spin network picture, the seemingly continuous space is actually made up of building blocks that are the nodes and edges of the spin network (Smolin, 2001). In the spin foam picture, the quantum transitions of spin networks represent the time evolution of said spin networks (Smolin, 2001). It is hoped that fermionic matter can be incorporated as the vibrations/excitations of the spin

networks by adding a new set of mathematical representations corresponding to the fermionic matter field (Crane, 2000; Mikovie, 2002).

Many others have also study the nature of spin from both classical and quantum-mechanical perspectives. For example, Newman (2002) showed that spin might have a classical geometric origin. By treating the real Maxwell Field and real linearized Einstein equations as being embedded in complex Minkowski space, he was able to interpret spin-angular momentum as arising from a charge and "mass monopole" source moving along a complex world line (Newman, 2002). Galiautdinov (2002) has considered a theory of spacetime quanta and suggested that spin might manifest the atomic structure of spacetime. Finkelstein (2002) is proposing that spin derives from a swap – a projective permutation operator, and the two-valued spin representation from a deeper 2-valued statistics.

Furthermore, Sidharth (2001a & 2001b) has discussed the nature of spin within the context of quantized fractal spacetime and showed that spin is symptomatic of the non-commutative geometry of space-time at the Compton scale of a fermion and the three dimensionality of the space result from the spinorial behavior of fermions. He showed that mathematically an imaginary shift of the spacetime coordinate in the Compton scale of a fermion introduces spin ½ into general relativity and curvature to the fermion theory (Sidharth, 2001a). The reason why an imaginary shift is associated with spin is to be found in the quantum mechanical zitterbewegung within the Compton scale and the consequent quantized fractal space-time (Sidharth, 2001a). Further, according to Sidharth (2001b), a fermion is like a Kerr-Newman Black Hole within the Compton scale of which causality and locality fails.

III. Mystery of General Anesthesia

It should be stressed that there is no commonly accepted theory on how general anesthetics work (see Cantor, 1997; Hu and Wu, 2001; Koubi, 2000; Tu *et al*, 1998). However, there are two schools of thoughts on the issue. The first and oldest is the "lipid theory" which proposes that anesthetics dissolve into cell membranes and produce common structural perturbation resulting in depressed function of ion channels and receptors that are involved in brain functions (see Cantor, 1997; Koubi, 2000; Tu *et al*, 1998). However, there has been no direct experimental evidence to support the notion that anesthetic perturbation of membrane depresses functions of membrane proteins (Hu and Wu, 2001).

The second, more popular and recent theory is the "protein theory" which suggests that anesthetics directly interact with membrane proteins such as ion channels and receptors that are involved in brain functions. But again there is no direct experimental evidence, e.g., that obtained by applying any of the established essays, such as radioligand-binding essay, to support the notion that general anesthetics specifically bind to these ion channels and receptors (Hu and Wu, 2001). In addition, this theory doesn' t seem to square well with the low affinity and diversity of the general anesthetics.

Furthermore, in contrary to the general assumption that cell membranes are readily permeable to O_2, existing publications support the possibility that these membranes are O_2 transport barriers (see Hu, *et al*, 1992; Swartz, 1994). The lateral movement of O_2 within the membrane to oxygen-utilizing protein may also encounter barriers. Further, the movement of O_2 in the protein to its site of utilization such as movement in a hydrophobic pocket may also encounter barriers.

Both theoretical and experimental studies have shown that many general anesthetics cause changes in membrane structures and properties at or just above the clinical concentrations required for anesthesia (see Cantor, 1997; Hu and Wu, 2001; Koubi, 2000; Tu *et al*, 1998). Further, as mentioned before, besides unconsciousness, general anesthesia is accompanied by overall depressed cerebral metabolic functions and sometimes hypoxia and acidosis (see Berthoud and Reilly, 1992; Fiset *et al*, 1999; Hempel *et al*, 1975). It is well known that hypoxia induces hypo-metabolism (Lahiri, 2000; Rohlicek *et al*, 1998).

Since both O_2 and general anesthetics are hydrophobic, we have speculated that the latter perturb the pathways of the former in both membranes and proteins (Hu and Wu, 2001). In essence, we have proposed within the framework of conventional neuroscience that general anesthetic may cause unconsciousness by perturbing O_2 pathway in neural membranes and O_2-utilizing proteins, such that the availability of O_2 to its sites of utilization is reduced, which in turn triggers cascading cellular responses through O_2-sensing mechanisms, resulting in general anesthesia (Hu and Wu, 2001).

In addition, we have also been asking the question whether anesthetic perturbations of neural membranes and oxygen pathways themselves are the direct cause of unconsciousness. This conjuncture requires that molecular oxygen and neural membranes be directly involved in consciousness. Indeed, The low affinity, diversity and pervasiveness of general anesthetics point us to this direction. If we assume that consciousness is an emergent property of the brain (Searle, 1992; Freeman, 20001) and further liken consciousness to the formation process of ice at 0 ^{o}C, anesthetic action would be like the action of salt preventing the formation of ice at 0 ^{o}C.

IV. Nature of Consciousness

There is no coherent view as to what is and causes consciousness (see Goguen, 2002). Some neuroscientists would say that it is the connections between the neurons and the coherent firing patterns thereof (e.g., Crick, 1994; Edelman, 1989). Some physicists would propose that it is connected to the measurement problem in quantum theory and thus the solution lies there (e.g., Donald, 1990; Stapp, 1993; Penrose 1989 & 1994). A few philosophers would suggest that it is an emergent property of the complex brain (e.g., Searle, 1992; Freeman, 2001) or a new kind of properties and laws are required (Chalmers, 1996). The literature in these areas has become so vast that it is impossible to discuss here even the major views expressed therein. Interested readers are thus directed to the Journal of Consciousness Studies at http://www.imprint.co.uk/jcs.html and a list of

online papers maintained by Chalmers (2002) for more exposure. For sure, such disarray has its historical reasons. Ever since Descartes promoted his dualism philosophy in the 17th Century, science has been for the most part steered clear from this subject until very recently.

Philosophically, Searle (1992) argues that consciousness is an emergent biological phenomenon thus cannot be reduced to physical states in the brain (also see Freeman, 2001). Chalmers (1996) argues that consciousness cannot be explained through reduction, because mind does not belong to the realm of matter. Thus, his approach is dualistic. In order to develop a consciousness theory based on this approach, he suggests expanding science in a way still compatible with today's scientific knowledge. Chalmers (1996) outlines a set of fundamental and irreducible properties to be added to space-time, mass, charge, spin etc. and a set of laws to be added to the laws of Nature. Further, he considers that information is the key to link consciousness and the physical world.

