Quantum Microbiology

J. T. Trevors[1]* and L. Masson[2]*

[1]School of Environmental Sciences, University of Guelph, 50 Stone Rd., East, Guelph, Ontario N1G 2W1, Canada
[2]Biotechnology Research Institute, National Research Council of Canada, 6100 Royalmount Ave., Montreal, Quebec H4P 2R2, Canada

Abstract
During his famous 1943 lecture series at Trinity College Dublin, the reknown physicist Erwin Schrödinger discussed the failure and challenges of interpreting life by classical physics alone and that a new approach, rooted in Quantum principles, must be involved. Quantum events are simply a level of organization below the molecular level. This includes the atomic and subatomic makeup of matter in microbial metabolism and structures, as well as the organic, genetic information codes of DNA and RNA. Quantum events at this time do not elucidate, for example, how specific genetic instructions were first encoded in an organic genetic code in microbial cells capable of growth and division, and its subsequent evolution over 3.6 to 4 billion years. However, due to recent technological advances, biologists and physicists are starting to demonstrate linkages between various quantum principles like quantum tunneling, entanglement and coherence in biological processes illustrating that nature has exerted some level quantum control to optimize various processes in living organisms. In this article we explore the role of quantum events in microbial processes and endeavor to show that after nearly 67 years, Schrödinger was prophetic and visionary in his view of quantum theory and its connection with some of the fundamental mechanisms of life.

Introduction
At the turn of the 1900's, one of the most successful theories, quantum mechanics (QM) arose from the understanding that Newtonian mechanics or classical physics did not account for new atomic knowledge (Witten, 1982). Prior to this time, atoms were considered as indivisible particles, even when electrons were discovered in 1897. Studies in heat radiation led a German physicist named Max Planck to create the Planck postulate, which states that energy is not continuous but is only emitted or absorbed in discrete units or quanta. This theory, which contradicted both classical physics and electromagnetic theory, signaled the start of a revolution in physics and the generation of various complex and novel ideas that formed the basis of quantum mechanics.

Simply put, quantum mechanics deals with the science of the small, the atomic or subatomic particles. Although quantum theory applies to all levels of physical and biological organization, from chemical bonds and subatomic particles, to the cosmos (Haydon et al., 2010), only the former can be explained by QM, whereas the latter is better explained by Einstein's theory of general relativity or the science of the big bang. Currently, one of the significant unsolved problems in modern physics is how to merge the two into a unifying theory. Since quantum mechanics describes the physical world, and living organisms are physical entities, it is rational and logical to examine the role of quantum mechanics in the matter and energy of living microorganisms, especially their origin about 4 billion years ago. To do so requires an understanding of quantum processes at the atomic scale and smaller where electrons, for example, do not collide with the atomic nucleus but defy electromagnetism and orbit at both an undefined speed and path around the nucleus. One distinguishing characteristic of quantum mechanics is the Complementarity Principle (or wave-particle duality) developed by Niels Bohr indicating that a particle can possess multiple contradictory properties.

A classic example of complementarity is Thomas Young's famous light interference, and later on the double-slit, experiment showing that light or other quantum particles exist as both a wave and a particle (Young, 1804). One particularly provocative quantum mechanical principle exemplified by the double-slit experiment is quantum superposition or coherence. It claims that while we do not know what the state of any object is, it is actually in all possible states simultaneously (a superposition of states), as long as we do not measure it in some fashion (which causes the object to collapse to a single state or possibility). In the double-slit experiment, each photon not only goes through both slits, but takes both routes to the target simultaneously! In other words, both photons act as if they are in two places at once. Even more bewildering is the concept of quantum entanglement, a principle of which even Albert Einstein was skeptical. This theory states that if two particles, for example photons, were produced from a single photon, they are entangled. If these photons were separated and one moved to the other side of the earth, influencing the spin of one particle instantaneously affects the spin of the other. Erwin Schrödinger, came up with the name "entanglement" to describe this peculiar, faster than light, connection between quantum systems. This instant communication phenomenon was later proven to exist by John Bell (Bell, 1964).

