

Quantum Realities and Medical Practice

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INTRODUCTION

Quantum physics challenges our view of Reality. Many interesting questions have been raised by twentieth-century physics, as to the nature of the deepest level of reality. That doesn't sound like a *medical* concern, but it is: In affirming our commitment to evidence-based practice, we assert that we base our work on reality; thus we must revise our opinions about reality as new evidence comes to light. Familiar terms, such as *reality*, *being*, *existence*, etc. take on new shades of meaning when dealing with the implications of the new physics.

The subtleties of quantum physics are difficult to grasp by those of us who are not experts, who do not have a solid mathematical background, and we are beholden to those experts who interpret the findings to a general public. However, there is still much in quantum physics which confounds even the experts, for the findings seem to contradict ordinary experience and long-accepted theories of what is real.

In trying to grasp its meaning, surely we can be forgiven for wanting to translate its lessons into non-mathematical descriptive models in the mind which help simplify that which is complex, and which make it easier to correlate concepts of the small and the large, namely our concepts of “the quantum” and “the classical” as separate realms.

The goal of this modeling process is to make friends with quantum concepts which then may no longer seem weird. The process leads toward new ways of thinking about healing,[1] and toward a more coherent worldview, with implications for individuals and for society at large. In doing so, we might realize that in an important technical sense we are also caught up in a *mythopoetic* enterprise, in that reality is showing itself to be nonlinear, many-layered, and perhaps even meaningful.

THE CHALLENGE OF SIMPLIFYING COMPLEXITY

In writing of a project to model galaxy formation, Boylan-Kolchin presents a dramatic image spanning 150 million parsecs, with nested insets which zoom in, each by a factor of 10,000 : “It is

this huge range in scales that makes modeling of galaxy formation such a challenge.”[2] The aim here is simpler: to compress the cosmos into an impressionistic model which, when run as a thought experiment, seems to account intuitively (if only roughly) for the way the cosmos is seen to work, yet which still allows plenty of room for expanding in any dimension that new evidence may require.

WHAT IS THE NATURE OF ULTIMATE NATURE?

This model begins by defining *cosmos* as the “All that is,” physical and abstract. We generally define *real* (at least in casual speech) as that which is physical, brought into *order* (Greek: *kosmos*) by links of mechanistic causation. We also call this *nature*, and label that view as *naturalistic*. We then relegate any remaining aspects of the “All that is” to the abstract realm of thought. In the light of quantum mechanics (QM), we must include the abstract in our concept of cosmos, for that which has effect must be acknowledged to be real. Otherwise, we fall into the trap of construing cosmos as imaginary, at least in part. In QM especially, the maths of probabilistic causation are very much a part of the real, and must be included in the concept of cosmos. At that point the physical and the abstract alike emerge from the one reality, Being itself.

What Does It Mean To BE ?

In simplest terms, Being is that quality which distinguishes between something and nothing. Yet “nothing” may not become “something” without Energy, nor may we have Energy divorced from the quality we call Being. Therefore it seems both reasonable and convenient to postulate the equivalence, or at least the complementarity, of Being and Energy. One finds it hard to proceed further without switching (prosaically or not) into a poetic mode of description: *Being is One. Being is reality, a quality unquantifiable, undefined and without limit, indivisible, inextinguishable. Once Being has appeared non-being can be no more.*

Being is what IS is, what Existence is made of. Existence is a wrinkle on the bed of Being. Existence twisted into threads must ultimately unravel, but only then can Being cable it with other strands to weave and then re-weave the tapestries of form.[3]

WHAT KIND OF COSMOS IS THIS?

Quantum physics challenges the mechanistic model in important and unexpected ways, especially these:

- 1) there is interaction between consciousness and physical outcome;
- 2) there is a deep reality which is unlimited by space or time, *i.e.* nonlocal;[4]
- 3) an uncertainty principle (Heisenberg)[5] limits precision of measurements;
- 4) two quantum objects related by *entanglement*, though separated in space, react together instantaneously; the quantum state of entangled objects may not be described separately.[6]

The proper interpretation of quantum experiments is still actively debated, and here we mention only a few theories, especially interesting for our purpose. The “standard model” is that of Bohr, Heisenberg, *et al.*, worked out in Copenhagen in the decade of the 1920s.

