Article

Post-Classical Phase Transitions and Emergence in Psychiatry: Beyond George Engel's Model of Psychopathology

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Abstract

This paper explores the flaws underlying Engel's biopsychosocial paradigm of psychiatric illness and offers a quantum-neurodynamical alternative that addresses these defects. It is argued that the current conceptual foundations of biopsychosocial psychiatry, insofar as they rest upon analogies between neural network theory and classical statistical mechanics, are plagued by tensions and inconsistencies among notions of causation, physical scale, and objectivity. The recent rise of a potentially more adequate post-classical paradigm, grounding cognitive neuroscience in quantum principles, is described. The possibility is advanced that this developing quantum perspective on mind and brain can transform psychiatry's understanding of mental disorders through an explanatory adequacy and a theoretical coherence superior to Engel's classically limited ideas.

Key Words: biopsychosocial, Engel, emergence, quantum neurodynamics, phase transitions, psychopathology

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Since the publication of George Engel's seminal article in Science (Engel, 1977), most etiological and therapeutic thinking in psychiatry has owed at least a partial debt to his biopsychosocial model. This paper will argue that the science of quantum neurodynamics under more recent development both necessitates and facilitates a replacement of Engel's now superannuated ideas.

Engel, an academic internist with a psychoanalytic background and an interest in psychosomatic medicine, considered all psychiatric phenomena to be a mix of biological, psychological, and interpersonal elements (Shorter, 2005). He based this viewpoint on the "general systems" approach advanced in 1968 by von Bertalanffy, who offered emergent levels of explanation as a comprehensive theoretical framework for the diverse empirical data of biological science (von Bertalanffy, 1968). Von Bertalanffly's ideas drew exclusively on classical physical constructs with no substantive reliance on quantum mechanics or quantum field theory per se.

The concept of multilevel emergence invoked by both Bertalanffy and Engel had been in the air as a potential scheme for understanding medical phenomenology

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since the 1800's, starting with Russell Reynolds in 1869 and Hermann Nothnagel in 1882, and had been introduced into the specialty of psychiatry during the first half of the 20th century by Adolf Meyer (Shorter, 2005). The historical appearance of these conceptual antecedents before the maturation of quantum science conditioned an implicit reliance by Engel's biopsychosocial model of psychopathology on classical physical analogies, rooted in pre-quantum explanations of macroscopic thermodynamics by the classically atomistic statistical mechanics of Gibbs and Boltzmann.

After Engel published his 1977 article, his classical notions about emergence in psychiatry became ever more widely entrenched. Engel's continued popularity over the past three decades has been due at least in part to the ascendance of neural network theory, which harbors tight formal mathematical parallels with the Gibbsian paradigm but no explicitly quantum isomorphisms, among mainstream scientists investigating neurophysiological correlates of normal cognition.

The non-quantum neural network model that has both dominated recent mainstream normal cognitive neuroscience and lent credence to Engel's biopsychosocial understanding of psychiatric disease posits well defined conceptual correspondences between classical particulate ensembles and webs of interconnected neurons. The correspondences involve, on one hand, a deterministic Gibbsian collective of physical particles moving in space (or, in the spin-glass version, randomly oriented micro-magnets each with two possible mutually exclusive moments) and, on the other hand, a lattice of neuronal nodes linked by a network of synaptic connections (Hertz, Krogh, and Palmer, 1991). The relevant classical phase spaces entail aggregations whose statistics conform to Bayes' rule and whose degrees of freedom encompass non-latently possessed observables. These pre-quantum phase space conformities differ crucially from "generalized" phase space's accommodations both to quantum-superpositional probability amplitudes via fiber bundle maps (Bernstein and Phillips, 1981) and to the latency of observables expressed as incompatible quantum operators via offset phase space coordinates.