Although quantum mechanics allows descriptions of processes at the atomic scale, at the macroscopic scale, quantum events are not observed (decoherence). Schrödinger's cat thought experiment, was created to highlight the fact that quantum coherence is generally not observed at the macroscopic scale and to attempt this would result in absurd situations like a cat being dead and alive simultaneously. Quantum events are therefore manifested as classical events that we can often observe in living organisms. This type of *dual property of matter* poses a major challenge to understanding both quantum and classical events in living organisms. It is the increasing levels of organization from the subatomic to the community level in biology that challenges scientific research to its fullest capacity. Moreover, living organisms require specific, correct, genetic instructions in the form of an organic code to be highly organized living entities. This had to occur or

*Email: jtrevors@uoguelph.ca; luke.masson@nrc-cnrc.gc.ca

Table 1. Some Quantum Mechanic events in microorganisms.

1. Applies to all levels of physical, chemical and biological organization.
2. Quantum events are not observed at the macroscopic level.
3. Quantum mechanics accounts for bond strengths in biochemicals.
4. DNA possibly acting like a quantum computer, existing in superposition states that collapses to a single state. Counterargument is inability of DNA to remain in a coherent state long enough to get feedback on which mutation or sequence would be beneficial as coherence times are generally around femto to pico seconds.
5. Green sulfur bacteria transfer photonic energy at virtually 100% efficiency *via* a chlorosome antenna and a pigment protein complex (FMO complex) (Ishizaki et al., 2010). The energy transfer did not follow a randomized path but rather the energy was found in both places at once, in effect, a quantum superposition state (Collini et al., 2010).
6. Microbial genes are expressed under diverse environmental conditions with the genetic information originating in the quantum realm of atoms and the sub-atomic.
7. Using ultrafast laser spectroscopy, it has been shown the dynamics of excitation energy flow is along the stacked DNA bases of the same strand rather than through the potentially damaging excitation energy to the original excited strand is that it inherently minimizes any damage to the complementary DNA strand thus preserving it as an unmodified copy of the original genetic information (Bittner and Czader, 2009).
8. It can be hypothesized that pre-biotic life originated *via* quantum information processing but as evolution at the organism level took over, the initial quantum processing became part of the DNA replication, transcription and translation machinery. This could be viewed as a form of transition or progression ***from quantum to the cellular level of organization - a type of quantum evolution in living organisms.***

the first living microorganisms with their corresponding phenotypes would not have originated, reproduced and evolved. It is indeed a difficult world to understand at all levels of organized matter, especially when the matter is part of living organisms with a quantum basis, specific genetic instructions and also controlled by the laws of thermodynamics as entropy increases.

Quantum microbiology like quantum biology has been hypothesized to be based on a robust heat engine- the specific endothermic and exothermic biochemical reactions (Matsuno, 2006) that are encoded by specific, organic genetic instructions in DNA and RNA. A counter view is that very few processes in biological systems require an understanding of quantum theory even though all biochemicals are of quantum origins (Bittner and Czader, 2009). How rooted are quantum principles in biological systems at the molecular level like DNA replication or photosynthesis or at a higher level including the human senses or subconscious thought? We take the perspective that often the best advances in knowledge are made at the intersections of numerous disciplines, and therefore all links (and also disconnects, gaps, plausible hypotheses and not yet completed experiments) between knowledge should be explored, pondered and researched where possible.

Because quantum theory is the foundation of the physical world, it is central to all biological systems where physical organisms composed of specific and often interacting biochemicals (and dependent on specific genetic instructions and enzyme catalysts) are subjected to natural selection at the organism level, while attempting to reproduce for species survival. However, the influence of quantum events on the origin of non-living pre-biotic entities, and then the first microbial cells on the Earth, are not understood (Davies, 2004). In this perspective, the role of quantum theory is applied to microbial life on Earth and its subsequent evolution over 3.6 - 4 billion years. Since the cell is the basic unit of life, any quantum level information derived from microbial cells is presumably applicable to eukaryotic cells.

