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# Quantum mechanics and the mechanism of sexual reproduction

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## ABSTRACT

There are many claims that quantum mechanics plays a key role in the origin and/or operation of biological organisms. The mechanism of the meiosis, mitosis and gametes life cycle from the view-point of quantum for human has been represented. The quantum gates have been used to simulate these processes for the first time. The reason of several hundred sperms has been explained in the male too.

**Key words:** entanglement, quantum mechanics, gametes life cycle.

## 1- INTRODUCTION

There are evidence has demonstrated the importance of quantum mechanics for biological systems and thus a new field of quantum biology is emerging. Living systems have mastered the making and breaking of chemical bonds, which are quantum mechanical phenomena. Absorbance of frequency specific radiation (e.g. photosynthesis and vision), conversion of chemical energy into mechanical motion (e.g. ATP cleavage) and single electron transfers through biological polymers (e.g. DNA or proteins) are all quantum mechanical effects. Hopefully, the merging of disciplines known as nanotechnology will remove the interface between quantum physics and biology. Several researchers have spotted the sweeping consequences that would follow from the discovery that living organisms might process information quantum mechanically, either at the bio-molecular level, or the cellular/neuronal level (Beck, 1992; Matsuno, 2000; Vedral, 2003). An important contribution to the quantum theory of consciousness comes from the collaboration of Penrose and Hameroff (1996, 1994). According to this theory, consciousness appears during the Orchestrated Objective Reduction (Orch OR) of the wave function in the microtubules of the brain's neurons. This definition, even though it seems to be limited to the brain, also allows the possibility of consciousness to exist in the quantum field itself, outside the body. Today the cell is regarded not as magic matter but as a computer - an information processing and replicating system of astonishing precision. Davies (2004a, 2004b, 2004c) has discussed possibility that quantum processes may be a common denominator for living systems. It has been explained that quantum theory fills a missing link in existing models of the origins of life, of which there are many. The quantum effects

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underlie the living state. Quantum processes are at the core of living systems, and relevant to health (Zeilinger, 1999). The first principle for modeling behavior of living systems has been introduced by Zak (2007). The structure of the model has been obtained from quantum mechanics by replacing the quantum potential with the information potential. Biophotons were used the first time by Popp et al. (1998, 2002) in order to describe a permanent light emission from all biological systems in terms of single photons, indicating a biological quantum phenomenon.The processes that form the basis of life and evolution have been explained by Patel (2000). Replication of DNA and synthesis of proteins have been studied from the view-point of quantum Patel, 2001). A quantum algorithmic mechanism for DNA replication and protein synthesis has been proposed too.The action of enzymes in biological systems has been investigated using quantum mechanical principles by Frolich (1975).Thus there are many claims that quantum mechanics plays a key role in the origin and/or operation of biological organisms. We discussed virus life cycle from the view-point of quantum and simulate it using quantum gates (Shojaie & Dehestani, 2010). In this work, we present the mechanism of the meiosis I and II, mitosis and gametes life cycle from the view-point of quantum in human for the first time. We simulate these processes with quantum gates. Here, we explain the simulation of cell cycle (before mitosis) with quantum gates completely; the method is same for the other simulations (mitosis, meiosis and gametes).This paper is a theoretical work and is based on quantum theory of biology.

## 2-Simulation of cell cycle

The stages of eukaryotic cell cycle are G1-S-G2-M. The stages stand for growth and preparation of the chromosomes for replication ($G_1$), synthesis of DNA and centrioles (S), preparation for cell division ($G_2$) and mitosis (M). We have simulated the cell cycle mechanism from the view-point of quantum. This simulation is formed from two steps, before mitosis (G1-S-G2) and mitosis (M).

### 2-1- Simulation of before mitosis

A bit is the fundamental concept of classical computing and classical information. Quantum computing and quantum information are built upon a similar concept, the quantum bit, or qubit. Two possible states for a qubit are the states $|0\rangle$ and $|1\rangle$, which are corresponding to the states 0 and 1 for a classical bit. The difference between bits and qubits is that a qubit can be in a state other than $|0\rangle$ or $|1\rangle$. It is also possible to form linear combinations of states, often called superpositions as following:

