

## Is Quantum Magic Behind Life, Mind, and Rational Machinery?

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*How did our universe develop complexity and intelligent life? Quantum mechanics may hold the key. First, a classical universe could not form complex orderly structures. Second, both the time-asymmetric nature of wave evolution and collapse, along with the correlative power of entanglement, spreads increasing organized possibilities forward in time. We already know that quantum mechanics aids the efficiency of photosynthesis, it may also help drive evolution and the powers of the mind, "free will" in particular.*

How is our universe able to develop complexity and intelligent life? Is there a reason why, and can we know or at least get insight into either of these big questions? Let's first ask: could a classical universe turn out like ours did? You might be tempted to start by saying: maybe, just look at the Solar System and other gravitationally-bound complexes. But no. Yes, solar systems are impressive, but are fragile to outside interaction. They can't handle hooking-up with each other. What if atoms were really like solar systems governed by *classical* electrodynamics? First, the electrons would quickly radiate their orbital energy and collapse into the nucleus. But even if some special exemption prevented that alone, plenty other traits would be wrong for "building" purposes. Atoms would not have definitive identities. Even taking nuclei as givens, electrons could orbit at any radius and with any eccentricity. Most relevant to world-building: atoms could not link up to make stable molecules, even aside from losing the clarity of atomic speciation. Things would be a mess despite the technicality of expressing orderly laws!

Why are things not as outlined above? Because quantum mechanics. The quantization of orbital angular momentum confines electrons to distinct energy levels, but positional uncertainty also leads to an effective "cloud" of electron presence in-the-round instead of a step-ringed disc. Relations between these stable systems allow for stick-together construction of definite molecules thereby. All alanine is alike. Very fortunate for us, so to even have bodies, and then bodies that "work"!

This is a crude insight and not very illuminating per se, altho fans of teleology can wonder if it's part of the "why" of our world (whether you believe in a "someone" or ultimate cause out there, or selection from a multiverse, or Wheeler's Ouroboros-style circular manifestations of consistency for observers.) There are more subtle features and implications of QM that I believe are more relevant to further refinement of the growth of complexity and mind itself. In particular, I argue here that altho it apparently does not "technically" violate the Second Law of

Thermodynamics T-2, quantum entanglement can lead to an *effective* net increase in "order" in a closed system. Sure, planets aren't CS's anyway, but this process might help evolution along as I will explain. This correlative property may also be useful in the exercise of "will."

We are trying to explain how "intelligence" and "purpose" *etc.* can develop in a world like ours. Let's pivot to clarify what sort of capabilities and traits are we trying to explain. Before I present my own perspective, I offer some criticisms-by-thought-experiment of simplistic and reductionistic ways of thinking. Simplicity and positivism are certainly useful in proper context. Yet anyone not an ideologue should suspect they have their limitations, which is still the job of critics to uncover.

The popular functionalist perspective tends to define abilities almost behavioristically. Consider the wrangling over the implications of Searle's famous "Chinese Room" [1] for definitions and theories of "understanding." Briefly: a man who does not know Chinese is inside a room filled with elaborate rules he can understand and use (papers telling him how to respond to various questions in Chinese.) Manipulation of these directives allows the operator to output sensible answers in Chinese to questions in Chinese. Impractical, it is of course a principle-centered thought experiment. Searle says that "the room" (in the context of accepting that it is not the *man per se* we are asking about) does not really "understand" Chinese. More reductionistic critics say that, yes it does - essentially because it acts like it does.

I don't think that the CR really understands Chinese, even as a greater system. Yet what is proved there about possible systems in general? Consider the analogous but more focused "Addition Room." An innumerate person inside the AR just looks up and provides stored answers to integer addition requests. But the AR does not at any level know *how* to add. Not a true CI system, it responds correctly without "doing addition."

The AR does challenge *behavioristic* functionalism, more clearly than the CR does. It presses us to consider what is being "done inside," to accept the key significance of how something is done and not just that it can be done. Without going into details: I think that the AR supports for example Roger Penrose's perspectives on intelligence being more revealed by its capability for insights, such as into Platonic truths, than just by overt accomplishments like winning chess games.

So how does QM help to enable evolution, thinking, and other growth into complexity and awareness? Before looking closer at entanglement, let's consider a deep basic question: is quantum mechanics symmetric under time-reversal? The basic Schrödinger wave equation is t-symmetric (TS), in like vein to Maxwell's electromagnetism. (However, practical asymmetry between sources/emitters and sinks/receivers of **E** and **B** makes this rather an idealization about the fields more than the particles too.) Roger Penrose [2] powerfully argues that when we consider the entire picture of things, QM does not express TS. The core of his argument is the collapse event type **R** of "measurement." Simple emission and reception in QM of a photon between objects seems at a glance to be as reversible as either Newtonian billiards or EM wave interactions. However, let's conceptually actualize the intervening wave-function. It will be expanding into "more places" in positive time. It may cover a large area before some point impinged by that WF "grabs" the photon energy and it becomes localized right there, and only right there. The WF has been "reduced" according to rules of probability, *versus* smoothly

continuing to evolve (that we can find).