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Bioscientists understand that quantum theory needs to be extended to living organisms, especially when researching and applying nanoscale activities in living or enzyme systems, and when trying to understand the origin of the first microbial cells capable of growth and reproduction on Earth. One hypothesis of quantum evolution provides a framework in which DNA acts like a quantum computer in determining which mutation is the most beneficial. The premise is that DNA presumably exists in a series of states (superposition or coherence) and that this coherence collapses into a single state, i.e., a mutation. This approach is different from classical Darwinian theory whereby cells individually undergo mutation and it is the process of natural selection which selects those mutations beneficial to the organism rather than the DNA molecule itself. The main limitation to this hypothesis is the inability of DNA to remain in a coherent state long enough to obtain feedback (*via* natural selection at the organism level) on which of the mutations would be beneficial, as coherence times are generally in the domain of femto to pico seconds. This serves to illustrate an important question, do quantum coherent mechanisms actually play a specific role in more complex biological systems, or do they fall prey to the same problem of being unable to maintain a quantum coherent state of sufficient duration to have a significant influence? With the development of modern research tools, where reserachers can now follow ultrafast energy transfers in chemical reactions, biologists are starting to show that the answer may be, yes. Ultrafast laser spectroscopy is powerful technology for real-time observation (Trevors, 2010) of molecular dynamics in a complex environment (e.g. liquid). In particular, 2D electronic microscopy (Jonas, 2003), using laser pulses of ultrashort duration down to the femtosecond (10^{-15} seconds) time scale where reactions usually occur, allows the user to probe molecular transient states.

Recently scientists have been examining photosynthesis in green sulphur bacteria that can live in low light densities, conditions in which these bacteria can transfer photonic energy at incredible nearly 100% efficiency. For comparative purposes, solar panels achieve an average efficiency of about 20% with specialized laboratory research models running about 42% (http://www.udel.edu/PR/UDaily/2008/jul/solar072307.html). These organisms convert sunlight through a light harvesting chlorosome antenna which transfers the absorbed light excitation energy to a photosynthetic reaction center through a pigment protein complex (FMO complex) that bridges the two. This pigment process complex contains a trimer with each monomer composed of bacteriochlorophyll molecules wrapped up in a protein backbone. As such this arrangement creates a variety of potential paths that the absorbed energy can take to get from the chlorosome to the reaction centre (Ishizaki et al, 2010). Femtosecond laser pulses at very cold temperatures (Engel et al, 2007) and later at ambient temperature (Collini et al, 2010) revealed that the energy transfer did not follow a randomized path but rather it was found in both places at once, in effect, a quantum superposition state. This coherence transfer of excitation energy allows for the most efficient path to the reaction center by reversibly sampling multiple pathways simultaneously in an irregular space to find the most efficient path to the reaction center. Since FMO complexes in these simple marine algae do not have an analog in higher plants, has evolution worked against this system? It would seem not, as electronic coherence was also determined in the Light Harvesting complex II that contains the bulk of the world's chlorophyll (Calhoun et al, 2009).

Like photosynthesis, evolution has also been thought to play a role in selecting for efficient redox reactions in certain enzyme groups. Enzymes are central catalysts in biochemical transformations that, as defined by classical transition state theory, enhance reaction rates by lowering free energy activation barriers. Enzymes also provide direction to the reactions. This is accomplished by most enzymes through a conformation change to stabilize the transition state of the reactants by electrostatic effects. In other words, from a classical-mechanical perspective, substrates with thermal energies above the free energy barrier would pass over the barrier but those below would not. However, this sometimes fails to explain discrepancies such as temperature independent rates observed at low temperature, amongst others. In general, these inconsistencies are considered to be evidence for Quantum tunneling (particles like protons or electrons passing through rather than over the barrier and consequently the free activation energy). To date most scientists accept that tunneling occurs in enzymatic reactions. The current controversy is more a question of whether tunneling contributes to enzyme catalysis; to enhance rates directly as a result of quantum nuclear effects (primarily tunneling) as compared to what occurs in solution in the enzyme's absence. However, there appears to be little or no evidence supporting catalytic enhancement (Williams, 2010). In spite of this, another important question is whether enzymes have evolved by natural selection based on enhancing the tunneling phenomenon itself. This appears to be the case with electron transfer proteins (oxidoreductases) which are selected on the basis of fast catalytic turnover times. Surprisingly the selection is not based on the protein medium itself but rather on the basis of the proximity of the redox centres in electron transfer chains (Moser et al, 2006). It is interesting to note a similar evolutionary role in optimizing photosynthetic quantum processes through bacterial light sensing phytochromes, In the dark, most phytochromes adopt a red-absorbing state and, upon light absorption, convert to a far red-absorbing state. Recently, cyanobacteria were found to possess a large number of unique photoreceptors that are highly sensitive to colors other than red. Since these organisms live in a range of fresh and salt water depths, absorption of light by water changes with depth, being red near the surface, changing to green-blue and eventually blue as the depth increases. The ability to elaborate different color absorbing pigmented phycobiliproteins in their light harvesting antennae allows these bacteria to undergo chromatic adaptation. This is done by varying the ratio of these light harvesting pigments which in turn sense the type of surrounding light thus increasing the efficiency of photon harvesting (Bezy and Kehoe, 2010).