Fuchs[7] advocates Quantum Bayesianism (or “QBism”), which seeks to account for subjectivism, while denying nonlocality. In 1986 Cramer[8] presented a transactional interpretation which incorporates nonlocality. Ghirardi, Grassi, and Rimini (1989) have presented a continuous reduction model involving gravity. Though the effect is exceedingly weak the proposal is interesting as a possible bridge to a unified theory of quantum gravity.[9, 10]

Various other proposals seek to account for the non-intuitive non-mechanical “weirdness” of the standard model by introducing additional weirdness, as in the multiple universes theory of Everett.[11] These debates center around the “collapse” of the probabilistic wave function, which is also referred to as *reduction* or *decoherence*. These terms refer to the selection of one of a pair of superposed quantum systems only at the point of some interaction (*observation, measurement*) with consciousness. Until observed, the quantum state is predictable only probabilistically. It is not a linear direct mechanistic operation.

This association with consciousness suggests, as Penrose has noted,[12] that we will not have a complete picture of consciousness without also having a satisfactory theory of reality. Recent experimental findings seem to confirm that the orchestrated objective reduction (OrchOR) theory put forward by Hameroff and Penrose (see below) represents an important step toward such a unified theory of cosmos and consciousness.

There are many implications. Most compelling perhaps is the revealing of an abstract (nonlocal) aspect of cosmos which is not subsidiary to its physical (spacetime) aspect. Behind every physical (spacetime) object there is an abstract “cloud” of energy-information.

Is Quantum Mechanics a complete theory?

Einstein, with colleagues Podolsky and Rosen,[13] examined that question in their pivotal EPR paper in 1935. It concluded that QM is not complete, because the theory does not have an element which corresponds to every element of reality. The question was re-examined by John Bell[14] who in 1964 advanced a theorem which opened the way for a physical experiment which could answer the problem: If reality is *local*, a particular quantum experiment (comparing two widely-separated entangled photons) would yield certain inequalities.

Alain Aspect and colleagues[4] performed the experiments in 1981, and reported, “ Our results, in excellent agreement with the quantum mechanical predictions, strongly violate the generalized Bell’s inequalities, and rule out the whole class of realistic local theories”. The experiments have been repeated with many variations to rule out possible loopholes in technique, and the effect has been confirmed in open air with source-detector separation of 100 km.[16] Two entangled photons react together instantaneously; there is no speed-of-light delay. Reality is nonlocal.

Note, however, that it is the instantaneous “transfer” of the state which is nonlocal. Establishing the entanglement condition requires a physical relationship. In accordance with Landauer’s principle[17] that *information* is physical, the state cannot be used directly for faster-than-light communications. It does however have application in quantum key cryptography as well as in computation and an increasing number of other fields, medicine included.

The mystery of infinities

The concept of an abstract realm confronts us inevitably with infinity:

... what to do with those endless tails of trailing decimals wafting beyond our sight into that nebula of number / where primal chaos still holds sway[3] ...

Informally speaking, we assign to the abstract realm concepts which are not physical (not “concrete”), that is, those objects (of thought) which are not analyzable as force or mass, nor can they be positioned in space and time. The “many colors” of infinity include:

- Singularity, as at the Big Bang and in black holes;
- Gödel’s Theorem (non-computability: formally undecidable propositions);
- Cantor’s Dust (the Cantor set of uncountable thirds);
- Hilbert Space (an infinitely dimensioned array);
- Mandelbrot set (fractional dimensions); and most anciently,
- Zeno’s Paradox (an infinitude of halvings in the countdown from one to zero).