On the theoretical front, there are quite a few quantum theories of mind (e.g., Beck and Eccles, 1992; Donald, 1990; Hameroff and Penrose, 1996; Penrose, 1989 & 1994; Stapp, 1993; Walker, 2000). Among these, Penrose (1989 & 1994)'s Objective Reduction ('OR') together with Hameroff (19 96)'s microtubule computation is perhaps the most popular, and the combination of the two produced the Orchestrated Objective Reduction ('Orch OR') in microtubules (Hameroff and Penrose, 1996; Penrose, 1989 & 1994). According to Penrose (1989 & 1994), each quantum state has its own spacetime geometry, thus superposition of quantum states entails superposition of different spacetime geometries. Under certain conditions, such spacetime geometric superposition would separate under its own 'weight' through a no n-computable process, which in turn would collapse said quantum state superposition (Penrose, 1989 & 1994). Hameroff (1996) suggested that such self-organized OR could occur in microtubules because of their particular structures, thus, born the Orch OR. According Orch OR, each collapse of macroscopic spacetime geometry superposition corresponds to a discrete conscious event. In addition, it seems that Penrose does accept a separate mental world with grounding in the physical world (Penrose, 1989 & 1994).

There are also a number of theories based on conventional neuroscience (e.g., Crick, 1994; Edelman, 1989; LeDoux, 2002). Our view on these is that whatever the final accepted version based on neuroscience ('classical physics'), it may be accepted as classically correct. The reason is that we must rely on the classical parts of the brain working according to conventional neuroscience to provide us the necessary neural components and wirings such as coherent neural firings, neurotransmitter releases and neural plasticity to support any realistic quantum activities of the brain. The situation is much like that in quantum computation where classical components form the supporting system of a quantum computer. Without these classical components, quantum computation could not be implemented at all.

In comparison, our working philosophy is "pan-protopsychism"[*]. We adopt the notion that consciousness is grounded in physical reality (see Freeman, 2001; Penrose, 1989 & 1994; Searle, 1992). Next, we ask "where" and "how." To answer these, we take the reductionist approach both down to the end of physics to see what is left there and to the microscopic domain of a neuron to see what may be really important for the functioning of a conscious brain. What we found is that there is almost nothing left at the end of physics except the fundamental ideas of quantized space-time and spin. On the other hand, we found that what may be really important in the microscopic domain of a neuron are the nuclear spin ensembles and the fluxes of biologically available unpaired electrons carried by small molecules such as O_2 and NO as mentioned earlier in this paper. Naturally, we draw the conclusion that quantum mechanical spin together with its connection to spacetime geometry is needed to ground consciousness in physical reality such that conscious experience emerges from the collective dynamics of the neural nuclear spin ensembles under the influence of underlying spacetime dynamics.

Specifically, we try to answer these questions: (1) what are the neural substrates of consciousness; (2) what physical processes are involved in conscious experience; (3) what physical and biochemical process are involved in connecting consciousness to the classical neural networks of the brain and (4) what binding mechanism allows the mind to achieve unity.

V. General Postulates

With above discussions in mind, we present the following Postulates with grounding on the bottom of physical reality:

(1)   Consciousness is intrinsically connected to quantum mechanical spin since said spin is embedded in the microscopic structure of spacetime and may be more fundamental than spacetime itself. That is, quantum mechanical spin is protopsychic.

(2)   The "pixels" of a single mind are comprised of the unpaired nuclear spins distributed in the neural membranes and proteins of the brain. The pixel-activating agents of said mind are comprised of biologically available unpaired electronic spins. The records of a single mind are comprised of all possible entangled quantum states of the mind-pixels along with the underlying spacetime geometries.

(3)   Conscious experience emerges from the collapses of said entangled quantum states under the influence of underlying spacetime dynamics. The collapsing process may be non-computable. The unity of consciousness is achieved through quantum entanglement of the mind-pixels.

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[*] Though we hold a dualistic outlook similar to those advocated by Chalmers (1996) and Eccles (Beck and Eccles, 1992).

In Postulate (1), the intrinsic connection between quantum mechanical spin and mind is theorized. Combining this fundamental idea with those stated in Postulates (2) and (3) allows us to build a qualitatively detailed working mechanism of consciousness as will be seen later. Further, since we assume that fermions are the building blocks of spacetime fabric, there is no independent background spacetime.

In Postulate (2), we hypothesize that the unpaired nuclear spins in both neural membranes and neural proteins serve as the "pixels" of a single mind. Why use *unpaired* fermionic spins as pixels of mind? The answer is that tightly paired/entangled fermionic spins in quantum state $|S> = (1/[sqrt2])(|1/2>|-1/2> - |-1/2>|1/2>)$ have total spin zero and zero net magnetic moment, thus zero spin and magnetic interactions with others. The reasons why both neural membranes and proteins may be involved have been discussed before.

In theory the mind-pixels can self-activate by directly scanning and extracting information from their neural environment. But for reasons discussed later, the alternative is to have another group of fast moving unpaired electronic spins to do the job. Specifically, we propose that biologically available unpaired electronic spins such as those carried by O_2 and neural transmitter NO to be the mind-pixel activating agents (we call "spin beam"). This choice is dictated by what types of unpaired electronic spins a biological brain actually possesses.

In addition, we propose that the records of a single mind are comprised of all possible entangled quantum states of mind-pixels along with the underlying spacetime geometries because of the intrinsic relationships between quantum mechanical spin and the underlying microscopic structures of spacetime. It is not hard to see that the numbers and configurations of the constituent entangled quantum states depend on the history of said mind and is, thus, closely related to the concept of associative memory in neuroscience as will be discussed in more detail later.

In Postulate (3), we propose how conscious experience emerges. Since there are at the present several ontological interpretations of quantum mechanics with respect to the measurement problem, we accept, as the cause of conscious experience, the collapses of entangled quantum states of the mind-pixels under the influence of the underlying spacetime dynamics. We further theorize that the unity of consciousness is achieved through quantum entanglements of these mind-pixels. The idea of mind unity through entanglement is not new (e.g., Stapp, 1993).

In doing so, we have adopted a collapsing scheme similar to that advocated by Penrose (1989 & 1994) known as "objective reduction ("O R")" within which conscious experience emerges from one or a set of collapses of said entangled quantum states due to the separation of the underlying spacetime geometries through non-computable means (Penrose, 1989 & 1994).

Finally, it has been claimed by some that there is no large-scale quantum coherence in the warm and wet brain according to the decoherence theory (e.g., Tegmark, 2000). However, as will be discussed later, this claim does not seem to apply to nuclear spin

ensembles in neural membranes and proteins. Further, even if we assume the claim is true, consciousness can still emerge from the statistical mixtures of coherent and incoherent quantum states of the mind pixels, as long as we either accept some kind of quantum emergence theory (Freeman, 2001; Searle, 1992) or take a dualistic approach (see, Chalmers, 1996, Beck and Eccles, 1992) as will be discussed again later.

