Article

A Quantum Theory of Consciousness May Require a Paradigm Shift in Biology

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Abstract

It is often assumed that the known physical laws form a closed system and are complete. It is also assumed that biological theories require no additional principles that are fundamental other than those we already know. Assumptions such as these are acting as a barrier to progress in biological theories and an understanding of consciousness. This paper examines the unexplained inconsistencies among fundamental particles and forces and the fundamental gaps in our knowledge of biology and the cell in particular that may impact on such progress. Also, the laws of quantum mechanics are examined and found to be grossly incomplete. Furthermore, gravitational decoherence times are way too long and electromagnetic decoherence times are way too short to relate to millisecond brain processes. Surprisingly, weak force decoherence times over cellular distances are of the relevant dynamical timescale needed, suggesting that if any force is associated with the global properties in and between neurons (such as consciousness) it is the weak force. This finding concurs with a twenty year old theory that argues for a fundamental link between the weak force, electron neutrino and the biological cell. That theory also predicted the mass of the electron neutrino that is soon to be verified. The consequences for biology and future consciousness theories, of this radical change of paradigm, are considered.

Key Words: consciousness, quantum theory, decoherence, gravitation, weak force, electron neutrino, biology, paradigm shift.

It is often assumed that the known physical laws form a closed system and are complete. It is also assumed that biological theories require no additional principles that are fundamental other than those we already know. Assumptions such as these are acting as a barrier to progress in biological theories and an understanding of consciousness. This paper examines the unexplained inconsistencies among fundamental particles and forces and the fundamental gaps in our knowledge of biology and the cell in particular that may impact on such progress. Also, the laws of quantum mechanics are examined and found to be grossly incomplete. Furthermore, gravitational decoherence times are way too long and electromagnetic decoherence times are way too short to relate to millisecond brain processes. Surprisingly, weak force decoherence times over cellular distances are of the relevant dynamical timescale needed, suggesting that if any force is associated with the global properties in and between neurons (such as consciousness) it is the weak force. This finding concurs with a twenty year old theory that argues for a fundamental link between the weak force, electron neutrino and the biological cell. That theory also predicted the mass of the electron neutrino that is soon to be verified. The consequences for biology and future consciousness theories, of this radical change of paradigm, are considered.

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Introduction

In his paper Chalmers (1995) states that 'it seems that physical laws already form a closed system' and that "biological theories involve no principles that are fundamental". This paper examines how true these statements are, first by examining what is missing from our fundamental understanding of the known fundamental particles and the forces of nature. This is followed by an examination of what is missing from our fundamental understanding in biology and the biological cell in particular. Consideration of all of this and the possibility of quantum effects occurring in brain processes leads us to the paradigm shift that is necessary in biology if we are to develop a theory of consciousness based on quantum mechanics.

What is missing from the forces and particles?

It is disturbing to a physicist that only one of the four forces of nature (the weak force) does not build any structure and hence has no science associated with it. Gravity builds galaxies, the electromagnetic force builds atoms and the strong force builds nuclear structure. The weak force appears to have no attractive aspect that would be needed to build such structure and has no role in nature other than radioactive decay in the nucleus. Is it true that the weak force is only a repulsive force? Physicists find exceptions like this troublesome as nature is not known to lack the necessary symmetry, elegance and beauty which often act as a guide in physics. The argument most pointed to, to explain this exception, is that the range of the weak force is too short, thus confining it to the nuclear processes. However, in no case does the range of a force determine the size of any structure found in nature. For example, the size of an atom is determined not by the range of the electromagnetic force which is infinite but by the uncertainty in position of the electron. Therefore, the argument relating to the range of the weak force does not explain the lack of attractive aspect of the weak force. This exception needs an explanation.

Neutrino's, the particle associated with the weak force are now known to have mass and hence can be slowed down. We know of no, nor are we in a position to detect, very low energy interactions between neutrinos and bulk matter. That does not mean they do not exist. For example, high energy electrons can pass through millions of layers of atoms without interaction. Low energy electrons interact with all atoms. If only high energy electrons, with energies much greater than those in atoms, could be detected we would not be aware of the atom, atomic energy levels, or any of the interactions electrons can have with atoms, or indeed any interactions between atoms (chemistry). The same could be true for neutrinos. It would be a mistake to assume that high energy neutrinos interact with bulk matter in the same way as low energy neutrinos.

