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Implications of the quantum DNA model for information sciences

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Abstract

The DNA molecule can be modeled as a quantum logic processor, and this model has been supported by pilot research that experimentally demonstrated non-local communication between cells in separated cell cultures. This modeling and pilot research have important implications for information sciences, providing a potential architecture for quantum computing that operates at room temperature and is scalable to millions of qubits, and including the potential for an entanglement communication system based upon the quantum DNA architecture. Such a system could be used to provide non-local quantum key distribution that could not be blocked by any shielding or water depth, would be simultaneous over any distance, and could not be electromagnetically interfered with or eavesdropped upon. The quantum DNA model also has implications for artificial neural networks and can provide architecture for a system of quantum random number generation.

Keywords: quantum DNA, entanglement communication, quantum information processing, artificial neural networks, quantum random number generation

Introduction

The DNA molecule has been theoretically modeled as a quantum logic processor [1], and that model has been validated by pilot experimental research that demonstrated phase synchronized oscillatory depolarizations between cells in separated cell cultures that were modulated by laser pulsations and by pharmacological manipulation. [2] Consideration of the DNA molecule as not only a data storage medium, but also as an information processing medium that operates via quantum logic, has obvious significant implications in the biomedical realm, but also is a game-changing paradigm shift for the information sciences. The quantum DNA model operates via electron entanglement at biologically appropriate temperatures, rather than at the near absolute zero temperatures of conventional man-made quantum logic devices, and is scalable to millions of qubits because each nucleotide of the DNA molecule can be considered to function as a qubit.

The non-local entanglement and decoherence between electrons involved in the quantum logical operations that occur between strands of DNA in separated cells can provide the theoretical basis for development of an entanglement-based communication system. Such a communication system would provide quantum key distribution that is based upon the entanglement and decoherence of electron pairs, would provide unprecedented data security, and would function without any local physical connection (e.g. fiber optic lines). Such a system

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would operate simultaneously over any distance, and could not be physically blocked or jammed by electromagnetic waves.

An understanding of the quantum DNA model can lead to interface with the quantum mechanical processes occurring within the DNA molecule, and can also provide access to quantum random number generation in systems of relatively small physical scale. An understanding of the quantum logic processing capability that is possessed by each cell will also provide for improved conceptualizations of artificial neural networks and neuromorphic computing.

The Quantum DNA Model and Experimental Validation

Since the discovery of the double helix by Watson and Crick in 1953 [3], the DNA molecule has been considered as an information storage medium, but it should be remembered that Watson and Crick were significantly influenced in their x-ray crystallographic studies by Schrödinger's prediction that the genetic material of the cell nucleus must be some sort of "aperiodic crystal" in order to support the quantum "leaps" of electrons between energy states that would be a necessary part of the process of adaptation. [4] Schrödinger intuited that a crystalline structure would be necessary to support such a quantum mechanism, but that a typical regular crystal could not contain enough information to support a living organism, and therefore some sort of "aperiodic crystal" was necessary as the genetic material. Even from its initial inception the cellular genetic material was considered as necessarily possessing a quantum mechanical function in addition to an information storage function.

Three quantum mechanical processes theoretically combine to enable the DNA molecule to function as a quantum logic processor: coherent conduction, electron spin filtering, and quantum gate activity. [1] In the DNA molecule, the nucleotide base pairs that connect the two antiparallel phosphate backbones are aromatic molecules whose pi-electron clouds can run together to allow for coherent conduction of electron spin states along the electron delocalization of such "pi-stacking". The electron trapping frequency between base pairs in the DNA double helix is in the x-ray/gamma ray range, which provides an energy level that is much higher than that of energy fluctuations in the infrared range of the heat involved in biological temperatures, therefore the electron trapping between base pairs is not disrupted by room temperature energy fluctuations. [5] As the electrons that are involved in the quantum logic of the DNA molecule are coherently conducted along the delocalized electron pi-stacking, they also are affected by a spin filtering effect of the DNA molecule. Spin-down electrons can pass longitudinally along the DNA molecule, however, spin-up electrons are filtered out of the longitudinal pathway because the spin of those spin-up electrons will interact with the helicity of the DNA molecule to generate a spin motive force that will push a spin-up electron out of the DNA longitudinal conduction pathway. [6] Coherent electron spin states can be held in a logically and thermodynamically reversible enantiomeric symmetry within the deoxyribose moiety of each nucleotide that enables each nucleotide to act as a quantum gate, and a qubit can transition between quantum and classical information across an energy barrier that is appropriate to the Landauer limit. [7] [8]

