From Quantum Photosynthesis to the Sentient Brain

Donald Mender

ABSTRACT

Energy harvesting by photosynthesis in "brainless" plants and green algae is identified as the root non-trivially quantum process powering neural correlates of consciousness in humans and other "brainy" animals. Thermofield attributes of solar energy flow through the biosphere's food chain are suggested as a "bottom up" mediator between quantum-coherent aspects of photosynthesis and emergent dynamical architectonics of transmembrane electrical potentials in neurons. This quantum-ecological approach to energetics of brain function as part of an open dissipative world system offers a segue, experimentally grounded by empirical evidence for photosynthetic coherence, into qualitatively gauged links between quantum tunneling and the Hard Problem of consciousness.

Key Words: anthropic, coherence, chlorophyll, dissipative, entanglement, Explanatory Gap, food chain, Fourier duality, fractal, Hard Problem, Heisenberg, observable, photosynthesis, q-boson, qualia, thermofield, transmembrane, tunneling, Z-process

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Are the Quantum Roots of Brain Function Restricted to the Biosphere's Photosynthetic Energy Sources?

It has been a great hope of quantum-neurodynamical theoreticians (Globus, 2003; Hagan *et al.,* 2002; Hameroff and Penrose, 1996; Jibu and Yasue, 1995; Penrose, 1989; Penrose, 1994; Umezawa, 1993; Vitiello, 2001) that experiments will someday prove the existence of functionally nontrivial *in vivo* Bose Einstein coherent processes firmly linked to the sentient brain (Palermo Declaration, 2013; Tarlaci and Pregnolato, 2015). However, so far no unequivocal demonstration has been forthcoming (Mender, 2013a; 2015). In this regard quantum olfaction, quantum avian compasses, quantum genetic coding, quantum enzyme folding, sustainably orchestrated quantum tubulin superpositions, and ordered water to date all remain merely theoretically tantalizing proposals with at best debatable and in many cases no experimental support. At present one must consider the real possibility that experiments may never (Mender, 2013a; Tegmark, 2000) generate the kind of ironclad examples of overt quantum neurodynamical coherence imagined as a future vindication of existing quantum brain theories.

However, there is currently available one functionally significant example of nontrivial quantum coherence that is experimentally on fairly firm ground in what seems at first glance to be a systematically non-neural domain of biology, i.e. photon energy harvesting by the photosynthetic *Z*-process (Engel *et al.,* 2007) in

Corresponding author: Donald Mender
Address: Lecturer in Psychiatry, Yale University School of Medicine, USA.
e-mail ✉ onald.mender@yale.edu
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plants and green algae, two categories of life clearly possessing no brains, ganglia, or other neuronal structures. A plausible case has been made that metal (magnesium) ions embedded inside photon-harvesting chlorophyll molecules uniquely condition a "stiffness" consistent with scaled up quantum coherence which other wet and warm biochemical entities *in vivo* do not and in principle cannot support (Howard, 2007; Tegmark, 2000). Nevertheless, despite the fact that no chlorophyll resides in neurons or in any other animal cells, we may venture to ask whether quantum photosynthesis, which has the virtue of reproducible empirical verification (Collini *et al.,* 2010) currently lacking in quantum neuroscience, could have some heretofore unrecognized relevance to the theoretical hypotheses of quantum neurodynamics.

If nothing else, it can in fact be conceded that quantum coherent photosynthesis as the initial source of essentially all energy fueling eukaryotic life (Falkowski, 2015; Lane, 2105) is fundamentally necessary if not obviously sufficient for neurodynamics associated with sentience. We can make this assertion insofar as the supercharged energy output of the quantum photosynthetic Z-process funneled through the biosphere's food chain powers virtually 100% of the conscious brain's energy-hungry function. Given that future experiments may never delineate within biological systems any definite evidence of quantum coherent macrophenomena more directly proximate than photosynthesis to brain energetics, perhaps those of us interested in quantum neurodynamics (Mender, 2010b; Tarlaci and Pregnolato, 2015) should redirect our research inquiries, particularly with reference to dissipative thermofield energy flow marrying quantum field theory and nonlinear thermodynamics (Globus, 2003; Umezawa, 1993; Vitiello, 2001), toward opportunities presented by neurocognition's "green" quantum fuel supply.