A practical guide to physical numbers

An interesting exercise for an idle rainy afternoon is to make a Möbius band (∞) from a narrow strip of paper: make a half-twist and connect the ends to make a continuous surface. At some arbitrary point mark a zero point, then write a positive powers-of-ten number scale, zero to infinity, allowing extra room for detail in the zero to one range; the infinity end will be on the blank side behind the zero. We do not need now to fill in the negative number scale on the blank side. Note however that zero and infinity are in effect a complementarity in which each helps define the other.

Near zero, mark “(z)” as a reminder of the indeterminably small numbers in the *Zeno Zone*. The smallest physical numbers we are likely ever to meet are the Planck units: for time, 10^{-43} seconds and for distance, 10^{-35} m. The Planck units mark a boundary between relativistic spacetime phenomena, and the nonlocal abstract zone of faster than light (FTL) effects, such as quantum entanglement.

The character of the physical world below the nano-zone, 10^{-9} m, remains largely obscure. Small molecules and atoms appear in the 10^{-10} m range, and quarks are 10^{-16} m or so. Below that, physical detail is mostly theoretical, but as Feynman famously said, “There is plenty of room at the bottom.”[18] Quantum gravity and loop and string theory research (with M-theory) are expected by many to help fill in our knowledge about the near-Planck region and its interaction with the abstract world.

THE BOUNDARY PROBLEM

The pulsed nonlocality conjecture

In asserting the inseparability of Being and Energy we posit Being as a nonlocal continuous function; Energy is construed as waveform, with a frequency of 10^{43} Hz. Here let us interpose a conjectural thought experiment about the boundary of the physical, which quite naturally will look at the boundary problem from its physical aspect.

Imagine a projected lecture slide[19] divided by a single horizontal line of dashes, which separates the whole-cosmos physical realm defined by space and time from an indefinite abstract realm. Each dash represents a Planck time pulse (10^{-43} seconds) of energy. Conveniently, the arrow of time has been paused at NOW, at the interval between two Planck-time ticks:

1. In the succession of energy pulses local states of the whole-cosmos are read and integrated, preserving the relationships among all quantum objects. We will imagine that these data are stored (nonlocally) in Hilbert space; the interval between the ticks (“picks”) represents reduction (decoherence) of the wave function. Being is deemed to persist even while Energy is pulsatile;
2. At the subsequent pick the whole-cosmos is re-created, its energy assigned to mass or force and adjusted for momentum and other properties of each object as recorded in Hilbert space;
3. Personal consciousness arises through integration in the brain of quantum data across many picks, providing a non-local *screen* on which is projected *content* processed from sense data at ordinary local neurological scale.
4. This is consistent with the Hameroff-Penrose proposal[10] of orchestrated objective reduction of quantum states in neuronal microtubules (as mentioned below). The frequency of Planck time ticks also sets the speed limit of light, which is one term in the Planck time formula.

By this sequence, abstract (Hilbert) space becomes the observer who *measures* the transaction, sustaining a cosmos which is actualized even in the absence of existing sentient beings. The nature of cosmos is thus “realistic” (naturalistic), yet the actuality of the whole cosmos is both local and nonlocal.

Entanglement

In his 1935 paper, Schrödinger referred to entanglement as “the peculiar situation”. He was describing quantum systems which, after temporary physical interaction, when separated again, cannot then be described in the same way as before:

“I would not call that *one* but rather *the* characteristic trait of quantum mechanics – the one that enforces its entire departure from classical lines of thought. By the interaction the two representatives (or Ψ -functions) have become entangled.”[6]

In 2007 Horodecki *et al.* [20] wrote of entanglement as “a new resource as real as energy.” More recently, Krenn, Zeilinger and others[21] wrote “Entangled quantum systems have properties that have fundamentally overthrown the classical worldview.”

Entanglement is multi-dimensional. In reporting a (100x100)-dimensional entangled quantum system, Krenn et al.[22] wrote, “Increasing the complexity of entangled states by expanding their dimensionality allows the implementation of novel fundamental tests of nature, and moreover also enables genuinely new protocols for quantum information processing.” This implies that there are, or could be, multiple levels of relationship between quantum systems, for example drawing into coherence and stabilizing relationships at many degrees of complexity throughout the cosmos.