VI. Mechanism of Spin-Mediated Consciousness and Memory

Overview
Figure 1 is a highly schematic drawing of the overall picture of a spin-mediated consciousness model proposed herein. At this stage, the model is qualitative. A quantitative model will be built in the future. At the top of Figure 1, a two-neuron network is shown. The connections between the two neurons are made at the two synapses each of which consists of a synaptic knob with synaptic vesicles inside, a synaptic cleft where the neurotransmitters are released from an infusing synaptic vesicle at the presynaptic membrane on the knob, and a postsynaptic membrane located on the dendrite or the soma. The neural activities of the postsynaptic membrane are immediately shown below the neurons in Figure 1. These activities include biochemical reactions immediately following the release of neurotransmitters into the synaptic cleft, the ensuing collective activities of multiple ion channels and the action potentials and their propagations thereof, and other enzymatic activities.

The present model is mainly concerned with the spin dynamics of the proton nuclear spin ensembles in neural membranes and proteins such as those on the dendrites and soma under repeated activations by biologically available unpaired electronic spins, such as those carried by rapidly diffusing O_2 and neural transmitter NO, and the connections of such dynamics to underlying spacetime dynamics and, ultimately, conscious experience. The input and out information flows of said nuclear spin ensembles are schematically shown in the middle of Figure 1. On the bottom of Figure 1, what a single conscious mind perceives is schematically shown. The mechanism of spin-mediated consciousness including conscious experience will be described below.

Nuclear spin ensemble
Figure 2 shows side-by-side the chemical structure and atomic model of a typical phospholipid found in neural membranes together with the diffusing O_2 in Lewis structure and atomic model respectively. A similar but complex picture can be drawn for a neural protein with the presence of O_2. As can be seen, each phospholipid molecule contains more than 60 hydrogen atoms on its double lipid chains each of which contains proton nuclear spin ½. Because the small mobility of a proton in comparison to an electron, proton nuclear spins can only interact with each other and the environment through their small magnetic dipoles associated with their nuclear spin ½. That is why they have such long relaxation time after excitations (Morris, 1986). This property of proton nuclear spins is ideal for them to be used as mind-pixels. In addition, these nuclear spins can form various intra/inter-molecularly entangled quantum states under different external activations (see Khitrin et al, 2002; Khitrin and Ermakobv, 2002). These

entangled states represent different information to the mind. Thus, the proton nuclear spins of the two lipid chains of each phospholipid can serve as one pixel of a biological mind.

Spin beam
There are several reasons favoring a spin beam comprised of biologically available unpaired electrons. The nuclear spins ensembles in neural membranes and proteins alone are probably unable to extract useful information from said membranes and proteins because, as mentioned above, nuclear spins have small mobility and can only interact with their environment through their small magnetic dipoles. Thus, they probably can only feel the thermal noise from their surroundings without external activations.

In contrast, an electron, even attached to a molecule, is much more mobile and can interact with its environment and themselves through collision-induced conformational changes, spin-orbital coupling, its large magnetic dipole, and even Heisenberg exchange interactions under some circumstances (see Wertz, 1972). The magnetogyric ratio of the electron is about three orders of magnetude larger than that of the proton nuclear spin, which allows an electron to produce a strong and fluctuating magnetic field along its path of diffusion (see Wertz, 1972). Thus, the mobility and large magnetic dipole of an electron allow it to strongly interact with a nuclear spin through either its magnetic dipole or Fermi-contact interaction. Thus, a stable or semi-stable unpaired electron hosted in a suitable molecule is able to extract information from the diffusing path of the molecule and communicate said information to the nearby nuclear spins in the nuclear spin ensembles in neural membranes and proteins.

It turns out that among others O_2 and neural transmitter NO are such suitable molecules. O_2 contains two unpaired electronic spins that are in triplet state with a total spin $\mathbf{S} = 1$. In the absence of a strong external magnetic field, the triplet spin state is degenerate. It can be expressed as $|\mathbf{S}\rangle = a|\mathbf{1}\rangle + b|\mathbf{0}\rangle + c|\mathbf{-1}\rangle$ where $|\mathbf{1}\rangle = |1/2\rangle|1/2\rangle$, $|\mathbf{0}\rangle = (1/[\sqrt{2}])(|1/2\rangle|-1/2\rangle + |-1/2\rangle|1/2\rangle)$ and $|\mathbf{-1}\rangle = |-1/2\rangle|-1/2\rangle$. Similarly, NO contains one unpaired electronic spin with a total spin $\mathbf{S} = 1/2$. In the absence of a strong external magnetic field, the spin state is degenerate. It can be expressed as $|\mathbf{S}\rangle = a|1/2\rangle + b|-1/2\rangle$.
$\mathbf{S}$ can interact strongly with a nuclear spin cluster in a phospholipid, protein or other large biological molecules through Fermi-contact or dipole-dipole interaction as O_2 or NO rapidly diffusing through the neural membrane or protein so as to transfer the information it learned from its path of diffusion to the nuclear spin clusters along the path, while $|\mathbf{S}\rangle$ evolves successively under a time-dependent Hamaltonian H according to the Schrodinger equation.

Spin-Mediated Mechanism
The key circuits of spin-mediated consciousness are outlined here. The nuclear spin ensembles ('NSE') in both neural membranes and proteins quantum mechanically process consciousness-related information such that conscious experience emerges from the collapses of entangled quantum states of NSE under the influence of the underlying spacetime dynamics. Said information is communicated to NSE through strong spin-spin couplings by biologically available unpaired electronic spins such as those carried by

rapidly diffusing O_2 and neural transmitter NO that extract information from their diffusing pathways in the brain. In turn, the dynamics of NSE has effects through spin chemistry on the classical neural activities such as action potentials and receptor functions thus influencing the classical neural networks of said brain. Our proposal calls for associative encoding of neural memories in the dynamical structures of neural membranes and proteins. Therefore, according to the present theory: (1) the dynamical nuclear spin ensembles are the "screen" of mind with nuclear spins as its pixels; (2) the neural membranes and proteins are the mind-screen and neural memory hosts; and (3) the fluxes of biologically available unpaired electrons spins are the spin beam for information retrieval, communication and pixel-activation. Together, they form the neural substrates of consciousness.

Quantum coherence with entanglement
There are both theoretical and experimental research results indicating the strong possibility of large-scale quantum coherence with entanglement in the nuclear spin ensembles distributed in neural membranes and proteins of the warm and wet brain (e.g., Khitrin and Ermakov, 2002; Khitrin et al, 2002a & 2002b; Kun *et al*, 2002; Julsgaard *et al*, 2001; Warren et al, 1993 & 1998).

First, in a series of experiments, Khitrin *et al* (2000, 2002a & 2002b) have demonstrated that a cluster of dipolar coupled proton nuclear spins in the molecules of a nematic liquid crystal at room temperature can be manipulated to achieve long-lived intra-molecular quantum coherence with entanglement such that a large amount of information may be stored in said cluster. In particular, they have succeeded in storing at room temperature a 2D pattern consisting of 1025 bits of information in the proton nuclear spin states of a molecular system of the nematic liquid crystal and then retrieved the same as a stack of NMR spectra (Khitrin *et al*, 2002b).