We now deviate slightly from microbiology to illustrate the role of QM in eukaryotic organisms that evolved from prokaryotic organisms, and the role of the Earth's magnetic field in quantum events. It has been known for decades that some animals like birds possess a magnetic compass that can sense and use the earth's magnetic field to navigate. The first evidence linking avian magnetoreception to a biophysical process was demonstrated by Thorsten Ritz et al, (2004). The process is based on a radical pair mechanism which depends on the quantum evolution of a interacting pair of electron spins that are spatially-separated. These birds are sensitive to the inclination of the magnetic field by photons entering the bird's eye and activating a photo-sensitive molecule which in turn causes an electron to be transferred resulting in a short-lived reaction intermediate. This intermediate called a radical pair, possesses two unpaired electrons in a singlet state. Under the principle of quantum entanglement, the two excited electrons are linked, however since one electron is influenced by the nucleus of the acceptor molecule, the partitioning of the two electrons results in the original singlet state, leads to an angle-dependent singlet-triplet oscillation. The oscillation is sensitive to changes in both the strength and orientation of the earth's magnetic field and the relative concentration of these molecules in the eye subsequently acts as the previously defined magnetic compass.

Olfactory receptors were initially thought to act by recognizing the shape of a bound odorant molecule. However, in order to explain why similar shape molecules could smell differently, it was initially suggested by Turin (1996) that it is the bound molecule's vibrational state that is the determining factor and not a lock and key model. This new mechanism is based on the phenomenon of quantum tunneling which occurs when a subatomic particle like an electron passes through an energy barrier (because of an electron's wavelike property) when it lacks the sufficient energy to go over the barrier as dictated by classical physics.

Consequently if a particular molecule (odorant) having with the correct vibrational frequency receptor is bound, the vibrations selectively actuates the receptor and causes an electron to tunnel between different energy states in the receptor. This transition, which is sensitive to the odorants vibrational state, creates an electrical signal (*via* an influx of ions into the cell) in the cell which is sent to the brain thus transducing a molecule's vibrational signature into an electrical signal (Brookes et al, 2007).

Quantum mechanics has therefore been central in the evolutionary process from prokaryotic to eukaryotic organisms as demonstrated by the above mechanisms. Evolution and the organic, genetic code are the common factors over almost 4 billion years of life on the Earth with QM as the basis of the physical universe and being manifested as millions of diverse living species.

Quantum mechanics and the matter of life

Simple microbial cells and all other cells are quantum processors of specific, genetic, information that has been processed and forwarded through almost 4 billion years of evolutionary history. Quantum mechanisms explains the atomic structure of the genetic code and all molecules in living organisms, but it does not explain the origin of the organic, genetic code and the corresponding specific translated proteins. If a pre-biotic cell has no means to select for the necessary set of minimal or core genes required for life, then one gene is as useful or useless as another. By placing the emphasis on the chemical origin of microbial life, knowledge on the origin of genetic instructions in DNA and RNA and the corresponding proteins has lagged behind (Trevors, 2003).