In pursuit of such a reorientation, it may be useful first to touch base briefly with overarching principles of open nonlinear thermodynamics, especially regarding the theoretical vision of emergent macroscopic quantum coherence across the broad dissipative span of our planetary food chain, powered in bottom up fashion by the foundational energy input of ambient solar photons. The most salient point is that general laws of classical thermodynamics require systems internally maintaining or increasing their own energetic order (negative entropy) to radiate a commensurate amount of heat into the environment (Lane, 2015), which a dissipative quantum-thermofield framework can represent rigorously (Globus, 2003; Vitiello, 2001). To address the related issue of quantum coherence, representation of negative entropy must take into consideration ordering of phase relations among wavefunction components, and this leads to the compensatory association of Goldstone-Nambu or Higgs bosons in the cases, respectively, of global or local symmetry breaking (Coughlan and Dodd, 1991).

Can Thermofield Theory Transform a Foundation of Quantum Photosynthetic Energy Harvesting into an Emergent Coherence-Compatible Neurobiology?

One may enlist a) the above thumbnail rules for open dissipative thermofield phenomena, b) quantum photosynthesis as the energetic fountainhead of the biosphere, and c) other established empirical biophysical evidence from diverse experimental sources to assemble d) the following detailed picture of energy flow from chloroplast to central neuron:

1) Quantum aspects of solar energy capture by photosynthesis can be framed as a kind of Heisenberg-uncertain analogy to classically chemical enzymatic catalysis. This is justifiable insofar as both green quantum photon harvesting and catalytic enzyme activity accelerate biological processes by countering the obstructive effects of energy barriers between a reaction's initial and final minimal states. Enzymes and other chemical catalysts (Lane, 2015; Loewenstein, 2013) accomplish this speeding up by lowering energy barriers; quantum photosynthesis (Engel *et al.,* 2007) works by tunneling through energy barriers. The net result of the quantum photosynthetic contribution is to add an incremental coherently phase ordered "gift" of extra-efficient "push," kick starting the entry point of eukaryotic energy flow.

2) After capture of ambient solar photons and tunneled channeling of their quantum "kick" into the energy economy of eukaryotic cells, the Z-process locks down a particular route of dissipation which both increases the order of intracellular biochemistry and contributes to

electrical gradients across phospholipid bilayer membranes. This dual organizing influence proceeds through photon-driven splitting of water molecules into oxygen, hydrogen ions (protons), and electrons in a manner that ejects both the oxygen and positively charged protons from the cell's interior while the negatively charged electrons are transported to intracellular NADP complexes. Resulting separation of protons and electrons creates an electrical gradient across the cell membrane. It is only at the end of the electron transport chain that ejected protons are finally allowed back into the cell and, before they might have an opportunity as hydrogen ions to combine into molecular hydrogen gas and escape from the cell by diffusion, reunite with transported electrons in the construction of highly ordered carbon-based biomolecules from carbon dioxide. This last step traps within intracellular biochemistry a foundation of very low entropy while oxygen remains extruded as an exothermically reactive "waste contaminant" of the extracelluar environment (Falkowski, 2015; Lane, 2015).

3) Aerobic respiration completes a deferred cellular recapture of ambient oxygen, which through controlled combustion in mitochondria reacts with carbon-based biomolecules. The mitochondrial reactions liberate ordered energy then used by neurons in the production and maintenance of transmembrane electrochemical differentials involving cations larger than hydrogen on the periodic table. In particular, monovalent sodium and potassium ion gradients subserve electrotonic and action potentials, while bivalent calcium ions help to mediate other membrane processes and molecular messenger cascades. It has become clear in purely mechanistic terms that electrical fields set up by ion differentials across membranes can transmit "signals" from perturbing "stimuli" originating outside the cell to a responsive intracellular milieu. The specific albeit architectonically varied spatiotemporal forms assumed by electrochemical ion gradients across neuronal membranes have been experimentally demonstrated, by means of neurophysiologically replicated neural correlates of consciousness and in contrast with merely hypothesized substrates such as superposed tubulin, to be crucial for at least some contingently correlative aspects of the nexus between mind and brain. From Darwinian concepts we may also convincingly deduce ways in which spatially fractal architectonics and dynamical processes with fractal phase spaces, facilitating the inward diffusion of environmental oxygen needed for aerobic support of neural membrane potentials, have co-evolved through positive feedback loops with emerging consciously correlated nervous systems "on the way to" the human brain. Neurobiologically pertinent evo-devo pathways may have included not only the randomizing symmetries of genetic variation but also, as nonlinear attractor states, the relative stabilities of reduplicative homeosis (Mender, 2010a). These and other dissipative fractal architectures could be operating to conserve information that has been ecologically scaled up from the quantum-coherent microcosm (Falkowski, 2015; Freeman and Vitiello, 2006; Lane, 2015; Vitiello, 2015).