Furthermore, the neutrino is the only fundamental particle not associated with a macroscopic structure. Quarks have a key role in hadron structure and their overall properties and electrons have a key role in atomic structure and interactions with other atoms. This exception also needs an explanation. Once again, physicists do not like these incomplete patterns as it implies a lack of symmetry.

In summary, there are major gaps in our knowledge of the weak force and the neutrino which need to be addressed. In such circumstances one would be unwise to assume that physical laws are complete or that physical laws form a closed system as suggested by Chalmers (1995).

What is missing from biology and the cell?

It is also disturbing for a physicist not to be able to contribute to the fundamental understanding of any science. Biology is no exception. That does not mean, as stated by Chalmers (1995), that 'biological theories involve no principles that are fundamental'. It could just be the case that we have not found them yet. At present we cannot answer even basic questions such as why all cells, plant or animal, have similar size and why that size turns out to be approximately 10 microns. This highlights the huge gap in our fundamental understanding of biology. In chemistry, by comparison, we do know the reason why all atoms have similar size and why they have that size. As already stated, the reason relates to the uncertainty in position of the electron which in turn determines the scale of atomic orbitals in an atom and hence the size of the atom.

We think we know the force (electromagnetic) operating in biology but we are not really sure. Penrose and Hameroff (2011) think that consciousness may have some connection with gravity. Tegmark (2000) and most others consider electromagnetic forces as key. Could it be otherwise? Is there a force driving biology that is neither gravity nor electromagnetism? Handedness is known to be ubiquitous in DNA, RNA, proteins, amino acids and in biology in general. The weak force is the only force that displays handedness. Is this just a coincidence or is it pointing to something new?

According to Loewenstein (1999) the *sin qua non* of all molecular information transfer in the cell is the ability of molecules to fit together 'hand in glove'. This does not explain how the vital overall global communication in and between cells is achieved. All complex structure, from cells to cities, needs an almost instantaneous communications system to preserve and protect order in that structure and to defend against internal or external threats that would interfere with or damage normal structure function. The very complex environment present in every cell means that the current proposed mechanisms, for long range communication, based on diffusion and other chemical effects are way too slow to protect against such threats to overall order. How this instantaneous global communication, that is vital for survival, in and between cells is achieved is unknown.

In summary, there are also major gaps in our fundamental knowledge of biology and in particular, the cell. In such circumstances, it would be unwise to assume that there are no undiscovered fundamental principles associated with biology. It seems even more unwise to consider constructing a theory of consciousness when we clearly do not understand some of the very basic fundamentals of biology and the cell in particular.

What is missing from quantum mechanics?

As it stands today we have no concrete knowledge of quantum astronomy or quantum biology and only a rudimentary knowledge of quantum chemistry and quantum nuclear processes. For this reason I would agree with Stapp (1996) when he says that 'the quantum laws are grossly incomplete'. Furthermore the emergent properties of such quantum systems in astronomy and biology will bear no relation to quantum chemistry, as they will involve completely different systems, different fundamental particles, and different forces. We have a huge ignorance in this area and, therefore much scope to provide solutions to Chalmers (1995) 'hard problem'.

What makes quantum mechanics attractive, in consciousness theories, is that our brains appear to behave as a system that can absorb/store information over time and at, what seems like, arbitrary moments this information can collapse to an original thought or idea much like the Copenhagen interpretation of quantum processes. Is this just a coincidence? We have many expressions that indicate the instantaneous nature of this collapse to a single state. For example, eureka moment, penny drops, insight, flash of inspiration, bolt from the blue and brain wave to name but a few. Some interpretations of quantum mechanics give the observer an important role in this and suggest that consciousness causes the collapse to a single state. Furthermore, the properties of such quantum mechanical systems emerge from the whole system and are not traceable to any individual component meaning the properties of such systems are nonreductive which Chalmers (1995) suggests a theory of consciousness must be.

In summary, there are enormous gaps in our understanding and the laws of quantum mechanics are grossly incomplete.