Second, about a decade ago Warren *et al* (1993 & 1998) have discovered long-ranged intermolecular multiple-quantum coherence in NMR spectroscopy and imaging and have since successfully applied said coherence as MRI contrast agents. Indeed, they found that even the intermolecular dipolar couplings of the nuclear spins at distances larger than 10 microns are not averaged away by diffusions (Warren et al, 1993 & 1998).

Third, Julsgaard *et al* (2001) have first theoretically predicted and then experimentally demonstrated at room temperature a long-lived entanglement of two macroscopic spin ensembles formed by two caesium gas samples each of which contains about 10_{12} atoms. The entangled spin-state can be maintained for 0.5 milliseconds and was generated via interactions of the samples with a pulse of light (Julsgaard *et al*, 2001). The state they demonstrated is not a maximally entangled "Schrödinger cat" state but a state similar to a two-mode squeezed state; thus, it is an example of a non-maximally entangled state (Julsgaard *et al*, 2001). In addition, Kun *et al* (2002) have theoretically predicted a "Schrödinger cat" state to be found in highly -excited and strongly-interacting many-body system.

The results discussed above go heavily against the claim that there is no large-scale quantum coherence in the warm and wet brain (e.g., Tegmark, 2000). At least, this claim does not seem to apply to the nuclear spin ensembles in neural membranes and proteins. Further, in the case of Penrose-Hameroff microtubule model (Penrose, 1994; Hameroff and Penrose, 1996), it was strongly argued by Hagan *et al* (2002) that Tegmark (2000)'s theorectical calculations also do not apply.

"Consciousness explained"

The mechanism of consciousness according to our current proposals is schematically shown at the bottom of Figure 1. The geometry inside the spinning circle represents conscious experience and is part of a Penrose tiling (1989) generated from a java script available at http://freeabel.geom.umn.edu/apps/quasitiler/about.html. It symbolizes in the Penrose spirit (1989) that consciousness emerges from the non-computable collapses of entangled quantum states of the mind-pixels under the influence of spacetime dynamics schematically shown as the spinning circle in Figure 1. The edges in the Penrose tiling represent unpaired nuclear spins in neural membranes and proteins as mind-pixels, the nodes represent interactions between these nuclear spins and the colors represent activations of mind-pixels by biologically available unpaired electronic spins such as those carried by O_2 and neural transmitter NO. The whole tiling pattern in Figure 1 represents conscious experience and the underlying spacetime geometry. This pattern successively evolves under repeated activations by the spin beam representing successive collapses of entangled quantum states of the mind-pixels as a stream of conscious experience.

In proposing said mechanism of consciousness, we have adopted Penrose (1989 & 1994)'s long-standing view that human thought may involve non-computable processes, as Gödel's theorem of incompleteness would suggest. According to Gödel, any consistent system of axioms beyond a certain basic level of complexity yields statements that cannot be proved or disproved with said axioms. Yet human can decide whether those statements are true, thus human thought cannot be reduced to a set of rules or computations (Penrose 1989 & 1994).

So where can one find non-computable process in physics? Obviously it cannot be found in classical physics because classical physics is deterministic so, in principle, can be simulated by a computer (Penrose, 1989 & 1994). Thus, Penrose reasoned that some kind of non-computable *quantum process* must be involved in consciousness and further suggested gravity-induced reduction ('R') process of quantum state superposition to be the candidate (Penrose, 1989 & 1994). According to Penrose, each quantum state has its own spacetime geometry, thus superposition of quantum states entails superposition of different spacetime geometries. Under certain conditions, such spacetime geometric superposition would separate under its own "weight" through a no n-computable process, which in turn would collapse said quantum state superposition (Penrose, 1989 & 1994).

In proposing herein described mechanism of consciousness we have also adopted a view similar to Penrose's above suggestion. One may recall that, according to Einstein's theory of general relativity, gravity is spacetime geometry and, further, as we have discussed before quantum mechanical spin is embedded in the microscopic structure of spacetime. Therefore, the quantum state of said spin must be influenced by the underlying spacetime geometry. However, we still have the task of working out the details in future research. This will be especially difficult because at the present we do not have a satisfactory theory of quantum gravity.

Alternative approaches to consciousness

As mentioned earlier, some scientists have claimed that there is no large-scale quantum coherence in the warm and wet brain because of decoherence (e.g., Tegmark, 2000). If we assume that this claim is true, how can consciousness still emerge from statistically mixed quantum states of the nuclear spin ensembles in neural membranes and proteins? There are indeed at least two ways out. The first is to adopt a quantum emergence theory (see Freeman, 2001; Searle, 1992) and the second is to take a dualistic approach (see Chalmers, 1996; Beck and Eccles, 1992). Here, we will focus our discussion on the dualistic approach.

We can assume that mind exists and resides in a pre-spacetime. Then, the question becomes how does mind process and harness the information received from the spin beam so that it can have conscious experience? We can theorize that conscious experience emerges from those quantum states of the mind-pixels in the statistical mixtures that have grabbed the attention of the mind through quantum Zeno effect (e.g., Stapp, 1993) or some non-local means in pre-spacetime. Indeed, the many-mind interpretation of quantum theory as proposed by Donald (1990) supports this type of formulation. Thus, in this scenario, mind does not depend on large quantum coherence to work.

Furthermore, each proton nuclear spin is a qubit, each O_2 spin triplet is tightly entangled two-qubit and there exist coherent and incoherent intra-molecular superpositions of multiple nuclear spins under external stimulations (see Khitrin et al, 2002a &2002b; Khitrin and Ermakobv, 2002). Further, liquid NMR quantum computation is a reality (Nielsen and Chuang, 2000; Yannoni et al, 1999). So, mind, if exists, must have utilized these quantum resources to implement some kind of quantum processing in order to harness information.

It is also plausible that mind have utilized quantum statistical computations similar to those proposed by Castagnoli and Finkelstein (2001). In their model, a triode network made of triplet pairs of spin ½ fermions and their quantum statistical relations due to particle indistinguishability was utilized to implement the computation, together with a randomly-varying magnetic field as heat bath for annealing (Castagnoli and Finkelstein, 2001). The scheme develops quantum parallelism through the incoherent superposition of parallel computation paths (i.e., the mixtures). It replaces the superposition of coherent parallel computation paths with the almost indestructible superposition of different permutations of identical particles subject to a given statistics, thus surviving decoherence (Castagnoli and Finkelstein, 2001).

Associative memory model

We have proposed that the records of a single mind are comprised of all possible entangled quantum states of the mind-pixels along with the underlying spacetime geometries. We have also pointed out that the numbers and configurations of the constituent entangled quantum states of said records depend on the history of said single mind and are connected to the classical associative memory in neuroscience. The question is how are they connected? The answer is that, since the nuclear spins as the

mind-pixels are distributed in the neural membranes and proteins, the latter form the classical support system of the records of said single mind, thus the matrices of classical associative memory. Thus, we proposed that the classical associative memory is comprised of the conformational changes of neural membranes and proteins and the corresponding changes in their dynamical behaviors (see Marder *et al*, 1996).