Might an Ecologically Contextualized Thermofield Account of Quantum-Photosynthetically Powered Neurodynamics Complement a Potentially Productive New Approach to the Hard Problem of Consciousness?

The principles and phenomena of physics and biology summarized so far by the above discussion have been represented in essentially objective and mechanistic terms. Any reference to mentation has remained tethered to neural correlates of perception, comprising the "Easy Problem" of consciousness. Hence, without further development the foregoing perspective will not suffice to move extrapolations of a "green" quantum neuroscience, however well-grounded by experimentally reproducible evidence, into an epistemological or ontological framework adequate for the principled formulation of a truly sentient psychophysics deeper than mere *ad hoc* empirical correlation. A definitive trans-Cartesian leap, not merely contingently but rather necessarily bridging Levine's "Explanatory Gap" between the physical and the mental, between the brain as object and the experience of the subject, between the questions "how does it work?" and "what does it feel like?", requires a new synthesis, able to address more directly Chalmers' "Hard Problem" of the metaphysical relationships between ostensible scientific objectivity and subjective consciousness (Chalmers, 1995; 1996; Levine, 1993; Nagel, 1974).

This is not to say that quantum approaches are without any metaphysical

relevance whatsoever to the Hard Problem. An "incision point" for possible penetration through the Explanatory Gap may be located by fleshing out traditionally unexplored links between standard physical observables and consciously felt qualities, which phenomenalist philosophers have dubbed "qualia." Perhaps at this point speculative recourse to the technical artifice of an "isoqualitative distortion gauge" (Mender, 2013a; 2013b), whose extrinsic curvature (Sklar, 1976) can serve to keep qualia locally "hidden in plain sight" from the apparent causal completeness of orthodox physics, may be relevant.

To begin unpacking such a strategic device, we can return our attention to the previously mentioned entities called Goldstone-Nambu and Higgs bosons. Recall that for coherent quantum preparations, the germane negative entropy involves ordered phase relations among wave function components, which in turn entail the compensatory association of Goldstone-Nambu or Higgs particle-fields for the breaking, respectively, of global or local symmetry. We might tentatively extend such thinking further to the previously considered quasi-catalytic phenomenon of tunneling, a generator of vacuum energy both within and outside the specific setting of the Z-process. It is reasonable to ask whether vacuum energy in its narrower quantum green context may be conceptualized as betraying a kind of sub rosa hyper-anthropic (Barrow and Tipler, 1986; Gale, 1981; Gardner, 1986; Mender, 2011; 2013b) thermal exhaust, whose detectable signal in some ways mimics the scalar field of the Higgs boson. Under contingently reciprocal thermofield/evo-devo conditions, perhaps involving a classically effective ramping up of quantum coherent photosynthetic information to neurally networked scales, such hyper-anthropically epiphenomenal exhaust might exit commensurately from our universe into "parallel" regions of the multiverse (Mender, 2011).

Possible isoqualitative implications of neurobiologically scaled up green hyper-anthropy can be pursued by assigning to "subjective" qualia a causally extrinsic location beyond the relativistic event horizon of our own "objectively" accessible physical universe within the multiverse. Such remotely situated qualia, though inaccessible via locally causal mediation across spacetime, might nevertheless be nonlocally accessed through superluminal entanglement (Penrose, 2005) also engaging standard canonically conjugate pairs of "Fourier-dual" physical observables like energy and time, quantifiable qualities locally subserving photosynthetic tunneling. A fractal transformation of the quantum Z-process by dissipatively non-linear processes of coevolution in brain complexity and oxygen access could provide a spatiotemporally scale-transcendent bridge between local observables and nonlocal qualia.

To get more of a gut feel for the possibility of an isoqualitatively gauged trans-Cartesian quantum tunnel, nonlocally linking standard physical observables and qualia, it might be useful first to consider that Heisenberg's canonically conjugate operators, adapted from Newtonian and Hamiltonian paradigms to quantum mechanics, originated in the classical era as formal schematizations of intuitively understood primal qualities. Primitive qualia have long guided embodied sentient beings dealing purposefully with the existential mechanics and energetics of survival in their physical environments. One can think of animals seeking food and oxygen, or if starting with humans one can conceptualize hunter gatherers as practical instinctive protophysicists navigating their landscapes and food chains. Aristotle may then be seen succeeding hunter gatherers perhaps as a conceptual middle man, Newton and Hamilton as more recent mathematical formalizers, Einstein as the intuitive-scientific thought experimenter par excellence, and Schrodinger/Heisenberg as late abstractors.