Pilot experimental research at the University of Tennessee demonstrated non-local communication between rat neuronal stem cells in separated cell cultures. [2] A 2 Hz regular sequence of 50 msec laser pulses used to stimulate such a culture induced a pattern of oscillatory depolarizations in the stimulated culture (culture A), and this also induced a correlated pattern of oscillatory depolarizations in cells in a cloned separated culture non-locally (culture B). When cell culture A was then exposed to a general anesthetic (to theoretically inhibit microtubule function) and again stimulated with laser pulsations, the correlated oscillatory depolarizations in culture B were non-locally terminated. The non-locality demonstrated in this pilot experimental research supports modeling the DNA molecule as a quantum logic processor that functions via electron entanglement.

Theoretically, an entangled electron pair that is involved in the quantum logic of the DNA molecule can be coherently conducted longitudinally along the DNA molecule, and during DNA replication those two electrons can be separated into two different strands of DNA, and thereby separated into two separate cell cultures. Those entangled electrons are theoretically held in the topologically insulated and reversible conditions that exist in the deoxyribose moiety of each nucleotide. The biological expression of such entanglement and decoherence can thus be modulated by laser pulsations and by pharmacological manipulation.

The DNA Architecture for Quantum Computing

Theoretically in DNA, quantum information is coherently conducted and held between the electron delocalization of the pi-stacking interaction of the aromatic nucleotide bases, and the logically and thermodynamically reversible quantum gate function of the deoxyribose moiety of each nucleotide. That quantum information transitions to classical information across that quantum gate as the deoxyribose moiety on each side of the base pair simultaneously transitions across an energy barrier appropriate to the Landauer limit, between the C2-endo deoxyribose conformation and the C3-endo deoxyribose conformation, thus causing the nucleotide base pair to "roll" between the B-DNA position and the A-DNA position. Such a roll between the B-DNA and A-DNA positions of the individual nucleotide base pair changes the geometry of the pi-stacking interaction of the aromatic nucleotide base pairs, and thus can effect a change in the longitudinal coherence distance along the DNA molecule. Conformational changes in the deoxyribose moiety can also effect changes in the geometric conformation of the phosphate backbone.

The coherence of the quantum DNA system is theoretically maintained in two ways. As intuited by Schrödinger, the coherence of the DNA quantum computing system is maintained by the precisely designed crystalline nanospace of the DNA molecule that limits the effects of entropic factors such as solvation or temperature, to enable fault-tolerant topological quantum computational mechanics to take place therein. While the entanglement of the "logical electrons" that are involved in the process of DNA quantum logic can be very easily disrupted by electromagnetic radiation, theoretically those coherent electrons are shielded by a Faraday cage effect produced by the nuclear membrane that consists of a double lipid bilayer separated by a conductive ionic solution. That Faraday cage effect cannot be penetrated by electromagnetic radiation, but it can be penetrated by the magnetic vector potential that is created during cellular depolarization to synchronize and manipulate electrons that are in appropriate topological/geometric arrangement. [9]

Some of these aspects of the quantum DNA architecture might be emulated to enable development of a man-made quantum computing system. For instance, a functional quantum computer should provide for quantum-to-classical transition of information across a quantum gate operating at an energy level appropriate to the Landauer limit of a deterministic bit/qubit of information. In the quantum DNA architecture, each nucleotide functions not only as a piece of stored information but is also a quantum gate that can be concatenated by the millions via the coherence provide by the pi-stacking interaction of the aromatic nucleotide bases. Because the quantum gate of the DNA quantum logic system operates at the energy level appropriate to the Landauer limit, and a photon at that energy level has a frequency in the low-to-mid terahertz range, emulation of, and/or direct interface with, the quantum logic mechanics of the DNA molecule can theoretically be made with existent terahertz-speed nano-vacuum tube CMOS technology. Another architectural aspect of quantum DNA that can advance man-made quantum logic system design is that of surrounding a quantum logic system with a Faraday cage to protect it from electromagnetic radiation, and then manipulating the system with a magnetic vector potential to flip individual qubits and/or to provide a means of synchronization (i.e. "setting the system to zero") without causing a decoherence of the entire system. [10]

