The Possible Mediating Role of Quantum Mechanical Phenomena in Mind-Body Interactions

Larry Goldberg, Ph.D.

Larry Goldberg is a philosopher of science, environment, and mind who has applied his interdisciplinary methodology to program development at the University of California, Texas A & M University, the University of Colorado and the National Center for Atmospheric Research.

Much progress has been made in identifying neural correlates of consciousness (NCC), but most scientists who study consciousness have not addressed the question of how consciousness and electrochemical processes might influence or transfer information between one another. (Correlations are not causal explanations.) The question has been avoided for a number of reasons: (1) The popularity of monistic views such as materialism, idealism, or property dualism (once called "neutral monism"), which respectively hold that everything is material, or mental, or that consciousness and matter are independent expressions of a single underlying reality. (2) It is not clear how we could empirically observe any interaction between consciousness and electrochemistry, since spatial manifestations of consciousness are unknown and the consciousness of others, at least, can't be empirically observed. (3) There doesn't seem to be any room in the classical (pre-quantum-mechanical) worldview that many researchers still hold for anything "nonphysical" to influence the brain or body. (4) It is difficult to visualize or model how physical and "mental" phenomena can interact.

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Concern about the empirical inaccessibility of consciousness (2 above) can be dismissed fairly easily. The more "theoretical" theories of physics are all "instrumental" theories in that they have predictive value, but contain theorectical constructs that can't be directly observed or measured. Electrical and magnetic fields, for example, are not directly observable, but they help to explain the acceleration of charged particles (and moving charged particles) in their vicinity while their mutual interaction helps to explain the nature of light.

To be effective, a theory of the interaction between consciousness and the body must address the remaining reasons above for avoiding the problem. We show here: (1) how theories of the interaction of consciousness and the body are needed to explain current observations, (2) that they can be tested empirically, (3) that a quantum mechanical perspective leaves room for "nonphysical" and "non-local" influences in the body, and (4) that a theory of a quantum mechanical gateway between consciousness and electrochemical phenomena would allow us to visualize and model their interaction. We propose a theory here that is intended to be illustrative of the possibility of addressing the interaction problem in a way that makes methodological sense.

Background of the Problem. Since the *Decade of the Brain* in the 1990s, there has been increasing interest in the cognitive sciences, energy medicine, and the general public in the scientific study of consciousness. The cognitive sciences[1] (including cognitive neuroscience, cognitive psychology, and the philosophy of mind, with contributions from artificial intelligence, the philosophy of science, and system science) have made much progress in identifying some of the neural correlates of consciousness (NCC). Most dramatically, perhaps, studies of visual perception have identified a "binding frequency" of correlated neuronal firing (and associated brainwaves) in the 35-75 Hz (gamma) range (called "40 Hz" binding) that seems to be associated with the onset of certain kinds of visual perception. Visual perception is thought to start subconsciously with a number of assemblies or

"coalitions" of neurons respectively associated with the identification of specific features of an object or scene that compete for our attention. It is only when several of these coalitions are selected by an unknown process and become approximately synchronized in their neuronal firing rates (firing more or less together about once every 25 ms) that we attend to the object or scene as a whole in what cognitive psychologists call "working memory."[2]

There is some evidence that gap junctions[3] between dendrites of adjacent neurons within feature-specific cell assemblies enable coordination of the dendritic activity of the assembly's neurons, contributing to the synchronization of their neuronal firing during binding.[4] What is especially puzzling, however, is how long-range synchronization across feature-specific neuronal modules emerges, such as the binding among coalitions of neurons that respectively represent the color, motion, shape, and so forth, of a visual object or scene. While some neurophysiologists believe that widely distributed connections of inhibitory interneurons, known for their synchronous and synchronizing activity, can explain the emergence of binding, others believe that the speeds of neurotransmission are inadequate to explain the rapid emergence of binding and are more inclined to appeal to quantum effects and the integrating function of consciousness.[5]

In addition to their focus on the mysteriously coherent NCC, cognitive scientists have identified a "penumbra" of less coherent neuronal activity that doesn't seem to be directly associated with consciousness, but accompanies the NCC in a shadow-like way, interacting with it and possibly contributing to the evolution of conscious moments from presumed frame to frame, every 400 ms or so.[6] The field of energy medicine has made a possible contribution to the understanding of the penumbra in its conception of the "living matrix"