If we only consider simple points of "emission" and "reception" we can't see much problem even here, in practice - the WF is a sort of conceptual phantom we don't really see directly. However, Penrose uses more complex configurations with partially-reflecting mirrors to show that under such conditions, an emission/reception event does not "work" properly in reverse. This can be understood in part by the following big distinction between WFs and EM waves. If an EM wave expands and touches many things later, those things could in principle actually have been emitters of reverse-equivalent EM waves when it's all run backwards. That is because all the EM field stays "real" and is not just a basis for *chances* of things happening later. However, WFs are very different. We can imagine a WF expanding out and then going "pop" at one specific location out there. But all the other places it touched, do NOT properly serve *together* as "sources" in reverse! Regardless of how we "imagine" the WF, the "potential points of absorption" are not collectively physically equivalent to the emitting spot. They can't actually emit potentially *interfering* waves in the other direction.

Quick but notable pivot: but maybe there really isn't a collapse, maybe each alternative continues to evolve? I am not impressed by MWI/EQM as a concept, but more relevant and to the point: the supporting phenomenon of decoherence may not pan out as generally understood. Unlike the postulated many-worlds (continued co-evolving but non-interacting states), this distinction can be experimentally measured. Pursuant to this angle: my proposal [3], useful also as a thought-experiment, attempts to recover superpositions after "complete" pre-detection decoherence. (It can be set up for either cross-instance disordering of phases, or concurrent disordering.) It recombines presumptively-decohered outputs from a Mach-Zehnder interferometer having an asymmetric first beamsplitter. Subsequent interference can reveal the hidden superposed character of the output: it was not effectively a "classical" mixture. The detectors must then exclusivize the outcomes. Those results would hobble the decoherence interpretation of quantum reduction as generally imagined. And, a diminished role for decoherence enables the relevance of quantum action to consciousness.

The increasing complexity of life at least, in a universe where we are sure that "entropy" increases, is challenging. Sure, the Earth is not a close system, energy flows through it from outside. Still, the intricacy of our developed planet is amazing. Some kind of "information" is surely on the rise. How can that be? Is entanglement, and the possible time-asymmetry of quantum evolution, responsible for enabling this incredible progression?

Let's take a brief overview of entanglement: it is not just like *starting with* one green sock and one red sock and then separating them. In that case ("Bertlmann's socks"), finding a red sock mandates the other one be green in a straightforwardly logical way. The strong correlations of entanglement involve relations preserved under a wider variety of detection possibilities. There is a real sense in which "more order" is embodied in the *combined* set of data, than could classically be the case. Furthermore, this property can continue to expand the total number of correlations indefinitely in principle, limited only by "collapse" events reducing the connected possibilities to particular, local outcomes (which stops the "chain" of wave evolution, or at least "seems to" in our experience.)

Does entanglement violate the 2nd Law? We are assured [4] that it does not truly do so,

but we will see that it sure seems to. (Recall sayings like "technically it's illegal, but in practice you'd get away with it." This may be one of those cases where the "but" is the relevant distinction, not the law in question.) Note this is not the pre-fixed necessity of the classical socks, which have their combined "order" simply subjected to further separation etc. Instead, we start with an uncertain initial entangled state, and then (depending on interactive circumstances) we can end with two sequences of ordered pairs. Consider this pair of binary sequences:

1010101011010100111000101010 ...

1100101010011000100101110101 ....

Other than coincidental matches (themselves at random!), these series are not only individually random, they are mutually unrelated. Consider instead this pair, defined by maximum entanglement relations:

1101101010110101010001111101

1101101010110101010001111101 ....

The second set surely has more "order" *in toto* than the first set, despite the completely random nature of each separate sequence. Even if total "entropy" as formally defined must somehow diminish in the entire system, this implicit emergence of "distributed order" could lead to favorable collective features such as similar mutations in neighboring genes - which would allow for a more elegant and consistent expression of some trend, than would a complete mess of unrelated changes scattered about. There is a difference between independent randomness and correlated randomness, and here is where it may be very important. In banal terms "you can't send signals using entanglement." OK, but Nature at least could enable a "style" within an interrelated system. Again, I am only roughing out the "principle of the thing" in broadest terms.

So this is what we have posited so far: more and more possibilities expand into future time, and furthermore they are correlated to each other. How might this express itself in a way that helps drive evolutionary change to greater complexity? Consider that mutations (whatever the cause of changes) in genes may derive from stimuli that are often connected to a common source (such as a distant supernova explosion). They may also result from delicately balanced alternatives (such as just where in an electron cloud a given photon is "absorbed") to disrupt the cloud distribution and cause an error in replication. Perhaps emphasis on external disruption is misleading, and there is more intrinsic (or hypersensitivity-based) "bit rot" than is supposed or seems likely. Indeed, as an indication of this phenomenon at work, a study [5] notes first that "Spontaneous mutations in the germline are a significant factor influencing genetic risk for autism spectrum disorders (ASDs)." Later, the authors write:

*"Our findings provide some insights into the underlying basis of autism -- that, surprisingly, the genome is not shy about tinkering with its important genes" said Sebat. "To the contrary, disease-causing genes tend to be hypermutable."*

Furthermore, recent research [6] shows that quantum mechanics plays a key role (beyond the basics that enable the process at all) in the efficiency of photosynthesis.