Hypothesizing a primitive chemical mixture from which life emerged without any means for encoding organic genetic instructions into a functional macromolecular replicator (e.g., DNA) has not lead to a better understanding of the origin of microbial life. One knowledge challenge is to understand and obtain supporting and/or non-supporting evidence for the role of quantum mechanics/events in the origin of microbial life. What quantum mechanism(s) made available the correct, encoded, organic genetic instructions for the first microbial cells capable of growth and division? Science has yet to discover the quantum events that tipped non-living atoms and molecules to become a living organism (the quantum to classical transition) given that the pre-biotic cell has no known means yet discovered, to select for the code (genes) and hence the corresponding proteins that must be present and expressed in the same time and space domains, so the pre-biotic cell can make the transition to a living microbial cell. To create a more complex system, various origin of life theories have been actively pursued. One promising hypothesis is co-evolution where short oligonucleotides and peptides are created together through synthesis and polymerization on mineral surfaces (Griffith, 2009; Fishkis, 2011). Their potential for cooperativity has been shown through the selective binding of amino acids to certain oligonucleotide functional groups which now act as a functioning template to synthesis of peptides. Subsequent integration of both weakly catalytic peptides with oligonucleotides into a lipid vesicle may have given rise to the first self-reproducing biotic life form. However whether the pre-biotic organics came from comets or marine hydrothermal systems or from the RNA or fatty acid worlds (Tamulis et al, 2010), how does a single pre-biotic cell which may have originated from a hydrogel (Trevors and Pollock, 2005) obtain and process the correct information for growth and division, and billions of years later produce humans with a conscious mind? Evolution is what happens after you have the first cell capable of growth and division. Therefore, since life as we know it did arise from non-living molecules, it is rational to hypothesize that a better understanding of the quantum realm could eventually lead to an understanding of how specific genetic instructions became embedded in DNA and RNA during the transition from pre-biotic to the first living microbial cells capable of replicating their stored genetic information and then providing a semi-conservative genome for two offspring cells.

Indeed, it seems counterintuitive to think of DNA as inherently stable when all four bases photoabsorb under ultraviolet light and thus being susceptible to mutations due to the localization of this electronic energy. How then could DNA have become the information molecule selected in early life forms? One answer seems to be based in quantum origins in that DNA has become more photostable by developing a rapid decay mechanism. Recent research examined whether base stacking in single strands or base pairing between two strands mediates such a fast elimination of the excitation energy. Although early studies seemed to support proton tunneling between bases as a deactivation mechanism, this was based on isolated bases (Schultz et al, 2004). By using ultrafast laser spectroscopy, it has been shown that, in fact, the dynamics of excitation energy flow is along the stacked bases of the same strand rather than through the paired bases (Bittner and Czader, 2009). The biological significance of isolating the potentially damaging excitation energy to the original excited strand is that it inherently minimizes any damage to the complementary DNA strand thus preserving it as an unmodified copy of the original genetic information. It was speculated that this protection mechanism may have provided sufficient evolutionary pressure to select DNA as the hereditary material (Bittner and Czader, 2009).

An interesting hypothesis favouring a direct emergence of life from the atomic world, thus bypassing the intermediate chemical stages, has been proposed by Davies (2004, 2008). His hypothesis is based on the premise that the genetic information of life, not the reproduction of material substances, is the key factor. Since some quantum information like electron spins can be copied, therefore life may have started with a quantum replicator or Q-life. Mathematically speaking, this Q-life, could replicate 12 orders of magnitude faster than DNA. Quantum coherence would enable this Q-life to evolve extremely fast since superpositions could examine numerous variations for beneficial 'adaptations' simultaneously. To explain how this quantum world made the transition to nucleic acids in the classical world, a computer analogy is employed in which Q-life is the fast computer processor and the hard disk is the slow organic information storage backup. Since the quantum world is extremely susceptible to noise, our warm and wet world would result in decoherence unlike the more resistant (classical) hard disk which, eventually took over and separated from the quantum world. This creates uncertainty as to whether quantum-based improvements observed in larger biological systems like photosynthesis are relics from the Q-life, or alternatively are a result of billions of years of evolution.