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of the many forms of information and related energy exchange in the body.[7] In addition to the electrochemical signaling of the nervous system, photonic, acoustic, thermal, vibrational, and quantum mechanical[8] forms of physiological information transfer have been identified which may contribute to the penumbra of the NCC. Indeed, some of these forms of information transfer are faster than neurotransmission speeds and may help to explain the mysterious onset of the binding frequency that has been correlated with conscious perception. Since the living matrix minus the nervous system appears to be alive and well in animals without nervous systems, it may be worthwhile to explore its possible significance for studying any conscious behavior they may have. Moreover, since several modes of information transfer in the living matrix are found within cells as well as between or outside them, Oschman (ibid) has suggested that they may be *non-neural* correlates of a more primitive form of consciousness (NNCC?) that humans (or, at least, human cells) share with unicellular life as well other multicellular organisms.

While efforts to map the correlates of consciousness are perhaps as exciting as our mapping of the genome, it is important to recognize that correlations are not causal explanations. No one knows, for example, whether the onset of the binding frequency (or frequency band) causes conscious perception or consciousness has something to do with the selection of which coalitions of neurons ought to be included in the perceptual gestalt. Moreover, even if perception is occasioned, if not determined, by sensory information and the "penumbra" of related unconscious associations referred to above, there are forms of consciousness (such as thought, affect, imagination, valuation, dreams, and "altered states of mind") that are more active in their modification and integration of presented or preexisting components. If the presumably more complex neural correlates of more active forms of consciousness are identified, we would be even more obliged to consider whether consciousness somehow selects and organizes competing neural coalitions or associational modules, or whether it is simply produced, as an epiphenomenon, as a result of some form of frequency-related coherence (or direct interaction) among neural groups.[9] The need to explain the NCC can be extended to any non-neural physiological or biophysical correlates of consciousness, whether within

humans, other species, or even cells.[10] (Of course we'd have to have some basis for identifying conscious moments of cells before we could claim to find a correlate of consciousness.)

Defining the Problem. One strategy for developing a theory of consciousness or, more precisely, a theory of conscious systems, is to seek a gateway between the conscious and electromagnetic aspects of such systems that mediates and enables information transfer between non-spatial or non-local and indeterminate conscious phenomena, and local or spatially distributed physiological phenomena presumed to follow physical laws. In the "Theory" section below, a theory is developed of how certain quantum mechanical phenomena (a quantum *gateway*) might mediate the information exchange between the conscious and electromagnetic aspects of conscious systems. This theory is intended to illustrate how it might be possible to overcome the apparent incommensurability of consciousness and electromagnetic phenomena. At our current state of knowledge, any theory of this type would obviously be quite speculative. Even if a quantum gateway did exist, many alternative theories of how it might work could be developed. However, it is shown that theories such as the one presented here could be developed and empirically evaluated in interdisciplinary research programs that integrate the contributions of the cognitive sciences, energy medicine, quantum mechanics, and evolutionary biology.

Quantum Mechanical Background. Quantum Mechanics has developed theories of three forces—the electromagnetic, strong, and weak forces—and the particles (called exchange particles) that mediate their interactions. The electromagnetic force is responsible for chemical, electrical, magnetic, and the spectrum of electromagnetic phenomena (and their mutual interactions). The strong force holds protons and neutrons together internally and binds them together in atomic nuclei. The weak force is responsible for radioactivity. A successful quantum mechanical theory of the fourth known force, the gravitational force, has not yet been developed. The electromagnetic and weak forces have been integrated (in the theory of the electroweak force) and there have been many efforts to integrate all three quantum forces with each other and with a quantum theory of gravity in a unified theory of all four forces. For our purposes, however, it will be sufficient to indicate the scope of quantum electrodynamics (QED) and quantum chromodynamics (QCD), the respective theories of the electromagnetic and strong forces.

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QED treats the electromagnetic force interactions between pairs of electrically charged particles, such as electrons, protons, positrons (anti-electrons), and anti-protons. Virtual photons are the exchange particles of the electromagnetic force. QCD treats the strong nuclear force interactions between pairs of color-charged particles, including all the quarks and anti-quarks. Gluons, the exchange particles of quarks (and anti-quarks), themselves carry color charge. Protons, neutrons, and their anti-particles each contain three quarks and are called baryons. Pi mesons, the exchange particles between baryons, are composed of quark—anti-quark pairs. Baryons and mesons are color-neutral combinations of quarks called hadrons. Hadrons and leptons (such as electrons and neutrinos) are the building blocks of matter.