Is expansion and correlation of "randomness" going to be enough? Maybe. So what is "randomness" anyway? Now I step beyond even visionary orthodoxy into more speculative territory. Some preliminary disturbances (*sic*) serve as the point of the spear. First, and fundamentally, probability has a dirty secret: it isn't even clear whether and when a statistical

"law" is violated anyway. We don't know what run of suspicious results should count as a "violation" or change in propensity versus just an anomalous run! Claims that the probability rules of QM are as "exact" in their own way as true laws, are misleading in principle even if they act in practice as adequately reliable expectations. Quantum mechanical laws aren't *definably* broken if say "something" picks individual outcomes while preserving statistical trends. Entanglement broadens such selections to lawfully-correlated outcomes. Note that our "confidence" measures are arbitrary borders placed on qualitatively-homogenous slippery slopes of degree.

Also, we are often told that causality or as reduced to sequencing, is either determined or "merely" random. It is little appreciated how to instead make a trident from the simplistic fork of necessity versus chance. Consider this series: 1, 2, 3, 4, 5, 301, 7, 8, 9, ... . It is neither fully herded by a "law" nor is it "probabilistic" in the sense of a given chance operating across each series increment. Nor is it truly intermediate. It is a mysterious intrusion into the midst of apparent lawfulness. Maybe some willful choices are like that--after all, that is how I created it.

So is there choice ... With "free will" perhaps there is another way for some sort of correlative wholeness to express itself. I have argued [7], [8] in support of some kind of special, non-deterministic, global executive function or "will" not only in humans, but higher animals in general. Briefly: it is our ability to "freeze" despite the build up of supposedly bottom-up processes, and to recover from such freezes right back to what we were doing. It arguably would not be easy for a mess of independent signal storms to do such a thing. Perhaps a type of quantum wholeness can enable this functioning. Some recent findings [9] are supportive of such "orchestration", while not ruling out alternatives.

So, we have outlined some promising avenues to understanding our complex world, especially the biggest mystery of all: intelligent brains. However, let's end with a humbling demonstration of just how unsure we are about any of this. We don't know how likely it is that we can happen (sic.) Bayesian reasoning is of little use here because of self-selection. If the universe is infinite or very large (plausible because of the flatness of space), we might be the expression of a  $1:10^{500}$  chance. We would have no neighbors (at least thinking ones) for an equally stunning distance scale. So we can't even easily know how much "help" we need anyway! This should be a reminder that Bayesian reasoning fails us *when it matters most*: when faced with a rare but very important example. We think we are important, how rare are we?

## Citations

- [1] John Searle, (1980), "Minds, Brains and Programs", Behavioral and Brain Sciences, **3** (3): 417–457
- [2] Roger Penrose, (1989), *The Emperor's New Mind* (Oxford University Press), 354-359
- [3] Neil Bates, posted February 17, 2011; "Our Non-Deterministic Reality Is Neither Digital Nor Analog: Experimental Tests Can Show That Decoherence Fails to Resolve the Measurement Problem" (<http://fqxi.org/community/forum/topic/949>)
- [4] Vlatko Vedral, posted June 1, 2011; "Does Quantum Mechanics Flout the Laws of Thermodynamics?" (<https://blogs.scientificamerican.com/guest-blog/does-quantum-mechanics-flout-the-laws-of-thermodynamics>)
- [5] ScienceDaily, posted December 20, 2012, "Genomic 'hotspots' offer clues to causes of autism, other disorders" (<https://www.sciencedaily.com/releases/2012/12/121220143516.html>)
- [6] Phys Org, posted January 9, 2014; "Quantum mechanics explains efficiency of photosynthesis" (<https://phys.org/news/2014-01-quantum-mechanics-efficiency-photosynthesis.html>)
- [7] Neil Bates, (2000), "Chosen Sudden Behavioral Suppression: The Key to Understanding Free Will?", Poster Presentation, Toward a Science of Consciousness (Conference), Tucson AZ
- [8] Neil Bates, posted April 24, 2014; "Flashlights, Mirrors, Real Brains and Willpower: Steering Ourselves to Steer Our Future" (<http://fqxi.org/community/forum/topic/2119>)
- [9] Elsevier, January 16, 2014, "Discovery of quantum vibrations in 'microtubules' inside brain neurons supports controversial theory of consciousness" (<http://www.sciencedaily.com/releases/2014/01/140116085105.htm>)