Can quantum processes be involved in selecting beneficial mutations, a Quantum evolution? In the classical world, natural selection selects among naturally occurring random mutations; those sometimes imparting an advantage. Patel (2001b) hypothesized that the replication of DNA and gene expression (combined transcription and translation) can be viewed as quantum database searches where A-T and G-C base pairing explains the four nucleotide bases in DNA and 20 amino acids for protein synthesis. The combination of 4 bases and 20 amino acids are the correct solutions to a genetic information optimization problem with enzymes central to the quantum coherence (picture a particle in quantum mechanics where all of the alternative possibilities open to the system co-exist as a superposition in a pure state). Quantum directed mutations can theoretically occur *via* proton tunneling where protons can plow through the normal thermodynamic energy barrier and cause nucleotide bases to vacillate between two tautomeric states thus causing non-canonical base pairing and consequently mutations (Perez et al, 2010). DNA, acting as a quantum computer, can simultaneously examine and select a beneficial state (mutation) while held in superposition and then decohere, collapsing back into the classical world (McFadden et al 1999). Adaptive mutations, representing beneficial mutations that occur in response to an environmental signal, have been documented in the literature. The ability of the DNA molecule to remain in coherence long enough for it to interact with the external cell's environment to determine which mutation is beneficial is still controversial due to the normally short quantum coherence times. It is interesting to note however, that one group of researchers claimed that the DNA strands are actually held together by quantum entanglement (Rieper et al, 2010) since the natural oscillations shown by paired nucleotides oscillate in opposite directions, but since it occurs as a superposition of states, the overall movement of the helix is zero. In a purely classical model the helix would heat up and separate. It is not clear as to what effect this entanglement has on the way the DNA code is read.

As we have described, quantum mechanics has roles in biological systems, however these roles remain rooted at the atomic and molecular levels. Can it extend to whole living organisms? New advances in optomechanical systems are being examined for the possibility of creating superpositions of larger objects to look at quantum phenomena at an even higher level. Romero-Isart et al, (2010) discuss the creation of an optical cavity in which they levitate dielectric objects trapped by optical tweezers. The proposed dielectric objects are whole viruses like influenza or tobacco mosaic virus that retain viability in high vacuum environments. The purpose of drawing in a macroscopic organism into the quantum world is to test quantum mechanic principle like superposition as a new beginning to address some of the larger questions of the role of quantum mechanics in life or in consciousness.

Our future challenge will be to understand how a living cell occurs where quantum mechanics rules can function (growth and division) at the macroscopic levels of organization when there is absolutely no necessity for living organisms anywhere in the universe. Quantum effects are the basis of life if one takes the perspective that living organisms are thermodynamically possible structures driven by the energy from electron transitions from higher to lower energy levels and electron donors and acceptors (Ho, 2008). Quantum systems can be understood from the perspective of information, where information can be shared with another system and information can only be selected in a quantum system that already exists within it (information can also be modified) (Auletta, 2005). Living organisms are organized, capable of replication/reproduction, can code and decode organic, genetic information which allows negative entropy for survival while using and storing quanta of energy for diverse but connected biochemical metabolism. Because microbial cells are semi-permeable open systems, they are capable of assembling even more organized living structures from simpler structures during evolution and speciation. The genetic information that is the best, is selected for when an organism lives and reproduces. Another outcome is survival without reproducing for a period of time such as a bacterial spore may do. A final outcome is death. The survival of the fittest selects for the best genetic information at that point in time as future environments are not known. However, the classical replication of genetic instructions and cell division depends on the quantum activities of matter that makes up the living organism.

Perspective summary

The origin of microbial life on the Earth and /or elsewhere is one of the immense enigmas of science and humanity. The organization of living organisms has no equal in the chemistry and physics worlds. Living cells are open systems capable of exchanging both energy and matter with their surroundings, yet they originated from their inanimate environmental surroundings. Organic genetic codes, diverse genome sizes and linear sequences are very different from inanimate matter and a lack of cellular biological organization. At the scale of molecules and molecular interactions in living cells, the quantum effects of molecules, organic genetic information, gene expression and energy, a knowledge of quantum effects needs to be extended into the understanding of life (Matsuno and Paton, 2000).

Humans have a limited knowledge of all living systems. Cell sizes and shapes were initially studied, then cells were lysed and the macromolecular components studied, the structure and function of DNA was discovered, followed by the delineation of the genetic code, genetic engineering and sequencing analyses. What is now required are methods of studying cells in the living state without interfering with normal cell metabolism. The human imagination and rigorous experimentation and observations are still the best scientific tools in the search for our origins. Quantum events would have had a central role in catalysis needed for the organization and origin of the first microbial cells on the Earth. It now remains to be discovered if and how quantum events were responsible for encoding the organic, genetic, code in DNA and RNA and the translation processes at ribosomes.