A few illustrations are given here. Figure 3 (a) schematically shows a neural membrane containing only the same phospholipids. Such a membrane is much like a blank tape. Figure 3 (b) shows the same neural membrane after cholesterols are added. The changes in membrane configuration are quite noticeable (Raffy and Teissie, 1999; Smondyrev and Berkowitz, 1999). These changes can represent memory or information that can be read by a spin beam. Figure 3 (c) shows the chemical structure and atomic model of a stearic acid molecule - a saturated fatty acid. Figure 3 (d) shows the chemical structure and atomic model of oleic acid molecule – an unsaturated fatty acid. The only difference between the two fatty acids is that the latter contains a double bond in the middle that causes its kink formation when the double bond is in the cis form. When the double bond is in the trans form, the chain is doubly bent so there is no kink. Certainly insert either one of the fatty acids into the membrane shown in Figure 3 (b) would further increase its complexity thus information content. Furthermore, insertions of proteins to neural membranes also significantly change their conformation and dynamics surrounding the inserted proteins (Woolf and Roux, 1996). Thus, inserting different proteins to neural membranes both in numbers and types can significantly increase the information content of the neural membranes.

However, as we have discussed earlier, nuclear spins by themselves are probably unable to extract useful information from their neural environment, because they have small mobility and can only interact with said environment through their small magnetic dipoles. According the present theory, it is biologically available unpaired electronic spins as spin beams that are able to extract information from their diffusing paths and communicate said information to the mind-pixels thus activating the latter for consciousness-related processing.

Interface with classical neural networks
We speculate that there are two parts to the interface between spin-mediated conscious functions ('SMCF') and classical neural activities ('CNA'). The 'input circuit" from CNA to SMCF is responsible for converting classical neural activities into the dynamics of neural membranes and proteins from which spin beam can extract information. The very weak magnetic field collectively produced by all neural activities may also directly serve as the input to SMCF but its effect on SMCF is probably negligible in comparison the strong fluctuating magnetic field produced by the rapidly diffusing unpaired electronic spins in the spin beam as discussed below. The output circuit from SMCF to CNA is responsible for converting the functional output of SMCF into classical neural activities through spin chemistry and possibly other mechanisms.

With respect to the herein speculated input circuit, published studies showed that the dynamics of membrane proteins significantly affect the dynamics of surrounding

membranes (e.g., Marder *et al*, 1996; Woolf and Roux, 1996). Secondly, due to the very small thickness of the neural membrane (roughly 5 nm), even the small voltage (roughly ~50 mV) of an action potential can create enormous oscillating electric field inside the neural membranes that in turn can change the dynamics of the membrane components such as phospholipid and proteins through its interactions with the electric dipoles of these components (e.g., Akinlaja and Sachs, 1998; Sens and Isambert, 2001). Therefore, the classical neural activities of ion channels and receptors can affect, through at least two ways, the dynamics of the neural membranes and proteins from which spin beam can extract information. In addition, said electric field may directly effect the collective dynamics of the nuclear spin ensembles in neural membranes and proteins (e.g., Chapovsky, 2001).

Further, the electrical current accompanying the collective neuron firings could also produce a magnetic field in the order of 10^{-12} Tesla (Wikswo, 1990). In comparison, the magnetic field strength of earth is 5×10^{-5} Tesla (Wikswo, 1990), and the nuclear spin ensembles in neural membanes and proteins and biologically available unspired electronic spins such as those carried by O_2 and NO may, under some circumstances, produce a fluctuating local magnetic field in the ranges of a few Tesla (Slichter, 1990; Wertz, 1972). Thus, the effect of the magnetic field produced by classical neural activity on SMCF is negligible.

As to the herein speculated output circuit, many biochemical reactions mediated by radical pairs and biradicals, such as those dual path radical reactions driven/initiated by NO and active oxygen species, have been found to be influenced by the magnetic field in their local environment (Hayashi, 2002; Nagakura et al, 1998). Thus, the functional output of SMCF, being the varying local magnetic field generated by the dynamics of the nuclear spin ensembles as mind-pixels, can directly affect classical neural activities. Further, there may be other mechanisms through which the functional output of SMCF can affect the classical neural activities of the brain.

Mechanism of anesthetic action
As mentioned earlier in this paper, the mechanism of anesthetic action is closely related to the inner workings of consciousness (Hu and Wu, 2001). We describe here said mechanism in accordance with our present theory. Figure 4 (a) schematically shows the normal diffusion of biologically available unpaired electrons such as those carried by O_2 and neural transmitter NO without anesthetics dissolved into neural membranes and proteins. As these molecules rapidly diffuse through the membranes and proteins, their unpaired electrons in various spin states extract information from the membranes and proteins along their diffusion paths and communicate said information through strong spin-spin couplings to nearby unpaired nuclear spins such as proton nuclear spins for consciousness-related quantum mechanical processing. Figure 4 (b) schematically shows anesthetic perturbations of O_2 and NO pathways and neural membranes themselves by anesthetic molecules and the resulting distortion and/or obstruction of these pathways. A similar picture can be drawn for neural proteins and other components. Such perturbations result in O_2 and NO not being able to perform their spin beam functions such as extracting information from the neural membranes and proteins and nuclear spin

ensembles not being able to perform its normal mind-pixel functions resulting in altered mental state or unconsciousness.

VII. Important Predictions and Supporting Evidence

Several experimentally verifiable predictions can be drawn from the theory of consciousness proposed herein:

(1)   Any mean that significantly replaces hydrogen atoms of the neural membranes with those with zero nuclear spin such as deuterium will interferes with or totally block the conscious functions of the brain;

(2)   Any agent or mean that significantly interferes with the dynamics of the nuclear spin ensembles in neural membranes will interfere with the conscious functions of the brain;

(3)   Any agent or mean that significantly perturbs the structure or dynamics of the neural membranes will alter or disrupt the normal functions of consciousness;

(4)   Any agent or mean that significantly perturbs or interferes with the oxygen pathway inside the neural membranes will diminish or block consciousness; &

(5)   Any mean that stops oxygen flow through neural membranes will disrupt conscious functions of the brain even if everything else in the brain functions normally.

Of course, other important predictions and inferences can also be drawn from the present theory. But we will focus our discussions on the above listed a few to see whether there are any experimental evidence supporting these predictions.