A quantum system may be a photon, quark, cluster of quarks, atom, molecule, *etc.* After a perturbation of a “single body” an entanglement condition spreads to related bodies (“many-body” entanglement). The condition propagates to other bodies (quantum states/systems) through time, related to complexity which grows as systems entangle systems. The entanglements become established in a (nonlocal) hierarchy of systems which change states simultaneously, irrespective of the distances between them.[23, 24] One is led, on present evidence, to think that entanglement is a cosmic connecting principle, and that cosmos is a structure of entanglements.

Orchestrated objective reduction

The Hameroff and Penrose theory of consciousness,[10] designated OrchOR, is a multifold theory which treats quantum reduction as an objective physical event, and provides a description of the locus and process by which conscious events are realized in individuals, advanced by a

mathematical physicist (P) and an anesthesiologist (H). Diósi[25] and Penrose[10] had done prior work on objective reduction of the wave function (which *inter alia* resulted in the quantum-gravity link mentioned above). Hameroff had identified brain neuronal microtubules (MT) as the locus of effect by inhaled anesthetics.[26]

Neuronal MT, 24 nanometer in diameter, are present in the cytoskeletal structure of all nucleated cells, but are especially numerous and well-organized in neurons. They consist of an alternating spiral latticework of proteins, alpha and beta tubulin, winding around a central cavity. Electron crystallography studies have shown a “quantum channel” in tubulin, through which dipoles of “information current” (as I am calling it, informally) can flow to accomplish quantum computation. The Bandyopadhyay physics group[27] in Tsukuba Japan has demonstrated quantum vibrations in MT, strongly supporting a role in the generation of consciousness.

In the OrchOR theory, brain neuronal microtubules in concert (entangled), at sufficient information density, generate discrete events of waking awareness as the basic experience of consciousness. The pulsed nonlocality conjecture (metaphorically) imagines the result as a mental “screen” on which may be projected data from the sense organs, integrated within the brain at ordinary neurological scale.

THE NOETIC REALM

Seeking a neutral and nonsectarian term for the abstract aspect of the whole cosmos, I have suggested *nuocontinuum*,[28] based on the Greek word *nous*, for mind. It remains an appropriate term in the light of the pulsed nonlocality idea, which might itself be a superposition: whether the “pulsing” is seen as local or nonlocal depends on which side of the Planck boundary an observer has chosen (mentally) to stand.

Quantum theory seems weird only when we search for an intuitive description while clinging to a rigid materialistic view. We may not then reject the abstract levels of mind-consciousness in the cosmos, because intuition is itself an abstract function.

Our capacity for consciousness increasingly opens before us an endlessly entertaining and manifold realm ranging from mind to meaning. Our ideas of reality must continue to unfold as

new evidence emerges, for we, too, “are cosmos”, a quantum state that especially deserves to be celebrated.

Layers (and layers) of Abstraction

The experiences of humanity, as implied by ancient art (such as at the Lascaux caves), and especially as expressed in writings ancient and contemporary, bespeak a many-layered realm of the Abstract, encompassing mind, mathematics, model-making, mythos, mystery, and meaning; and no doubt, much more, reminiscent of Kantian categories. This string of M-words might well guide us in further exploration of the abstract realm. All of these objects of thought share the characteristic of nonlocality. That is, though the thoughts must be processed in a living brain, the mental product itself cannot be fastened upon coordinates of space and time.

If the cosmos were set up in accord with the *pulsed nonlocality conjecture*, we would expect the nonlocal realm to provide a repository of data by which quantum states could “remember” the conditions between one plick and the next. Perhaps we must posit something like the persistence of vision in a series of discrete retinal images, permitting us to see motion as continuous, even though projected from a series of still-frames. Metaphorically speaking, the brain projects onto the screen of mind the data it has interpreted from sensory (physical) inputs, as well as data from the brain itself, interpreted as “inner experience”.