DNA is the organic, genetic macromolecule that bridges the quantum world of atoms and subatomic particles to the highly organized world of diverse living organisms. Genomes based on the quantum basis of matter allow the manifestation of highly organized and diverse living organisms by acting as the bridge or transition mechanism between the two very different but connected levels of the organization of matter. How could it be any other way and achieve the process of life? Even if the organism dies, the DNA code can be preserved at low temperatures in a laboratory setting or in permafrost, amber or other matrices in the environment. The genetic information can be retained and even cloned into living organisms. The connection from the quantum world to the manifested physical world can be maintained in its entirety or fractionally. In spore-forming bacteria the genetic message can be completely maintained for millions of years. The DNA acts like a computing device spanning or bridging two levels of the organization of matter with the assistance of the necessary enzymes.

The DNA in genomes is relatively constant but at the same time subjected to mutations, repairs, recombination events, transposition events and destruction. From the first microbial cells on the Earth to the present day species diversity, demonstrates the immense capacity of the organic, genetic code during evolution of species using optimized, organic, genetic information processing. Possibly, the first microbial cells were the first organic quantum computing entities. Moreover, as proposed by Ho (2008) there may be some global orienting field responsible for the liquid crystalline alignment in living organisms and the liquid crystalline structure of organisms. Although the field was not hypothesized, the electromagnetic field surrounding and protecting the Earth is one possibility. It is also known that this electromagnetic shield has completely inverted in the past and will do so in the future. Again, the influence of the Earth's electromagnetic shield on quantum events in the origin of life have not been examined in depth. Experimentation on such events is an immense challenge.

As proposed by Pattee (1967), quantum mechanics is the most appropriate approach to understanding energy and matter, while the theory of evolution is the best method for understanding natural selection and inherited traits. Possibly a combination of these two approaches will in the future bring forth **a *theory of the origin of microbial life*** with supporting data. As in most scientific research, the difficult research is done first, and the seemingly impossible research takes more time and effort. The unifying connections in science that may lead to a better understanding of the origin of microbial life and all biology may be quantum mechanics, the laws of thermodynamics, time, light as a particle and wave, and organic, genetic instructions and a better understanding of the dual nature of matter when quantum events are manifested as classical events or conversely *classical events are organized quantum events.* These areas need to be better understood and connections drawn between them in living organisms. As humans go forward, maybe we will better understand our human mind and its beginnings as a primitive microbial cell.

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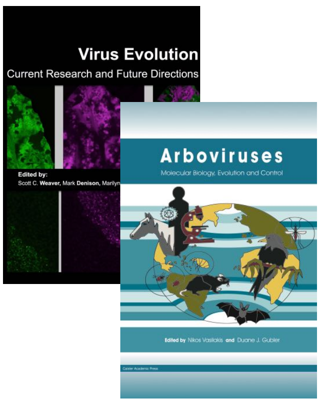

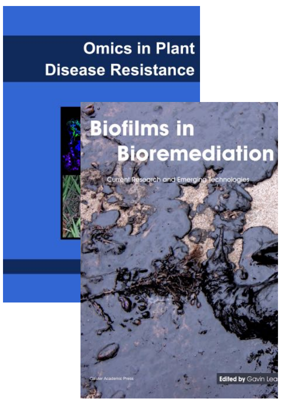

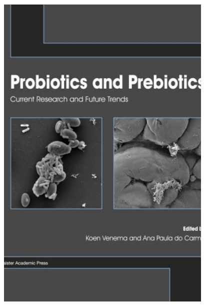

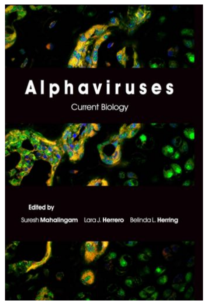

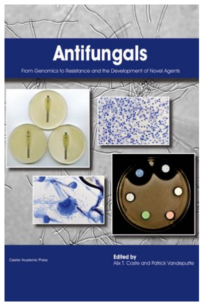

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