Global coherent states in the brain, decoherence, and the forces of nature

Whether quantum processes occur in the brain or not, the disagreement between Hagen, Hameroff and Tuszynski (2002) on the one hand and Tegmark (2000) on the other demonstrates that a model of consciousness that has enough degrees of freedom and assumptions can yield any decoherence time you like. However both sides understand the importance of having decoherence in the millisecond range as this is the relevant dynamical timescale in brain processes. The very basic and valid point that Tegmark (2000) was making was that electromagnetic decoherence times are way too short to have an influence on global quantum brain processes. This, on the other hand, does not mean there are no global quantum mechanical processes occurring in the brain, just that they are not electromagnetic in nature. They may not be gravitationally based either.

There are not just two but four forces of nature. Their relative strengths (S) are 1 for the strong force, $\sim 10^{-2}$ for the electromagnetic force, $\sim 10^{-9}$ for the weak force and $\sim 10^{-35}$ for the gravitational force. The weaker the force operating on a system the smaller the binding energy and hence, the longer the decoherence time associated with such a system. The decoherence time ($h/2\pi E$, where E is the separation energy for a particular force) is equal to r/Sc where c is the speed of light and r is the scale over which decoherence takes place. If brain processes and consciousness are quantum mechanical in nature this decoherence scale would need to be

cellular distances (10^{-5} meters) or greater. Using this, the following table shows the calculated decoherence times for each of the forces.

Force	**Relative Force Strength**	**Decoherence Time**(seconds)
Strong	1	$>10^{-13}$
Electromagnetic	10^{-2}	$>10^{-11}$
Weak	10^{-9}	$>10^{-4}$
Gravitational	10^{-35}	$>10^{+22}$

These simple comparable calculations rule out both quantum gravity and quantum electromagnetism in inter-neuronal brain processes. The table also implies that, if brain processes and consciousness are fundamentally quantum mechanical the relevant dynamical timescales in the brain ($\sim 10^{-3} - 10^{-1}$ seconds) clearly suggest that the force likely to be implicated in this is the weak force. Is this just another coincidence? Once again we are being led in an unexpected direction.

In summary, if quantum mechanics is at the heart of consciousness, in the brain, then the most likely force it is associated with is the weak force and not the gravitational force or the electromagnetic force.

Paradigm shift for biology and consciousness theories

For the last twenty years, a wide range of philosophers, scientists etc. have made a concerted effort to come up with a fundamental theory to explain consciousness. It was in the words of Chalmers (1995) a 'hard problem' looking for a solution. Over those twenty years progress has been slow. This is not surprising given the number of gaps in our knowledge highlighted so far in this paper. The most rigorous quantum theory is the Orch OR theory (Penrose and Hameroff 2011). However, this theory is not convincing as it has fundamental problems with decoherence times as discussed in the previous section.

About the time the drive to come up with a theory of consciousness began, a paper was published (Goodman 1994) that argued for a fundamental link between the weak force, electron neutrino and the biological cell. While a theory of consciousness appears to be a long way off the solution that this and subsequent papers (Goodman 1997), (Goodman 2003), (Goodman 2007) provide, offers a route to get to a better understanding of the cell that, may lead ultimately to such a consciousness theory. The paradigm shift that is required, as discussed previously would involve abandoning quantum gravity and quantum electromagnetism in favour of quantum weak force effects in any theory of quantum biology or consciousness.

The theory (Goodman 1994) was developed in the normal way by induction. It begins with observations on the mass and size of all key structures in the universe. It was noticed that masses seemed to vary in proportion to the square of their size and not the cube of their size as might be expected in a three dimensional universe. Using this, a theory was developed about the general relationship between the key masses, both structures and fundamental particles, in the universe.

This theory was then used to deduce a very specific prediction about the mass of the electron neutrino at a time when it was generally accepted the neutrino was likely to have no mass. Also, the predicted mass was some four hundred times smaller than the experimental upper limit at that time. This implied a long wait before this theory would be experimentally verified. However in the years since, this upper limit has been decreased by a factor of 20 and a new experiment is about to reduce it by another factor of 10 if not measure the actual mass of the electron neutrino itself.