The mathematical phase space known as Hilbert’s Space is such an abstract construction, most easily described as an infinitely-dimensional array, incorporated into the whole-cosmos aspects of quantum theory.

Mind

Here *mind* must be sharply distinguished from the organ which processes it, the *brain*. As consciousness seeks to identify its origins, we still do not yet know in physical terms just how the data inherent in this string of abstract M-words are stored. Perhaps loop quantum gravity theory or the string theories (with the M-theory which seeks to unify them) will provide a better description of “ultimate nature” in a physical sense,[30] but with a new conceptualization of time.[31] For the present we must make do with concepts such as *quantum vacuum*, or *quintessence*, or perhaps *proto-consciousness*.[10]

Mathematics

Mathematics is an abstract system of logical relationships which may be verified both internally and in reference to physical systems (when there is a doable experiment by which to test it). We consign it to the abstract realm since its findings are generally applicable, in appropriate physical contexts. For example, the familiar formula $d = r t$ (distance equals rate times time) is applicable everywhere, but like any thought object may not be positioned in spacetime. Its symbols are arbitrarily chosen: the relationship could be expressed just as well by any other arbitrarily chosen set of symbols ($\Delta = \text{£ } \text{道}$), so long as the interpretation (representation) of the symbols is made clear.

There are other systems too which are based on nonlocal systems of logic, outside the purview of mathematics conventionally defined. Consider the grammars of our languages which specify meanings in various ways: word order, for example, and verb tenses and rules about modifiers of meaning. Consider musical (and dance) systems of notation, which specify pitch, rhythm, movements, etc. and are also “languages” applicable anywhere, among persons trained in the system. Consider philosophy’s use of notation systems to express logical relationships, and of course systems of computational logic.

Model-making

Model-making, such as we are engaged in here, also qualifies as non-local activity. Though a model properly represents a physical object, there are inevitable (and useful) differences between the object and its representation, such as of scale and function. As in the painting by René Magritte (1898-1967), “This is not a pipe.” The image of the smoker’s pipe is not the pipe itself, nor is the image *local* as such. The image somehow is “in the mind,” thus nonlocal, even though physically it is an arrangement of pigments on canvas within a reference frame, the frame of the painting, which can be repositioned within the larger frame of cosmos; and of course, the brain which is “reading” the image is a physical object.

Mythos

Of all the sets of experiences of humanity through time, the impact of the set of experiences related to the domain called “spiritual” has been especially enormous, both in the sense of “vast size” and an older use which hinted also of that which is “ominous.” I hesitated to refer to *spirit* at

all, since understandings of it are so varied and vexed, yet it is always there whatever the culture, supporting those who are aware of it, through days of mourning and other difficulties, as well as in times of celebration, inspiring (in some sense) all human creativity and all of the arts. It engenders our impulses to create religions, and it lies at the heart of impulses to reach out to help and to heal in times of misfortune, misjudgment, and misunderstanding.

Unfortunately it is also active in pathologic and destructive ways, fomenting aggressions of various kinds, and seemingly endless wars. Perhaps the reason that we have so much difficulty with these darker aspects of the “spiritual realm” is that spirituality too is nonlocal. It is not a physical object that is easy to “get a handle on” when problems are created. In such psychologically *activated* situations interventions seem to have even greater uncertainty of outcome than usual, though I am not able to cite evidence for that impression. Obviously, here we have made complete the transition from a paper about modeling an interpretation of quantum physics to one which is (also) a philosophical essay.

By using the term *mythos* I hope to encompass all of the symbol systems which bear on such concerns. As a global culture we have confused the term *reality* with the idea of physical (including historical) actuality, and we have come to denote “myth” as meaning false, fueling fires of EITHER-OR conflicts about science and religion. Here *myth* is defined not according to tests of true versus false, but in terms of psychological efficacy in representing and supporting the meaningfulness of life, and the healthy continuity of human cultures, realizing that the symbols are speaking in non-literal representational ways. Such an approach encourages us to be as fully in accord as possible with cosmic actualities, physical and abstract.