A Gibbsian collective's degrees of dynamical freedom are constituted by the number of involved particles multiplied by three possessed spatial and three possessed momentum observables, and the dimensions of a non-superposed spin glass arrangement are similarly possessed albeit simpler. Analogously, a neural network is assigned strictly non-latent degrees of freedom based on the number of its individual participating neurons and on the number of possible neuronal activation states; no observable latency conditioned by canonically conjugate quantum operators applies to neural network formalisms. An energy input into the classical Gibbsian or the spin-glass collective causes a widespread perturbation which can lay down a memory trace through the system's post-perturbative settlement into its nearest locally minimal energy state. Analogously, a stimulus input will perturb a neural network and then settle into an engram as the system self-"optimizies" by equilibrating into its own local energetic minimum; there is no possibility of quantum tunneling between such neural network minima. The emergent macroscopic non-quantum phase of a Gibbsian collective may change discontinuously back and forth between solid and liquid, liquid and gas, or gas and plasma at critical points along a continuum of temperatures as long-range classically ordered correlations among dynamics of particles wax and wane, and in similar fashion the bulk magnetic properties of a spin glass may undergo similarly sudden transformations at critical temperatures. Analogously, a neural network may morph from one cognitive "phase" to another as its own aggregate balance between energy and classical correlations among micro-states evolves; the Maxwell-Gibbs-Boltzmann statistics of relevant neural network entropies preclude explicitly quantum phase-like phenomena based on superpositionally constructive and destructive interference among probability amplitude waves.

In these ways an emergent understanding of neural network theory's role in normal mentation rests on a thoroughly non-quantum analogy between, on one hand, the above-mentioned macroscopically observed "phases" of classically particulate physical collectives in the form of solid, liquid, gas, and plasma (or in the form of paramagnetic spin glass phenomena), and, on the other hand, global phase-like properties of a whole neural network. Global "mental" phases of neural networks are considered to emerge at the macro level relative to neural network configurations at the micro level, with social phenomenology emerging at a level still more "macro" than the individual mind. Concrete inferences from analogies of this sort argue that small scale changes in the configuration of synaptic connections among many neurons distributed throughout a brain are associated not only with stable memory registration but additionally with the large scale emergence of specific, discrete "phases" in consciousness. These conscious phase-states include dreaming, non-REM sleep, alpha wakefulness, and stimulus-oriented alertness (Hobson and McCarley, 1977). In explicitly computational versions of neural network modeling, such states of consciousness are said to be comprised of the forms assumed by a globally scaled quasi-serial thread emerging from the "weave" of overall interactions among specialized local parallel information processing channels that both cooperate and compete with each other (Baars, 2003).

It should be noted, however, that postulates of explicit computation are not strictly necessary for phase-emergent Gibbsian neural network theory, and parallel distributive computer analogies pose their own special challenges for phase analogies. Parallel distributive computation is limited in its ability to bootstrap locally ordered global disorder into locally ordered global order. This limitation arises because, for the many specialized parallel subsystems of a classical "brain" to cooperate and compete with one another, they must communicate across bridges which, in aggregate, cost substantial computational efficiency. Beyond a small peak-efficient number of inter-parallel links, a bridge-clogged network can begin to generate its own entropic baggage. Hence a sufficiently intercommunicative global "weave" in any parallel distributive tapestry of brain-like complexity may effectively constitute a level of scale capable not of massive brain phase transformations but only of phase entropies remaining unservicably close to that of a disjointed parallel system. For this reason, the potential for parallel distributive neural networks, insofar as they are explicitly computational, to create a critically negentropic global phase of emergently conscious "mind" remains problematic.