With respect to (1), there are published results concerning the biological effects of heavy water, in which proton is replaced by deuterium - the spin zero isotope of hydrogen, which lend support to our proposal of the mind-pixels being based on proton nuclear spin ensembles in neural membranes and possibly proteins (see Kushner *et al*, 1999). Indeed, the only observable physical and chemical difference between regular and heavy water is that the latter has a slightly higher viscosity (Kushner *et al*, 1999). For example, it was reported that rats restricted to heavy water (99.8%) would drink it freely the first day, then drank progressively less and died within 14 days (Richter, 1976). It was also reported that the incremental increase of the amount of heavy water in regular drinking water lengthened the 24-hour clock of the Circadian rhythm in blind hamsters or normal hamsters kept in constant darkness (Richter, 1977). In principle, these observations can be explained as animals literally loosing their minds because of the loss of their mind-pixels due to gradual deuterium substitutions of protons in neural membranes and proteins. The complication is that the higher viscosity of heavy water might have also

contributed to the observed effects. It is possible to design a better experimental procedure to either account for or exclude those effects attributable to the higher viscosity.

As far as (2) is concerned, there also exist quite a few published results based on transcranial magnetic stimulation ("TMS") that can all be explained based on our proposals desribed herein (e.g., Limoniemi et al, 1997; also see Chicurei, 2002), although the common wisdom is that TMS induces electrical currents in the brain, causing depolarization of cellular membranes and thereby neural activation (Limoniemi et al, 1997). What TMS does is that it creates random neural noise through millisecond magnetic pulses that in turn produces temporary neural lesion (Chicurei, 2002). It has been found that depending on the locations of stimulation TMS affects the test subject's verbal ability, visualization and other conscious functions (Chicurei, 2002).

According to our proposals, TMS directly affects the dynamics of nuclear spin ensembles in neural membranes and proteins as the mind-pixels and possibly that of biologically available unpaired electronic spins as the spin beam, which in turn result in altered, diminished and/or disrupted conscious functions of the brain as reported by the TMS-related literatures (e.g., Limoniemi et al, 1997; Chicurei, 2002).

With respect to (3) and (4), many general anesthetics have been found to disturb the structures and dynamics of neural membranes (see Cantor, 1997; Hu and Wu, 2001; Koubi et al, 2000; Tu et al, 1998). Thus, the mechanism of their anesthetic action can be interpreted, according the instant theory, as their direct effects on O_2 pathways and nuclear spin ensembles inside the neural membranes and proteins. Our other paper (Hu and Wu, 2001) contains a more detailed treatment on anesthetic perturbations of oxygen pathways and membranes themselves.

Here we will focus our attention on one particularly small anesthetic agent, the nitrous oxide (N_2O), also known as the laughing gas. Indeed, the size of N_2O is similar to that of O_2 but it does not contain unpaired electrons and is not reactive. It has low polarity that makes it soluble in both water and lipid. Thus, it can be carried to the brain through blood stream and accumulate in the neural membranes. Inhalation of N_2O will cause disorientation, euphoria, numbness and ultimately loss of consciousness if the inhalation dosage is high. The cellular mechanism of these actions by N_2O is so far unknown but seems confined to postsynaptic targets (Mennerick et al, 1998). On the other hand, its closely related "cousin" nitric oxide (NO) contains one unpaired electron and has been discovered as the first small and highly diffusive neural transmitter produced in the brain through enzymatic reactions (see Philippides et al, 2000).

According to our theory of spin-mediated consciousness, there indeed exist a natural and straightforward explanation. By dissolving into neural membranes in an inhalation-dose-dependent fashion, N_2O gradually displace O_2 in their membrane pathways thus diminish or totally block the spin beam function of O_2.

With respect to (5), it is probably very hard to deprive brain oxygen and yet at the same time require its neurons to keep their metabolic functions normal since oxygen is an essential component of brain energy production (Magistretti et al, 2002). However, according to the present theory, in many cases of temporary-hypoxia-induced unconsciousness such as those due to sudden loss of air pressure on an airplane, the actually cause may not be the depletion of brain energy resources because of the lack of oxygen, but the loss of mind-pixel activating agents, the oxygen spin beam. This scenario should be testable in a suitable animal model.

Finally, we turn our attention to the associative memory model based on neural membrane plasticity proposed herein. There are tens of thousands of research papers on the subject of synaptic plasticity/modification (e.g., Fu *et al*, 2002). The commonly accepted assumption in neuroscience is that synaptic efficacy is both necessary and sufficient to account for learning and memory (see Marder *et al*, 1996). Our associative memory model not only does not conflict with the synaptic efficacy view but also provide more details because, according the present theory, the postsynaptic membranes and proteins on the dendrites and soma, which are part of the synapses, are the main sites of micro-consciousness. However, our theory also encompasses other parts of the neural membranes of the neurons and other neural proteins since all of the sites of micro-consciousness must also be dynamical connected in order to formed a unified mind through entanglement. Indeed, classical neural activities modify not only the synaptic efficacy but also the intrinsic properties of the neuron (see Marder *et al*, 1996).

VIII. Conclusions

Our current expedition to the terrains of mind-matter is guided by our working philosophy that consciousness is grounded in the bottom of physical reality and emerges from the collective dynamics of known physical candidates inside the brain. We strongly believe that quantum mechanical spins are such candidates because they are the most fundamental entities in modern physics and, on the other hand, neural membranes and proteins are saturated with these spins through chemically bound hydrogen atoms, rapidly diffusing oxygen molecules and neural transmitter nitric oxides and other neural substances. That is, quantum mechanical spin is protopsychic and our working philosophy is pan-protopsychism. We have applied reductionist approaches in both physics and neuroscience to reach our tentative conclusions. However, our present theory as it stands now is speculative and only qualitatively detailed. A quantitative model will be built in the future.

We have made important predictions from our theory and presented experimental evidence in support of the same. We have also suggested new experiments to verify the present proposals. We stress that our predictions experimentally verifiable with the present technologies. Indeed, recent experimental realizations of intra-/inter-molecular nuclear spin coherence and entanglement, macroscopic entanglement of spin ensembles and NMR quantum computation, all in room temperatures, strongly suggest the possibility of a spin-mediated mind.

However, we would like to caution that even if the instant proposals are confirmed partly or as a whole by more experiments it will only mark the beginning of a new direction towards a better understanding of our mind. There are still many questions need to be answered, especially those "hard problems" (Chalmers, 1996). Fo r example, what are the roles of other nuclear-spin-containing isotopes ("impurities") of biologically essential atoms such as C^{17}. Are they part of the mind-pixels? Do they represent different emotions or feeling of our mind when strongly coupled to the proton nuclear spin ensembles? What are the roles of other biological available unpaired electronic spins besides those carried by oxygen molecules and neural transmitter nitric oxides? Are they related to the different perceptions of mind?

In summary, a novel theory of consciousness is proposed in this paper. We postulate that consciousness is intrinsically connected to quantum mechanical spin since said spin is embedded in the microscopic structure of spacetime and may be more fundamental than spacetime itself. Thus, we theorize that consciousness emerges quantum mechanically from the collective dynamics of "protopsychic" spins under the influence of spacetime dynamics. That is, spin is the "pixel" of mind. The unity of mind is achieved by quantum entanglement of the mind-pixels.