The original paper (Goodman 1994) used a typical galaxy mass to calculate all other masses including the electron neutrino mass. If instead of a typical galaxy mass we use the mass of the electron (the only fundamental particle mass we know with precision) and the exact same theory we deduce a more exact prediction for the electron neutrino mass of 0.16 eV/c^2. However, any mass between 0.40 eV/c^2 and 0.05 eV/c^2 would make the theory convincing. Recent experiments around the world seem set to confirm this prediction in the next year or so.

There are three types of neutrinos each with different mass. Evidence of neutrino mass comes from three sources. These are cosmology, oscillation experiments and direct mass measurement experiments (Weinheimer 2013). At present cosmology sets an upper limit on the sum of the three neutrino masses of ~0.5 eV/c^2. Oscillation experiments have set a lower limit on the sum of the three neutrino masses of ~0.05 eV/c^2. The direct mass experiment called the KArlsruhe TRItium Neutrino experiment (KATRIN) is about to measure the mass or push the upper limit of the mass of the electron neutrino from 2.3 eV/c^2 down to 0.3 eV/c^2. KATRIN is to start producing results in early 2016. This means that within the next year the mass of the electron neutrino will have been measured or pushed into the range of masses that are acceptable for the proposed theory, hence completing the deduction process by confirming the 20 year old theory.

Most importantly, a link between the electron neutrino and the weak force on the one hand and the cell and biology on the other, in one stroke, erases the uncertainties, fills in the gaps in knowledge, explain the coincidences and exceptions highlighted in the early part of this paper. It also provides symmetry as we now have one fundamental particle, one force and one key structure associated with each of the sciences of structure namely, Astronomy, Biology, Chemistry and Nuclear science.

Consequences for biology and future consciousness theories

A confirmation of this theory (Goodman 1994) will force a paradigm shift that will leave us at the beginning of a new chapter in biology. We need to start to consider the cell, not only as a classical system but also, in certain circumstances as a quantum system (duality) in the same way we can consider the atom as a classical system on occasion and on others as a quantum system, but never both at the same time. However, because the system, the force and fundamental particle are completely different the quantum cell will be completely different to the atom with the global cellular properties being nonreductive (more than the sum of its parts), just as Chalmers (1995) believes an explanation of conscious experience should be.

The weak force, which we know very little about, will be the force operating in the cell from a global cellular point of view and be responsible with the electron neutrino for all global

properties of the cell. With a mass of ~0.16 eV/c^2 the uncertainty in position of the electron neutrino will coincide with the size of a typical cell and will in all probability be found to be responsible for the cell size, just as the electrons uncertainty in position is responsible for the size of an atom. Needless to say, the linking of cell size with a fundamental particle mass will have profound implications for all life in the universe. In this way quantum coherence inside and between neurons in the brain would be possible over large areas of the brain at room temperature. The "too wet, too warm and too noisy" objections that have often been raised in the past will no longer be an issue.

What is being suggested here has a resonance with spin mediated consciousness theory (Hu and Wu 2004). The main property associated with neutrinos apart from their tiny mass is spin which is quantized. Because of its tiny mass the uncertainty in position would mean that two nucleons could interact directly, without the need for the involvement of electrons associated with the nuclei over cellular distances via Z^0 (the neutral weak mediator) and exchange of neutrinos. Based on what we currently know about the weak force and in particular direct neutral weak interactions such interactions might look as follows:

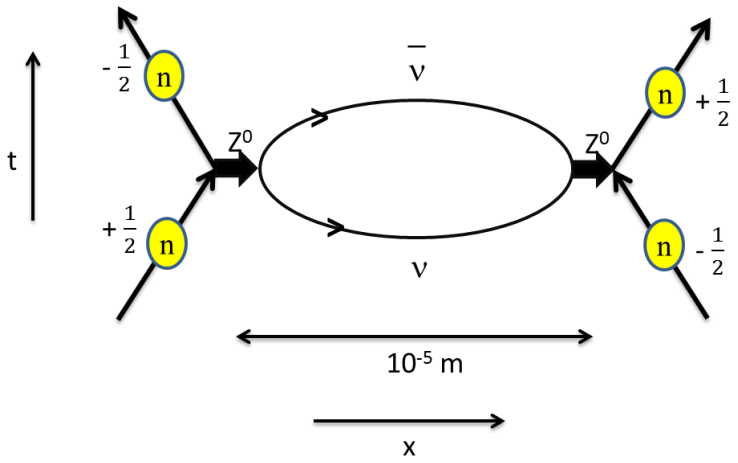

Figure 1. Spin swapping between nucleons via neutrino pair creation in the vicinity of one nucleon followed by pair annihilation in the vicinity of another nucleon over cellular distances. (Note: t = time, x = position, n = nucleon, ν = neutrino)