Nevertheless, biopsychosocial ideas about mental illness derive their principle recent theoretical support by extrapolating from the non-quantum assumption that normal individual consciousness and group psychology emerge, phase-like, out of classical neural network dynamics to which additional, explicitly computational postulates may or may not be engrafted. According to the biopsychosocial approach, specific, aberrant kinds of interneuronally connective micro-structures in the brain are linked with abnormal "phases" of individual consciousness, such as delusory thought content, hallucinations, formal cognitive disorders, mania, depression, dysfunctional anxiety, addiction, and characterological syndromes. Emergence at a yet more macro level is postulated to yield social pathologies such as family disintegration, crime, and war. Many current notions concerning the etiologies of psychiatric disease with molar implications for both the psyche and society invoke modification of connective strength among neurons across synapses by neuromodulators and neurotransmitters such as dopamine, GABA, norepinepherine, glutamate, and serotonin at the micro level in the pathogenesis of diagnoses macroscopically expressed by symptoms and signs outlined in DSM IV-R, the manual of diagnostic nosology in current use by American psychiatrists. Enthusiasm for such models is greatly fueled by clinically observed therapeutic effects of drugs that alter the neurochemistry of synaptic transmission in the human brain. All such lines of pathogenetic thinking, like their progenitors in the classical neuroscience of "normal" cognition, rest upon a variety of computational and non-computational neural network analogies to Gibbsian and non-superposed spin-glass models fashioned purely from classical statistical dynamics (Globus, 1995; Globus and Arpaia, 1994; Spitzer, 1998) without any reliance on quantum physics.

More specifically, accounting at a neuronal level for the molar clinical manifestations of schizophrenia has been a major focus of interest by classical neural network theorists. Hoffman has elaborated a detailed non-quantum model of Schneiderian phenomenology based on Hopfield networks. His work explains schizophrenic psychosis as an emergent expression of the "parasitic" attractor, a dysfunctionally deep classical energy minimum formed from the pathological coalescence of many shallower normal minima due to inordinately sustained axonal pruning in the frontal lobe; network-wide psychopathology is understood by Hoffman as abnormally indiscriminate assimilation of all inputs into the overpowering depths of a parasitic (non-relativistic) "black hole" (Hoffman, 1987; Hoffman and Dobscha, 1989; Hoffman and McGlashan, 1993; Hoffman and McGlanshan, 1994). Cohen and Servan-Schreiber have proposed a non-quantum back-propagation network model of schizophrenia deriving emergent attentional abnormalities from reduced dopaminergic gain mediated by alterations in mesolimbic projections to the prefrontal cortex (Cohen and Servan-Schreiber, 1992). Krieckhaus, Donahoe and Morgan have suggested another classical kind of dopaminergic network model for schizophrenia, whereby increased gain renders parieto-temporo-occipital cortical neurons over-associatively hyperactive because of altered D2 modulation by CA1 hippocampal input (Krieckhaus, Donahoe and Morgan, 1992). Chen has linked Hoffman's concept of a classical parasitic attractor to the actions of dopamine through the notion of "spurious" attractors arising when the noise level in a neural network is decreased by dopaminergic suppression (Chen, 1994; Chen, 1995). Vinogradov, King, and Huberman have constructed an explicitly phase-transitional classical model of fixed delusions; hyperconnectivity among neural nodes is posited by these investigators to underlie delusional thought content, and the fixity of delusions is ascribed to non-quantum phase transitions "crystalizing" false beliefs (Vinogradov *et al.*, 1992; Vinogradov *et al.*, 1998).