Applying these ideas to the particular structures and dynamics of the brain, we postulate that the human mind works as follows: The nuclear spin ensembles ("NSE") in both neural membranes and proteins quantum mechanically process consciousness-related information such that conscious experience emerges from the collapses of entangled quantum states of NSE under the influence of the underlying spacetime dynamics. Said information is communicated to NSE through strong spin-spin couplings by biologically available unpaired electronic spins such as those carried by rapidly diffusing oxygen molecules and neural transmitter nitric oxides that extract information from their diffusing pathways in the brain. In turn, the dynamics of NSE has effects through spin chemistry on the classical neural activities such as action potentials and receptor functions thus influencing the classical neural networks of said brain. Our proposal calls for associative encoding of neural memories in the dynamical structures of neural membranes and proteins.

Therefore, according to the present theory: (1) the dynamical nuclear spin ensembles are the "screen" of mind with nuclear spins as its pixels; (2) the neural membranes and proteins are the mind-screen and neural memory hosts; and (3) the fluxes of biologically available unpaired electrons spins are the spin beam for information retrieval, communication and pixel-activation. Together, they form the neural substrates of consciousness.

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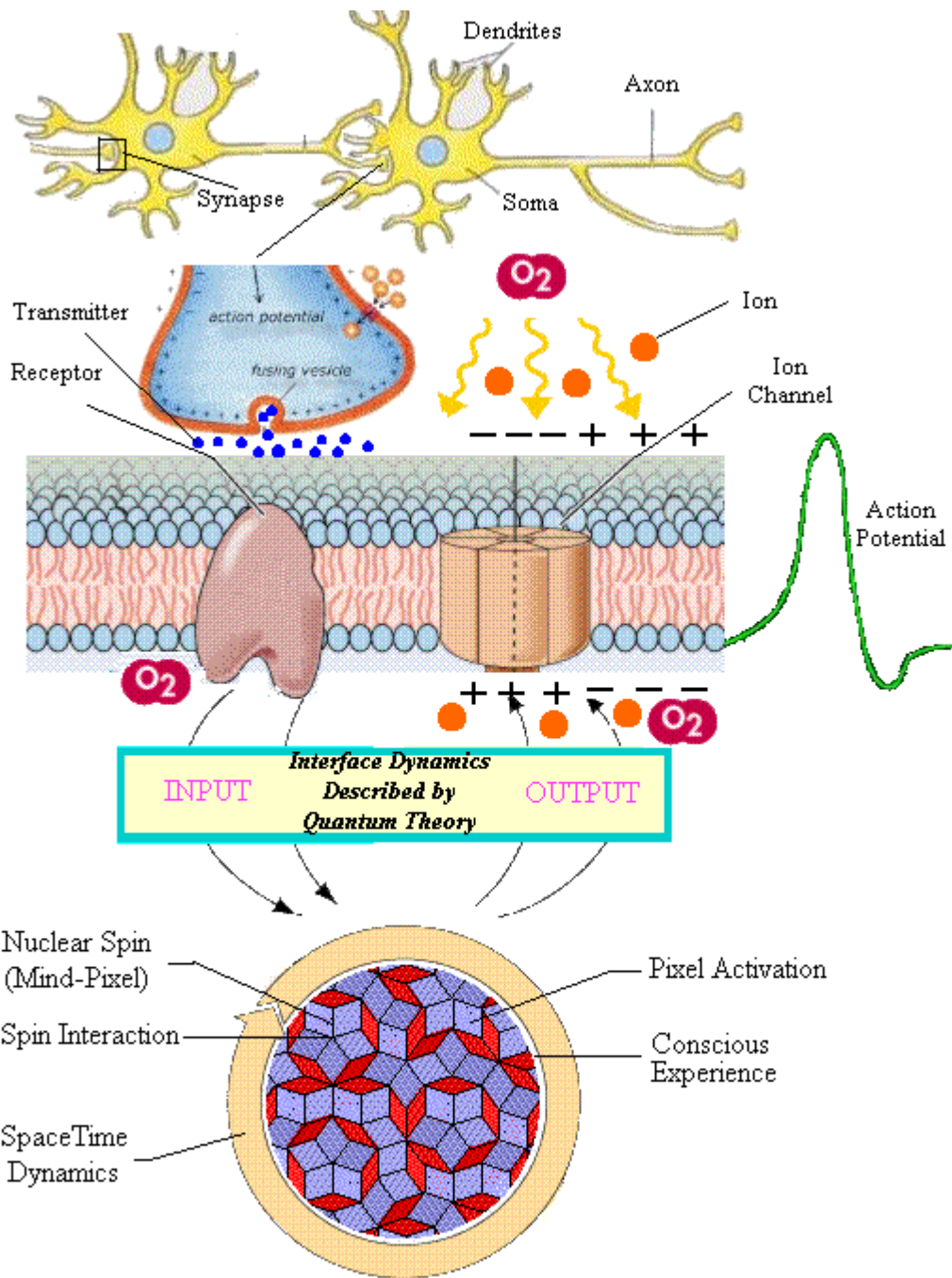
Figure 1. Schematic drawing of the mechanism of consciousness according to the present theory. The drawing is self-explanatory except the part dealing with conscious experience. The geometry inside the spinning circle represents conscious experience and is part of a Penrose tiling (1989) generated from a java script available at http://freeabel.geom.umn.edu/apps/quasitiler/about.html. It symbolizes in the Penrose spirit (1989) that consciousness is about quantum coherence with entanglement (non-locality and co-operation), non-computability and quantum state collapses under the influence of spacetime dynamics (the circle). The edges in the tiling represent unpaired nuclear spins in neural