One interesting aspect of QED and QCD is that their theories of the electromagnetic and strong forces are based on models of the interactions of electric and "color" charges with temporary particles, called virtual particles, that fill the space around them. After Einstein eliminated the "aether" in special relativity, empty space has generally been called the "vacuum," although in view of how space is filled with virtual particles, some have proposed to call it the "plenum" to emphasize its fullness rather than its emptiness.[11]

Physicists have known for decades that so-called "empty space" is not empty at all. It is filled with four sources of virtual (temporary) particles: spontaneous emissions from particles, empty space, and electromagnetic fields, all associated with the *Uncertainty Principle,*[12] and induced emissions from charged particles when they interact. (Emissions from empty space are called "vacuum fluctuations," although the term is often

used loosely to refer to fluctuating virtual particles from all four sources.) The virtual particles from all these sources continually interact with one another, photons, for example, splitting into particle-antiparticle pairs and particle pairs in turn annihilating one another to produce photons. Virtual particles also interact continually with "real" particles and fields through the spontaneous emission and adsorption of virtual particles by real particles and their induced emission and adsorption in the interactions of the electromagnetic, strong, and weak forces. The strength of the electromagnetic and color forces, according to QED and QCD, each vary as a function of distance from the source charge as a result of the mutual interactions between real and virtual particles.

Electrons, for example, attract virtual particles of the opposite charge, such as positrons, while repelling virtual particles of the same charge. Outside the spherical shell of virtual positrons around electrons, the electromagnetic force falls off with the square of distance from the electron. Inside the shell of antiparticles, however, the strength of the electromagnetic force is much greater. Likewise, interactions between the electrons of atoms and virtual particles determine the strength of the electron's magnetic moment. Atomic structure, as well as the forces that respectively hold atoms and their nuclei together, are all believed to be emergent properties of the mutual interactions of real particles and the virtual particles that surround them. Similar considerations apply to molecules, macromolecules, and certain biological nanostructures such as microtubules. Their structures, vibrational modes, and any alternative conformations or polarities are negotiated not only with the surrounding physical or biological medium, but also with the virtual particles that continually interact with and shape the probabilistic distribution of their electrons. It is best to view atoms and ions, molecules and macromolecules, and certain nanostructures not as independent structures at all, but rather as steady-state patterns that emerge from the mutual interactions between the system and both its virtual and real environments.

The speculative theory proposed here is intended to be illustrative, not exhaustive. . .

Wavefunctions in quantum mechanics are used to represent the state of a particle or system of particles. The square of the amplitude of the wavefunction, when integrated over a region, yields the probability of finding particles at particular location. When the Hamiltonian representation of the system's kinetic and potential energy operates on its wavefunction in the Schrödinger Equation, the possible quantized energies of the system and the evolution of the wavefunction in time and space are determined.[13] When the state of a particle is partially determined (under the constraints of the Uncertainty Principle) at a particular time, it is expected to be consistent with the system's quantized energies and the probabilities derived from the current state of the wavefunction. Sometimes the states of several particles are "entangled," so when the state of one particle is partially determined, the state of one or more others is logically constrained.

While the temporal evolution of the wavefunction is deterministic, the time at which the possibilities it represents (as a function of time) are realized in a particular measurement or interaction is not determined at all. Thus the time of measurement or interaction (and the much popularized configuration of the measurement or interaction) determines the probabilities of the outcome. Depending on one's interpretation of quantum mechanics, if the particle survives the measurement or interaction, the measured or physically determined aspects of its state constrain the continued evolution of its previous wavefunction or the initial conditions of a new wavefunction. In the former case we could speak of a "partial collapse" of the wavefunction; in the latter, simply its "collapse."

Although it is not usually emphasized, the evolution of the wavefunction describes the many possible alternative evolutionary paths and associated states of real particles between measurements *under the constraint of the distribution of virtual particles in their environment.*

Theory. In order for consciousness to influence the brain (or living matrix) in a non-arbitrary way, it would also have to be informed by the brain (or living matrix). We propose that the elec-

tromagnetic state of the brain (or living matrix) mutually interacts with the surrounding virtual particles and alters their distribution. Any electromagnetic system would do so. Atoms, for example, interactively alter the surrounding pattern of vacuum fluctuations and the result is the cloudy configuration of electrons distributed around atomic nuclei that are described by wavefunctions. The difference between brains and atoms is that the contributions of virtual particles to atomic structure are already built into quantum mechanical laws and the resulting wave model of the atom, while the contributions of living systems to the configuration of virtual particles are not taken into account in our models of neurophysiological and biophysical processes.