In this light it is possible to ask, as Nagel inquired in his qualia-implicit paper "*What is it Like to be a Bat?*" (Nagel, 1974), what it must have been like to be a hunter gatherer interacting with raw material comprising the untamed geography and food sources of prehistoric times. Early humans while hunting and gathering had to get from "here to there" (distance) by expending raw muscular effort (energy) over a substantial time (temporal duration) to haul their own weight and that of their cargo (inertia related to momentum) and avoid dizzying (spinning) falls. In modern times, metrical distance has emerged through the lens of mathematical physics as an abstraction of our inherited sense of bodily translation in space; momentum is an abstraction of our sense of bodily inertia whose change is signaled by vestibular input to the brain; energy is an

abstraction of our sense of muscular "work," which has both a personal and physically measurable meaning; angular momentum is an abstraction of our spinning sense of vertigo; physically dimensionalized duration is an abstraction of our psychological sense of time passing (even the "tensed" aspect of concrete inner temporal experience resurfaces, after a Newtonian absence, in the rectified "non-unitarity" of abstract quantum wave function collapse).

All of these derivations from primitive human intuition and sensation were formalized by classical physics and became radically more abstract in quantum mechanics. Yet they can trace their roots back to a subset of conscious qualia that we share with Cro Magnons and other forbears who had no recourse to the quantitative tools of contemporary physical science. Other qualia, such as sweetness, pain, etc. may also be abstracted from human consciousness into analogies with classical observables and in fact were thus schematized in the 19th century by the German psychophysicists Weber and Fechner.

However, unlike canonically conjugate observables, "subjective" qualia a la Weber and Fechner have not customarily been interrelated by quantum physics through the Fourier dual formalism responsible for photosynthetic and other tunneling (Mender, 2013a; 2013b). Yet an occult Fourier dual interrelationship may be uncovered among psychophysical qualia (Pothos and Busemeyer, 2013) and between those qualia and the observables of orthodox physics, if we posit the aforementioned "isoqualitative distortion gauge." Moreover, configuring that distortion gauge with a curvature of connection extrinsic to the apparent causal completeness of local physics (Mender, 2013b; Sklar, 1976) should allow trans-Cartesian tunneling that is locally "hidden in plain sight" from our proximately "objective" physical universe but is nonlocally emergent with hyper-anthropically dissipative thermofield dynamics.

It may be mathematically possible to harness the above hypothesis of an extrinsic distortion gauge in a "psychophysically" unifying attempt to interrelate canonically conjugate physical observables and "mental" qualia. The reconceptualization would not merely endow qualia with both the quantitative and qualitative predications of classical physical observables but would also attach to qualia, under appropriately defined conditions, the linguistically freighted agency and formal algebraic noncommutativity of quantum mechanical operators (Mender, 2013b). One pair of suggestive isomorphisms is encouraging: isoqualitative distortion gauges may be akin to q-bosons, which change physical observables in second quantization (Tuszynski, 2013), while change may be built as well into qualia via empirically well-known habituative and dishabituative modifications of perception.

The behavior of q-bosons also happens to converge on "condensed" Bose-Einstein statistics at certain limits (Tuszynski, 1993). An approximate albeit locally hidden resonance might thereby be inferred between the quantum coherence of photosynthesis, as the ecologically embedded brain's quantized fountainhead of physical energy, and boson-like aspects of isoqualitative distortion gauges, harboring extrinsic quantum-psychophysical links between standard neural correlates and qualia.

Nevertheless, many technical hurdles loom in connection with the agenda of isoqualitatively psychophysical unification. Not least among these difficulties is the non-differentiability of locally antisymmetrical manifolds needed to model the non-commuting Fourier duality of canonically conjugate observables in orthodox physics (Penrose, 2005). Ramified superpositions already implied by neurally hyper-anthropic dissipation of fractally scaled up green thermofield "exhaust" (Barrow and Tipler, 1986; Gale, 1981; Gardner, 1986; Mender, 2011) may help to make the relevant geometries more tractable (Mender, 2013b).

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