membranes and proteins as mind-pixels, the nodes represent interactions between these nuclear spins and the colors represent activations of mind-pixels by biologically available unpaired electronic spins such as those carried by O_2 and neural transmitter NO. The whole tiling pattern represents conscious experience and the underlying spacetime geometry. This pattern successively evolves under repeated activations by the spin beam representing successive collapses of entangled quantum states of the mind-pixels as a stream of conscious experience.
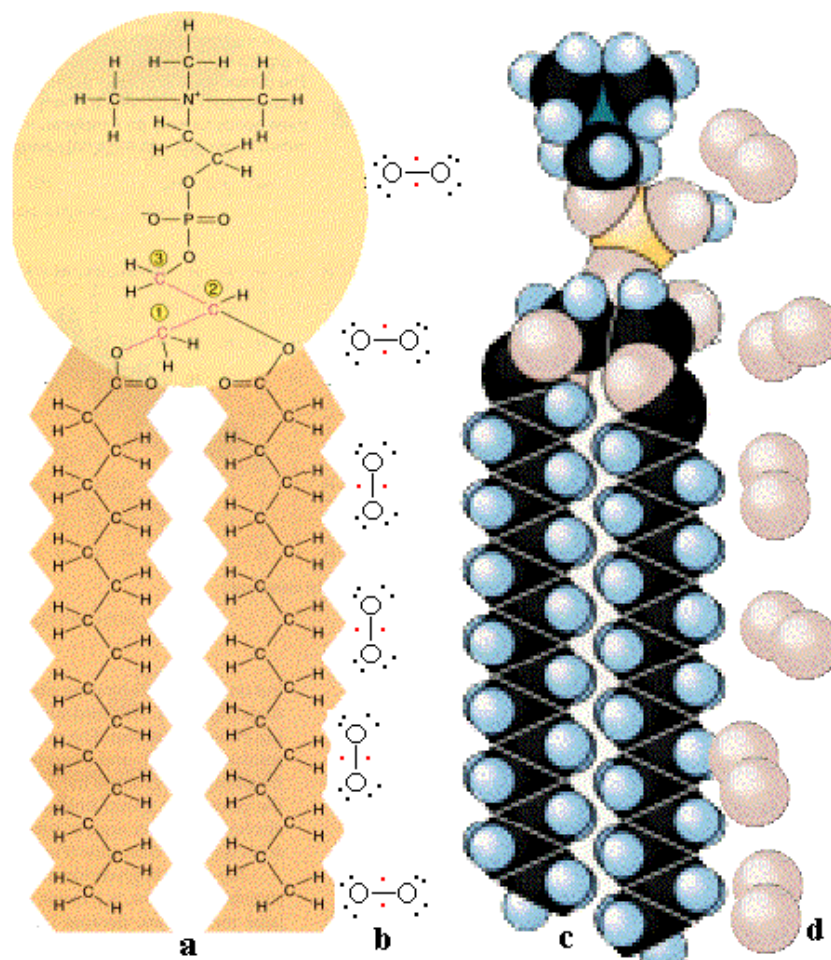

Figure 2. Schematic drawings of chemical structure (**a**) and atomic model (**c**) of a typical phospholipid with diffusing O_2 in Lewis structure (**b**) and atomic model (**d**) shown along the side. Two unpaired electronic electrons are shown in Lewis structure as two red dots (**b**). They are in triplet spin state. In the atomic model, the white, black, purple and orange balls respectively represent hydrogen, carbon, oxygen and phosphonium atoms. A similar but more complex figure can also be drawn for a neural protein surrounded by O_2 and/or NO.
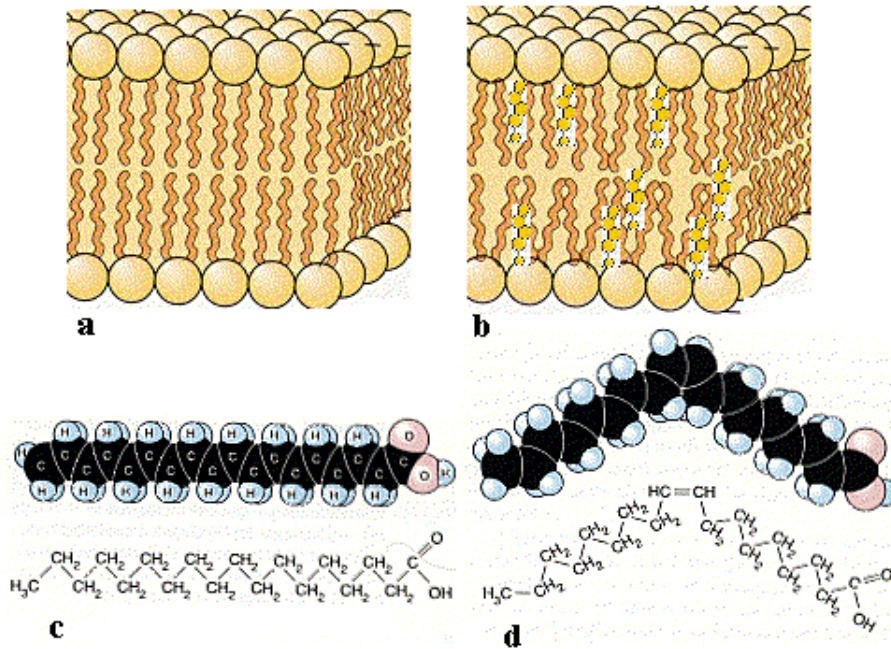
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Figure 3. Schematic drawings of an associative memory model. **a** shows a neural membrane containing only the same phospholipids. Such a membrane is much like a blank tape. **b** shows the neural membrane after cholesterols are added. The changes in membrane configuration are quite noticeable. These changes represent memory or information that can be extracted by spin beam. **c** shows the chemical structure and atomic model of a stearic acid molecule - a saturated fatty acid. **d** shows the chemical structure and atomic model of oleic acid molecule – a unsaturated fatty acid. The only difference between the two fatty acids is that the latter contains a double bond in the middle that causes its kink formation when the double bond is the cis form. When the double bond is in the trans form, the chain is doubly bent so there is no kink. Certainly insert either one of the fatty acids into the membrane shown in **b** would further increase its complexity thus information content. A similar but much more complex picture can be drawn for a neural protein with its conformational changes as memory/information.
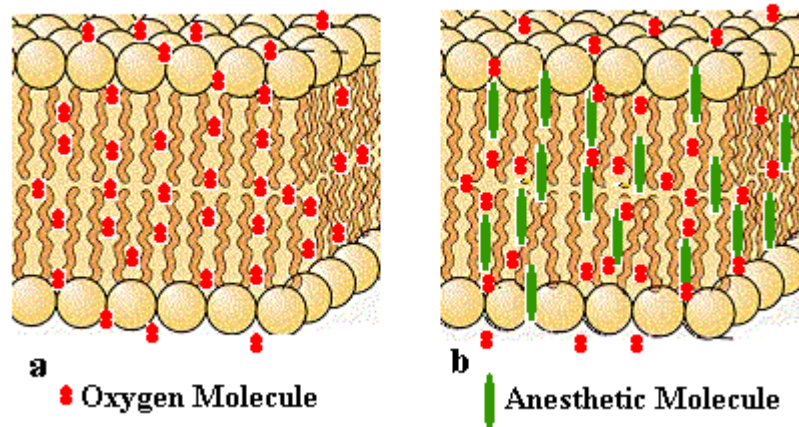
Figure 4. Schematic drawings of the mechanism of anesthetic action. **a** shows the normal diffusion of O_2 without anesthetics dissolved into neural. As O_2 rapidly diffuse through the neural membranes, their unpaired electrons extract information from the membranes along their diffusion paths and communicate said information through strong spin-spin couplings to nearby nuclear spins for consciousness-related processing. **b** shows anesthetic perturbations of O_2 pathways and neural membranes themselves by anesthetic molecules and the resulting in distortion and/or obstruction of O_2 pathways and even disturbance to the conformations of membrane components. Such perturbations result in O_2 being able to perform their normal spin beam functions such as extracting information from the membranes and proteins and nuclear spin ensembles in neural membranes and proteins not being able to perform their normal mind-pixel functions resulting in altered mental state or unconsciousness. Neural transmitter NO can also be included in the picture.