The biopsychosocial paradigm, which circumvents quantum concepts and propounds (a la Vinogradov et al above) that mental illness emerges like an aberrant "phase" of consciousness from a classically inter-"particulate" matrix of pharmacologically dysfunctional synaptic connections, has significant, well known flaws as an overall explanation of psychopathology. First, there exist clinical phenomena, including gross lacunae in symptomatic responses to medication, that do not support chemical neural network aberration as a complete explanation of psychiatric disease. Second, a causal role for synaptic modification in the genesis of psychopathology has been called into doubt by the question of epiphenomena (Mender, 1994); this problem is illustrated by the proposal that observed brain changes, rather than causing schizophrenia, may issue from poor nutrition and other biological stresses generated by the inattention of many chronically psychotic patients to their own day-to-day self care. Third, as Ghaemi has pointed out, the biopsychosocial model offers no intrinsic theoretical principle for apportioning the relative weights of etiological contributions by different emergent levels to any particular diagnostic category of psychopathology; such weights must be inserted "by hand" ad hoc on the basis of clinical data (Ghaemi, 2003). Fourth, and most troublesome, a specific metaphysical catch exists in a key practical claim of Engel's approach to psychosomatic psychiatry: biopsychosocial psychiatry extolls the potentially therapeutic efficacy of social and psychological interventions in somatic morbidity; however, the classical concept of emergent phases, insofar as it relies on notions of supervenience, offers no clear route by which "higher," i. e. social and psychological, levels of psychiatric phenomenology can exert causal influences on "lower," i. e. classically atomistic neuronal, elements (Malmgren, 2005). This last deficiency in emergent aspects of the biopsychosocial perspective holds special significance with regard to quantum theory.

A grammatical analogy by Margenau elucidating formal mathematical differences between latent and possessed observables (Margenau, 1977) sheds a sharp light on the relevance of the fourth above-listed classical difficulty to a possible need for quantum-theoretic reconceptualization of psychopathogenetic emergence. Margenau likens the operators that constitute quantum observables to transitive verbs acting on functions similar to grammatical objects. In contrast, classical observables are "objective" functions rather than "transitive" operators and hence serve only an objective role. If it is granted that within complete sentences, which are required for linguistic connection to the world of truth values, verbs have at least implicit subjects, then the idea posited by Von Neumann, Wigner, and Stapp that a subjective agent initiates quantum measurement (Albert, 1992; Stapp, 2004) becomes compelling.

Margenau notes that the exclusively objective character of classical observables as functions formally inheres within both microscopic degrees of freedom such as momentum and position and macroscopically emergent thermodynamic properties such as heat content and free energy. In contrast, active subjective agency implied by the verb-like nature of quantum observables is built into the intrinsic structure of quantum mechanics at every level of formulation. While Margenau alludes to this at the microscopic level with respect to the sub-atomically manifested position and momentum operators of first quantization, the same potentially macro-observable point can be made for second quantization in quantum field theory. For example, creation and annihilation of bosons, whose non-local interrelations configure the potentially macroscopic quantum phase known as the Bose-Einstein condensate, take the form of operators.

Moreover, the Heisenberg principle constraining canonically conjugate pairs of operators as observables guarantees that uncertainty in quantum measurement will reach down from the macrocosm to express itself as well in the microcosm. This happens insofar as the creation and annihilation of bosons (and of fermions as well) trade off 1) certainty in oscillatory correlations among the relevant particle-waves against 2) certainty in the number of "individual" particles. No such "downward" action can be adduced from the formal properties of classical statistical mechanics. The exclusively objective character of thermodynamically observable functions, even when they are considered under dissipatively non-linear circumstances entailing sensitivity to initial conditions and fractal phase spaces with chaotic attractors, admits no notion of an active verb with an implicit subject reaching via an uncertainty principle across progressively "lower" levels of emergence. Classical feedback, whether negative or positive, and whether serial or distributively parallel, remains purely mechanical and objective.

For these reasons it is fortunate that since the 1980's more potent quantum-theoretical developments in the neuroscience of cognition, supplementing and potentially supplanting classical neural network models, have spawned new views of mind-brain relations based on post-classical principles. Despite persistent controversies like Tegmark's decoherence objection (Hagan *et al.*, 2002; Tegmark, 2000), these innovative quantum frameworks for relating mind and brain may yet prove able to address the thorniest flaws of classically emergent neural network models. Most notable among the new quantum-neurodynamic perspectives have been the thermofield approaches of Umezawa, Jibu, Yasue, Vitiello, and Globus (Globus, 2003; Globus, 2009; Jibu and Yasue, 1995; Vitiello, 2001), along with the Orch OR hypothesis of Hameroff and Penrose (Hameroff and Penrose, 1996; Penrose, 1989; Penrose, 1994). Insights of these and other quantum-oriented investigators with reference to normal mind-brain relations, if extended into the domain of abnormal mental "phases," may come to replace Engel's biopsychosocial perspectives on pathogenetic and therapeutic aspects of psychiatric disease.