Entanglement Communication System

The non-local communication between cells in separated neuronal cell cultures that was demonstrated in the pilot experimental research at the University of Tennessee, can serve as a proof of concept upon which to build an encryption and communication system that is based upon electron entanglement and decoherence (see Appendix). Such a system could not be blocked or inhibited by any physical structure, and so would function deep in the ocean or deep in the earth, making it ideal for communication with submarines or drones half a world away. Such a system would also be simultaneous over any distance, which would make it ideal for interplanetary and deep space communications. A communication system that is based upon electron entanglement could be protected from electromagnetic interference or jamming by being completely enclosed in a Faraday cage (without an outside antenna) and still function.

Data encryption based upon electron entanglement would provide the utmost security. The only way that such an encryption system could be broken would be if an eavesdropper were able to somehow physically obtain a source of electrons that were entangled with those being used by the system. For instance, if live cell cultures were being used to provide DNA for such purposes, then some piece of that cell culture would need to be obtained to provide the source of entangled electrons. Without having electrons that had been physically entangled with the electrons being used for communication between parties, it would be impossible to intercept the communication between those parties. Such an entanglement communication system could thus theoretically provide for a secure non-local system of quantum key distribution that would operate without any form of physical linkage.

Quantum Random Number Generation

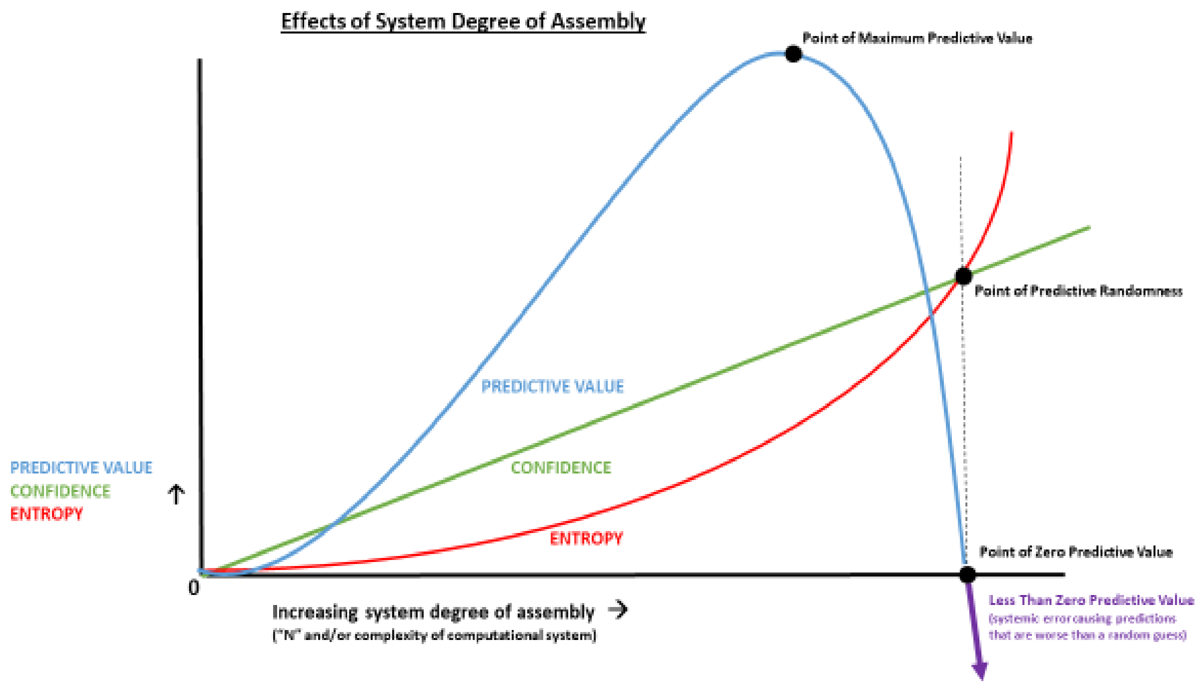
The position of a delocalized electron within the pi-stacking interactions that occur along a DNA molecule in the B-DNA configuration is quantum random. That quantum randomness can provide a source of quantum random number generation that can be used in encryption and for other statistical purposes. That source of quantum randomness can theoretically be interfaced with or emulated via terahertz-speed nano-vacuum tube CMOS technology and by other technologies.