To use the example of perception outlined above, let's say that the preconscious coalitions of neurons associated with respective features of the object or scene that are competing for conscious attention each leave a pattern in the arrangement of virtual particles surrounding them. Since neurons fire repeatedly (about every 25 ms, but not necessarily synchronously prior to binding) in exhibiting the neuronal interconnectedness characteristic of coalitions or assemblies, we are speaking of a temporal as well as spatial pattern. Let us furthermore assume that different subsets of coalitions intermittently and fleetingly get approximately correlated with one another in firing rate (at some point between the 25 ms time frames of neuronal firing and the 400 ms timeframes of perceptual emergence). Each time a particular combination of coalitions gets momentarily synchronized, it associated with a characteristic dynamic pattern of virtual particle activity.

Now let us make a critical assumption: that the oscillating patterns of vacuum fluctuations that result give rise to wavefunctions that entangle particles, molecules, or structures (such as microtubules or cytoskeleton states) in multiple coalitions. (This is much the way, remember, that the patterns of vacuum fluctuations give rise to the wavefunctions that describe atomic structure and its possible perturbations.) We now assume that as these wavefunctions evolve in time within the 400 ms (or greater) timeframe, consciousness cycles with pre-perceptual awareness through the different possibilities represented by the wavefunctions that emerge.

Eventually, consciousness makes a choice (presumably the outcome of considering the possibilities) and selects those wavefunction realizations that result in correlated changes in the states of particles, molecules, or structures of the selected subset of coalitions. If these changes get sufficiently amplified, neurons in the respective coalitions may move toward more correlated firing across coalitions, eventually becoming sufficiently correlated to produce "binding." The entire process may be repeated iteratively (in frames of consciousness every 400 ms or so), thereby creating the explicit content of the stream of perceptual consciousness. A similar process of iterative choice and sequential binding may help to explain more complex forms of consciousness as well.

The quantum gateway we are speculatively describing can iteratively "translate" or "transduce" brain or living matrix patterns into virtual particle patterns; give rise to conscious exploration of current options in association with the emergence and evolution of wavefunctions; and translate or transduce conscious preferences back into correlated "trigger" activity when the wavefunctions collapse—fine-tuning neuronal firing in a way that reflects the conscious choice. Some such process may characterize thought, affect, valuation, imagination, dreams, and altered states of mind as well as perception.

It would be a shame if the quest for a theory of everything failed to investigate the interdependence of quantum mechanical, electromagnetic, and conscious phenomena.

Conclusion. The speculative theory proposed here is intended to be illustrative, not exhaustive, of quantum gateway models of the possible interactions of consciousness and electromagnetic processes.[14] However, it may be in a position to make some predictions, such as the likelihood that the onset of neuronal binding can't be explained by the speeds of neurotransmission and the iterative nature of the pre-binding process at timescales that are shorter than those generally associated with perception. Functional MRIs may be able to identify signatures of wavefunction collapse in disparate brain locations, while the extension of our neuronal monitoring ability to hundreds of neuronal

sites may allow us to track gradual shifts in inter-coalition correlations of neuronal firing rates that brainwave monitoring may not reveal. Energy medicine may help us to discover the role of alternative information processing pathways that mediate binding, with implications for the kinds of quantum entanglement that may be involved. Such biophysical discoveries may help us to model the evolutionary emergence of consciousness as a function of electromagnetic or vibrational organization, which, in turn, would provide a context beyond that of humans and other primates for further developing and testing quantum gateway theories.

Perhaps most critically, the collaboration of quantum mechanics researchers with cognitive scientists and energy medicine researchers will ensure that quantum gateway models such as the one here developed on philosophical grounds, make quantum mechanical sense. It would be a shame if the quest for a theory of everything failed to investigate the interdependence of quantum mechanical, electromagnetic, and conscious phenomena.