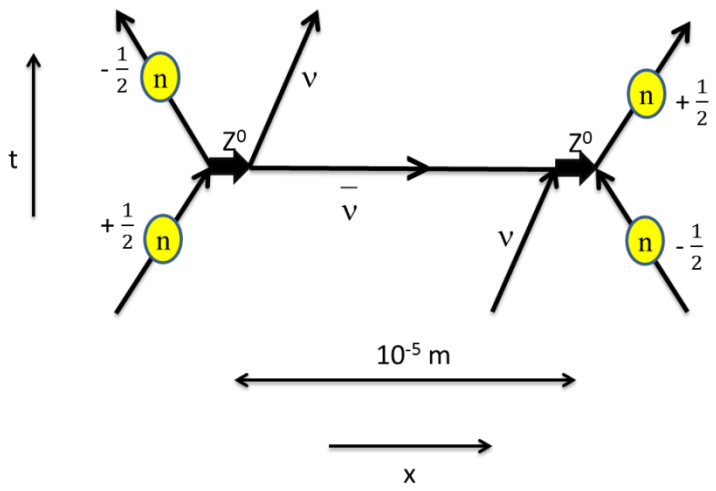

Figure 2. Spin swapping between nucleons via neutrino pair creation in the vicinity of one nucleon followed by an antineutrino-neutrino interaction in the vicinity of another nucleon over cellular distances.

Both these diagrams depict a spin interaction (a swapping of spin) between two nucleons (protons or neutrons) over cellular distances via known Z^0 decay modes. As 20% of Z^0 decay modes are invisible such interactions are conceivable. These interactions would be responsible for all the global properties within and between cells. An example of such a global property might be the long range communications needed within and between cells to protect, preserve and defend the overall structure as discussed earlier. As is currently the case chemical processes will still rule at the 'local' molecular level and be responsible for all local properties of the cell, including local information transfer. The long range quantum communication system would be the substrate upon which a theory of consciousness could be built. This substrate provides the two requisites, for quantum computation required by Loewenstein (1999) namely, insulation from the cell sap (by not being an electromagnetic process) and intercellular continuity in order to allow for multicellular quantum-coherent states, hence allowing us to begin to construct a theory of consciousness.

Conclusion

There are still large gaps in our knowledge of biology, the cell, the forces of nature, fundamental particles and quantum mechanics. For these reasons, unlike Chalmers, I do think there are principles, such as those proposed here, that are fundamental in biology that we have not yet discovered. Also physical laws do not, as yet, form a closed system.

Decoherence times necessary for quantum brain processes strongly suggest that the weak force is at the heart of these processes. The imminent verification of the electron neutrino mass of ~0.16 eV/c^2, predicted 20 years ago, will force the paradigm shift that is suggested in this paper, upon us. It will require us to view the cell as a quantum mechanical system to provide an explanation for vital global, cellular and intercellular, processes such as rapid almost instantaneous communication. This communication system would be the substrate upon which a theory of

consciousness could be built. While a theory of consciousness seems to be even more remote than before at least we will be building the theory on solid foundations.

Finally, the link between the neutrino and the cell via the weak force and quantum mechanics gets rid of all the problems, coincidences, exceptions, knowledge gaps, incomplete patterns and general lack of symmetry mentioned throughout this paper. All of these will still remain and still need an explanation if what is suggested here is not the case. The link between electron neutrino and cell is a simple, elegant and even beautiful solution to several very fundamental difficulties with current scientific thinking that have been highlighted in this paper. For these reasons, this paradigm shift should be given serious consideration if we wish, ultimately, to construct a quantum theory of consciousness.

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