As discussed above in connection with Margenau's grammatical analogies, the clearest theoretical reason for looking to quantum neurodynamics as a way past classical flaws is supervenient restriction of causation in classical emergence to "horizontal" influences within a given level of scale and to unidirectionally "upward" influences between scale levels. The problematic nature of "downward" causation in classically emergent systems is well modeled by the semi-group structure of block renormalization in non-superposed spin glasses (Bruce and Wallace, 1989; Wilson, 1979), In contrast, the relationship between causation and scale within quantum physics is more expansive in several fundamental ways, including not only allowance of "downward" causation among scales, but more pointedly the potential relief of phase transitions from encumbrance by any rigid notion of scale whatsoever. This tendency toward a loose metric of scale relates to quantum ambiguities in the concept of space.

No quantum ontology yields an unambigious understanding of space, and the irreducible spatial ambiguities of quantum theory may be expressed in several ways, at least partly depending on the interpretative ontology employed. First, as previously noted, the active agency of the canonically conjugate operator in quantum observation, seen through the interpretations of Von Neumann, Wigner, and Stapp, may account for causality breaching emergent levels of scale in a downwardly counter-supervenient way not commensurately explicable via non-quantum perspectives. Second, as highlighted by Bohm's interpretation of quantum physics, "guide wave" dynamics require entangled non-locality as a consequence of measurement. Third, in a decoherent account of wave function collapse, features of a "larger" embedding system must be interpolated between the quantum states of a "smaller" embedded object of interactive reduction. Fourth, according to Everett's "many worlds" interpretation of collapsing superposition, limiting the configuration of space to one universe is not an option for physics. Fifth, Born's interpretation of the quantum mechanical wave function reveals that particles, even when not subjected to the uncertainty of measurement, must be regarded as probabilistically "smeared" throughout space. Sixth, quantum field theory implies that all particles which might be considered distinct in a Gibbsian context but which in a non-classical framework have the same quantum numbers harbor a shared identity. Seventh, the "background-independent" research program of quantum loop gravity now beginning to influence string theory points toward an eventually total obsolescence of a priori spatial scaffolding in the conceptual foundation of any unified physics; it is anticipated that unification will completely replace distance with observables such as energy in the delineation of scale (Albert, 1992; Smolin, 2001; Treiman, 1999).

All seven of the above points suggest that quantum notions of physical phases and their transitions might be available for adaptation to normal and abnormal modes of consciousness without the most causally crippling of rigidities linked to emergently scaled classical properties of unambiguous spatial distance. Post-classical physical paradigms may thus come to contribute their distinctly counter-supervenient capabilities to future concepts of mental "phases" and in the end may completely supplant the directionally limited notions of multi-level causation borrowed from systems theory by classical biopsychosocial theoreticians.