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Larry Goldberg may be contacted by writing him at: P. O. Box 1713 • Boulder, CO 80306 • Email: lgoldberg@quantumphilosophy.org

REFERENCES & NOTES

1. For an extensive bibliography of the cognitive science literature, see Thomas Metzinger's *Consciousness: Selected Bibliography 1970-2004*, http://www.philosophie.uni-mainz.de/metzinger/publikationen/ConsciousnessBib.pdf.
2. See the review by Francis Crick and Christof Koch of their "binding" theory of visual perception in "A Framework for Consciousness," *Nature Neuroscience* **6** (01 Feb 2003), pp. 119-126.
3. Intercellular channels that permit the exchange of cytoplasm and bridging of cytoskeletal structures between certain animal cells.
4. For discussions of the controversy surrounding the possible involvement of dendrites and potentially related quantum effects in synchronized neuronal firing, see Stuart Hameroff's critical review in *Science & Consciousness Review* (Nov 2004 No 2) of Christof Koch's *The Quest for Consciousness: A Neurobiological Approach* (Roberts & Company Publishers, Englewood, CO, 2004) and Koch's response *Science & Consciousness Review* (Dec 2004 No 2). Hameroff has suggested (personal conversation, Apr 2005) that microtubule and microtubule associated proteins may form complexes across the dendrites of adjacent neurons that alternate between the coherent quantum state and decoherence (wavefunction collapse) in ways that regulate the firing of neurons in an assembly. See S. Hagen, S. R. Hameroff & J. A. Tuszyn'ski, "Quantum computation in brain microtubules: Decoherence and biological feasibility," *Physical Review E* **65** (19 June 2001), for a discussion of the feasible timescales involved that could contribute to binding.
5. For a theory of how quantum effects reflective of consciousness might mediate the long-range coordination of neuronal firing (via quantum tunneling of electrons across extracellular RNA molecules), see Ch 12 of Evan Harris Walker's *The Physics of Consciousness* (Persius Publishing, New York, NY, 2000).
6. See Crick & Koch (ibid) for this perspective on the possible contributions of a surrounding "penumbra" of subconscious activity to the successive frames of consciousness.
7. The theory of the living matrix has been systematically developed by James Oschman in *Energy Medicine in Therapeutics and Human Performance* (Elsevier Science, Philadelphia, PA, 2003).
8. Note that from a quantum mechanical perspective, the quantized carrier of acoustic, thermal, and vibrational energy is the *phonon*. Oschman (ibid) also emphasizes the possible importance of solitons, nonlinear solitary waves that are stable over long distances, in the transfer of information and energy in the living matrix.
9. Interactionism and epiphenomenalism are the two primary forms of dualism. Monistic views are mentioned in the first paragraph above. Monistic responses to the mind-body problem don't deny the NCC, but they avoid consideration of bidirectional (interactionist) or unidirectional (epiphenomenalist) interpretations by presuming that one day mind will be reduced to body, body to mind, or both to a more fundamental reality.
10. Note that consciousness could causally influence the body even as a property of matter or of an underlying reality. As a property of matter, it could feasibly have effects on material processes that aren't conscious. As a property of an underlying reality, it could feasibly influence the material expressions of that underlying reality. So questions about the possible causal interaction of consciousness and physiological process don't necessarily have to treat issues about the ontological status of consciousness. Eventually, of course, issues of reality as well as causality must be addressed.
11. Harold Putoff and Mark Comings have been among the many to prefer the term.
12. Heisenberg's Uncertainty Principle expresses the tradeoff between the possible precision with which we can determine momentum and location or energy and time. For example, in the context of measuring the state of a particle, the more certain we are about its location, the less certain we can be about its momentum, and vice versa; the more certain we are about its angular position, the less certain we are about its angular momentum, and vice versa; and the shorter the period of time over which we attempt to determine its energy, the less certain we of the exact value of that energy, and vice versa. Similar tradeoffs apply to the constraints on measuring the states of fields and empty space.
13. Evan Harris Walker has suggested (personal conversation, May 2005) that the mathematically equivalent representation of the evolving quantum state in terms of state vectors rather than wavefunctions may lend itself more naturally to models of quantum effects in the brain that might be influenced by consciousness.
14. A different quantum gateway model was developed by William A. Tiller, Walter E. Dibble, Jr. & Michael J. Kohane, *Conscious Acts of Creation: The Emergence of a New Physics* (Pavior, Quality Creek, CA, 2001).

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