Implications of the quantum DNA model for neuromorphic computing

Modeling the DNA molecule as a quantum logic processor has important implications for neuromorphic computing because such conceptualization means that the conventional designs of artificial neural networks and neuromorphic integrated circuit hardware are based upon incomplete models of neuronal function. Contemporary conventional designs model neuronal function as that of complicated on-off switches akin to the deterministic function of transistors, but the overwhelming bulk of information processing taking place in biological neurological systems (e.g. the brain) theoretically occurs as a result of the quantum logical mechanisms taking place in the DNA molecule rather than as a result of cellular depolarizations. Biological neurological computing takes place within a multi-agent system of cells that are each capable of quantum logic, and it is that multi-agent quantum logic capability that enables a biological system to adapt and grow in the face of systemic entropy and an entropic environment.

Improvements in the predictive accuracy of conventional neuromorphic computations can be made by adding more computational nodes, such as more artificial neurons to the software system or more transistors on a neuromorphic chip, and/or by increasing the amount of data available for computation. Conventional wisdom is that such a more complicated system can provide an increase in computational/data confidence and an increase the predictive value of the system. This is true to a point, but as a system grows the entropy accumulating in the system is another factor that must be taken into consideration. By the Boltzmann equation, entropy compounds logarithmically with increasing degrees of freedom of the system ($S = kT \bullet \log w$), and both the number of computational nodes and the amount of data involved in the computations will increase the degrees of freedom (w) in the system. In a relatively small system (e.g. working with a relatively low number of computational nodes and/or a relatively low number of data points) such entropy might provide a relatively low and easily quantifiable error rate, however, the entropy in such a system compounds logarithmically and as a system becomes relatively more complicated and/or operating with relatively more data involved in the system computations, that entropy will eventually compound to the point that it overtakes the confidence in the system and eventually causing predictions by the system to be no better than random guesses. (Figure 1) This means that the computational system would have a point of maximum predictive value that would be rapidly overcome by logarithmically scaling entropy, causing the predictive value of the system to drop off rapidly in a lognormal fashion to a point of zero predictive value. Such an "entropic catastrophe" cannot be avoided by adding further error correction or inputting more data because such manipulations would serve to increase the degrees of freedom in the system (w), thereby increasing the entropy even further and thus leading to systemic errors that would cause the predictions of the system to be of statistical accuracy worse than that of a random guess. Such error levels are difficult to quantify because they would be different for every computational system and for every data set.

Figure 1.



How is it that a biological system consisting of trillions of cellular agents (e.g. in a eukaryotic organism) can function despite such systemic entropy? The quantum logic processing involved in biological neurological networks serves to reduce the system entropy, thereby increasing the predictive value of the computational system while allowing the system to grow and expand the number of computational nodes, and to increase the amount of data involved in the computation. In quantum logic the hardware and the software are one and the same, and because the DNA molecule is both a data storage medium and an information processing medium, the quantum logic of the DNA molecule can provide for a quantum walk through a massively complicated system containing a massive amount of data, thereby increasing the system's predictive value and preventing an entropic catastrophe. Conventional neuromorphic systems are limited because they are based upon a classical logic model of neuronal function and operate upon classical logic computing systems. Such limitations can be improved by multi-agent system design and eventually, of course, through the use of quantum logic processing.