Quantum neuroscience even as it now exists in its first stages of elaboration reaches beyond classical neural network foundations by postulating that states of consciousness are not simply macroscopic manifestations emerging from aggregations of optimized micro-connectivities among discrete neurons. Instead, mental "phases" of the quantum-inclusive brain arise also in a more penetrative way throughout the brain's entire bulk, both inside and outside the neurolemma, from quantum-field-theoretical symmetry-breaking processes. These broken symmetries involve a potentially infinite number of inequivalent "vacuum" states, each configured by non-local Bose-Einstein-statistical correlations among orientations of local electrical dipole moments across water molecules. Coordination between the above quantum-field-theoretical vacuum phenomena and classical synaptic events is achieved via essentially non-degradable solitons, traversing proteins spanning a continuum occupying both intraneuronal and extraneuronal compartments. Such protein-mediated afferent and efferent influences if sufficiently energetic can shift ordered water from one vacuum state to another, and those shifts are then said to constitute the basis of conscious memory formation. Vitiello has proposed and Globus has refined the idea that the durability of this vacuum-encoded memory is promoted by dissipative thermofield exchanges between the brain's ordered water and the time-reversed analog of a "heat bath." Jibu and Yasue have suggested that sub-thermal quantum fluctuations reflecting spontaneous tunneling among vacuum states may countervail to degrade memory over time. Penrose and Hameroff have built upon and superseded such quantum-field-theoretic concepts by marrying the quantum to gravitation in their "Orch OR" (orchestrated objective reduction) theory. According to Orch OR, gravity plays a key role in the water-controlled collapse of specific dimeric tubulin protein superpositions, and the process results in emergence of conscious "qualia" originating beyond the Planck energy. A subjective variant of this theory, harking back to the interpretations of measurement by Von Neumann, Wigner, and Stapp, has also been proposed (Globus, 2003; Globus, 2009; Hameroff and Penrose, 1996; Jibu and Yasue, 1995; Mender, 2007; Penrose, 1989; Penrose, 1994; Vitiello 2001).

A catalogue of newly introduced, post-classical phase change types implied by the above accounting of quantum brain theories includes: 1) quantum vacuum phase transitions of ordered water energized by external stimulus inputs, 2) tunneling among phases in association with spontaneous sub-thermal quantum fluctuations, and 3) transformations across gauge-theoretic domains. The third post classical phase change type entails negentropically broken quantum-field-theoretic symmetries of Coulomb, Higgs, and confinement phases giving way to the massively entropic local supersymmetry of quantum gravity in relation to the Planck energy (Bruce and Wallace, 1989). Quantum-oriented assimilation of all three post-classical phase change categories (i. e. stimulated, tunneling, and gauge-theoretic types) into the broader perspectives of neurodynamic science may prove to be key signposts along a space-independent path affording psychiatry the opportunity to extend quantum-paradigmatic insights about "normal" mental and social phenomenology into the neurophysics of individual and social psychopathologies.

In particular, a "quantum psychiatrist" might be able to entertain the following hypotheses: 1) The energizing of quantum vacuum phase transitions by "false positive" input from aberrant protein solitons may underlie the emergence of hallucinations. 2) Imbalances between memory-conserving dissipative thermofield exchanges and memory-degrading sub-thermal quantum tunneling may generate both the dysfunctionally durable recollections of post traumatic stress disorder and the deficient recall of organic amnesia. 3) Aberrations in wave function collapse, insofar as they interfere with the "grammatically transitive" agency of observational measurement, may help to explain the abnormal volition associated with compulsive, impulsive, and addictive disorders. 4) Flaws in the gravitational orchestration of tubulin state vector reduction may subserve, in their quantitative aspects, formally disordered thinking. 5) Qualia-accessing aspects of faulty Orch OR may underlie disturbances of mood including disruptive anxiety.

Additionally, with the aid of quantum-field-theoretic neurodynamics, it might be rigorously possible for a "quantum social psychologist" to conjecture that collective psychopathologies (the "madness of crowds") emerge from solitonic interchanges between quantum-ordered water and embedded classical neural network proteins; these mutual influences might be interpersonally transmitted as the impact of solitons and phonons on language and pheromone exchange. It might also be rigorously possible to hypothesize that analogs to Bose-Einstein-condensed and Fermi-gaseous phases organize statistical properties of pathologically herd-like and maladaptively hermitic behavior.

All such quantum-neurophysical reinterpretations of psychopathology must, of course, be fleshed out to the point of empirical testability. Development in that direction may await more detailed refinement of foundational quantum neurodynamics in their normal theoretical domains.

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