Mystery

Yet the world of the abstract remains a realm of mystery, heavily laden with turbulent histories, particularly with respect to “spiritual” abstractions. Hoping to side-step unproductive discussions about “your spirituality” versus “my spirituality”, etc., and allowing us to think more dispassionately about abstraction in general, I use a neutral nonsectarian term for the abstract realm, *nuocontinuum*[9], the multidimensional continuum which (especially by its mathematical content) contains and supports the spacetime continuum, as outlined in the pulsed nonlocality conjecture. Would this perspective help analyze the dynamics of abstraction, by which the global culture might hope to react in constructive ways?

Would *symbolic dynamics* (SD, a math new since 1938) offer some help? As presented in its foundational paper,[30] SD was developed from traditional theoretical dynamics, separated at a natural fault line (if I may be permitted to call it that) between differential analysis and “a more abstract symbolic analysis.” The quotations in this paragraph are from Morse and Hedlund: SD “involves a characterization of the ordinary dynamical trajectory by an unending sequence of symbols termed “a *symbolic trajectory*.” A *symbolic element* (defined as a symbol taken from the trajectory, T) is analogous to a line segment used in analyzing for recurrence and transitivity as in traditional analysis, to be applied in information (computational) theory.

A recent paper[33] and a review[34] characterize the recurrence and transitivity of SD as “remembering” and “forgetting,” which hints of a possible approach to the symbolic dynamics of *mythos* and *maths* for analysis of such questions (as in the *layers* section above) of how quantum states could “remember” quantum states between one plick and the next, and of how Earth’s *mythos* might be steered toward greater stability. *Mythos* and *maths* are usually treated as noncompatible enterprises, but both are properly classified with the abstract realm, and symbols are symbols, however different their representations may be. We note too that Schrödinger[6] used the term *representatives* in referring to quantum states Ψ , implying that he was thinking of the observable quantum state as a *symbol* of some deeper reality of a quantum object (system).

Medical practice implications

Though medical interventions limited to the quantum mechanical level seem remote and presently out of reach, the properties of nonlocality and entanglement point toward a more general and pervasive systems-connectedness than envisioned by locality-based systems theory. The most immediate impact on medical practice perhaps will lie in the information science fields of quantum computation and cryptography, which could revolutionize medical information systems of all types. As discussed above there have been promising recent advances in support of quantum mind theories of consciousness[10, 27], which broaden the field of considerations of interest to neuroscience research generally.

Quantum dots (QD) are fluorescing nanoscale semiconductors, which as a quantum system can be entangled with single photons. QDs have been used experimentally to enhance imaging of neoplastic disease in mice, with improved resolution and precision.[35, 36] A new entanglement-enhanced quantum microscope uses an entangled photon pair as illumination source to obtain

better visibility than with a classical light source.[37] Eventually, patients will likely benefit from new findings using these new technologies, but clinicians will need a basic level of awareness of the sciences involved if they are correctly to interpret and implement new technologies.

The medical profession: a wider view

In our reductive specialized world it often takes several practitioners to treat an illness, so it is not surprising that affirming a big picture takes observers from many disciplines. Medicine, with healthcare in general, seems eventually to encounter the full spectrum of human concerns, so it is perhaps now easier to bring into perspective Osler's optimistic observation of a century ago that medicine (broadly defined), "forms a remarkable world-unit in the progressive evolution of which there is fuller hope for humanity than in any other direction." [35]

That is a sentiment which was in mind in published correspondence,[36] to the effect that humanity itself is in some sense the patient for contemporary medicine. However, that author, now older and with much more measured optimism would hold that if that is to become so, all disciplines must contribute to the ever-changing world-view projected from the oculus of the cosmic dome. Could not such a view help bring all human civilization eventually into some more hopeful sort of healing circle?

Coda

*The more widely we do see
The greater is the mystery,
Yet more vibrant then
the Beauty of it All.*

*The real M-theory is the
Universe of Me.[3]*

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