Conclusion

An understanding of the quantum logic taking place within the DNA of biological systems can provide for multiple disruptive technological advances in the information sciences. Man-made quantum computing can be advanced through emulation of aspects of the quantum logic architecture of the DNA molecule, or through direct interface with the quantum logic mechanisms of the DNA molecule. Quantum random number generation can also be accomplished by emulation of, or direct interface with, the quantum logic processes taking place in the DNA molecule. Secure non-local simultaneous communication can be enabled via a system of interacting quantum entangled particles, and neuromorphic computing can be revolutionized with new paradigms that take into account cellular mechanisms related to quantum logical information processing in advance of cellular depolarization. Systems of artificial intelligence must optimally recognize that human cognition involves the non-metaphorical quantum logic provided by the DNA molecule, especially if such systems seek interface with that human cognition. Quantum DNA is a “black swan technology” with research and developmental imperatives.

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Appendix: A Gedanken Quantum Love Story

You've probably heard a lot of talk about Alice and Bob, but most folks don't know that the original Alice and Bob were actually real people from the hills of East Tennessee whose names were Alice Hatfield and Bob McCoy. Like many kids in East Tennessee their parents were nuclear physicists working at Oak Ridge National Laboratory, but between their families there was a long-standing familial feud over something about quarks, and upon learning that Alice and Bob had taken a fancy to each other at school their families forbade any further interaction between the two. But Alice and Bob had already fallen deeply in love and planned to elope to Trenton, Georgia and get married. The plan was for Alice to find the right moment to slip away and signal Bob to come pick her up at her home, but they had a problem in that Eve Hatfield, Alice's mother, was a security freak and was monitoring all of Alice's communications, whether by cell phone, radio, internet, etc. Alice was very concerned and said, "Oh Bob, how can I ever let you know when I'll be able to sneak away to marry you without my family knowing?" Bob became very depressed over this and went to see his father's brother who was the town doctor, in the hope that his Uncle Leonard might prescribe him an antidepressant. Bob told his Uncle Leonard about his problem of not being able to arrange for an appropriate undetectable elopement signal with Alice, and after listening to Bob's predicament Uncle Leonard said, "Bob, you have situational depression and the cure for you is not in a medication, but rather is in the resolution of your situation. Now, I'm just an old country doctor but I do think that I have something that can help." Then Uncle Leonard stepped out of the exam room for a moment and returned with two identical small boxes saying, "Bob, like many folks here in East Tennessee I'm very interested in quantum information science, and here's something that I've been working on in my spare time. Each of these boxes contains one of a pair of quantum entangled particles that are being held coherently, and each box has three lights on it that tell the state of the particle. Green is for spin-up, red is for spin-down, and yellow is for the unmeasured coherent state. Each box also has a switch that can be moved from the coherent position to the measurement position, thereby measuring the state of the particle in the box. Right now the lights on both boxes are yellow, but when the particle spin direction is measured the light on either box will simultaneously change from yellow to either green or red, because the two particles that had been entangled would then declare their spin states. This is a way that Alice can signal you without being detected." Bob was delighted and when he saw Alice at school he gave her one of the boxes with the instructions to move the measurement switch on her box when the coast was clear for them to meet. Bob watched his box carefully, and when the light changed from yellow to green he drove by and picked up Alice without anyone else knowing, and they were married that day. Their marriage and subsequent children eventually led to resolution of the feud between their families, and Bob and Alice were living happily ever after until one night when Bob awoke in a cold sweat and shook Alice awake saying, "Alice, I fear that we have been living a lie because I learned in my graduate physics class that you can't send classical information between two entangled particles. You need a classical channel to send classical information, so how could you have signaled me through those boxes when we eloped? Did Uncle Leonard lie us?" Alice calmly answered him, "Honey, I asked your Uncle Leonard that same question before he left to join the Space Force, and he told me that in this case it was time that served as the classical channel." Bob thought about this briefly, and satisfied, he kissed his wife and went back to sleep, secure in his love for Alice and in knowing that his Uncle Leonard was out there somewhere helping to keep the galaxy safe.