$$|\psi\rangle = a|0\rangle + b|1\rangle \qquad (1)$$

Where $a$ and $b$ are the complex numbers, although for many purpose not much is lost by thinking of them as real numbers. Put another way, the state of a qubit is a vector in a two-dimensional complex vector space. The special states $|0\rangle$ and $|1\rangle$ are known as computational basis states, and form an orthonormal basis for this vector space (Nileson & Chuang, 2002); qubits can store more data than bits, too. When a qubit is measured we get either 0, with probability $|a|^2$, or 1, with probability $|b|^2$. Naturally, $|a|^2 + |b|^2 = 1$, since probabilities must be one. Before mitosis in the cell cycle, centrioles can be entangled with each other because a centriol is evenly divided to two centrioles. Thus the centriols are EPR pairs, in according to the EPR theory. Entangled states were first investigated in the famous paper of Einstein, Podolsky and

Rosen (EPR) (Einstein, Podolsky, & Rosen, 1935). It means we can generate the Bell states with a Hadamard gate and a CNOT gate. The EPR gate describes centrioles division in this cycle because in EPR gate, the first qubit is passed through a Hadamard gate and then both qubits are entangled by a CNOT gate. The Bell states are generated with EPR gate too. Since the Hadamard gate acts on one qubit, and places it in a superposition of $|0\rangle$ and $|1\rangle$, we have used this gate for chromosomes replicate in preparation for cell division (replication). A quantum gate can be represented as a matrix, which is directly derived from the linearity of quantum gates. The Hadamard operation H and the effect of the Hadamard gate on qubits are defined by:

$$H = \frac{\sqrt{2}}{2}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} \qquad \begin{aligned} H|1\rangle &= \frac{\sqrt{2}}{2}\left(|0\rangle + |1\rangle\right) \\ H|0\rangle &= \frac{\sqrt{2}}{2}\left(|0\rangle - |1\rangle\right) \end{aligned} \qquad (2)$$

The most important enzyme in DNA replication is DNA polymerase that doing the hard work. Enzymes play a very important role in many biochemical reactions. Here, the CNOT gate describes operation of DNA polymerase in the duplication of DNA with cooperation of ribosomes, since this gate is useful for demonstrating one particularly fundamental property of quantum information. The single-qubit operations and the CNOT gate constitute a universal set of gates (Reith & Schommers, 2007). The CNOT operation and the effect of the CNOT gate on qubits are as following:

$$CNOT = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \qquad \begin{aligned} CNOT \quad |00\rangle &= |00\rangle \\ CNOT \quad |01\rangle &= |01\rangle \\ CNOT \quad |10\rangle &= |11\rangle \\ CNOT \quad |11\rangle &= |10\rangle \end{aligned} \qquad (3)$$

2-2-Simulation of mitosis

Mitosis is the process by which a cell ensures each daughter cell will have a complete set of chromosomes. The phases of cell division are prophase, metaphase, anaphase, and telophase, and these occur in both mitosis and meiosis. Meiosis produces 4 haploid cells and mitosis produces 2 diploid cells. During prophase the chromosomes become condensed and key proteins begin to bind the kinetochores, preparing for spindle attachment. At metaphase, all of the chromosomes are attached to microtubules via their kinetochores, and aligned at the metaphase plate. At anaphase, the sister chromatids are separated and moved_toward the poles of the spindle. During telophase, the mother cell is physically divided into two daughter cells by cytokinesis. In the cell division process the cells are evenly divided to two cells in mitosis, which can be entangled with each other, it means daughter cells are EPR pairs. Thus we can generate the Bell states with the Hadamard and the CNOT gates. The separation the paired chromosomes at the kinetochores and their movement to opposite sides of the cell during anaphase with cooperation of prophase and metaphase can be stimulated with the Hadamard gate. The CNOT gate can be used to stimulate operation of cytokinesis during telophase. So, the cell division in mitosis can be described by

the EPR gate. The normal mitosis has been organized using the quantum entanglement and quantum coherence among centrioles by Hameroff (2004) too.

**3- Simulation of meiosis**

Specialized type of cell division that occurs during the formation of gametes is meiosis. Although meiosis may seem much more complicated than mitosis, it is really just two cell divisions in sequence it means two successive nuclear divisions occur, meiosis I and meiosis II. Each of these sequences maintains strong similarities to mitosis. The process of the pairing between homologous chromosomes of maternal and paternal origin during the prophase I, leading to the formation of gametes is called synapsis. The resulting chromosome is termed a tetrad, being composed of two chromatids from each chromosome, forming a thick (4-strand) structure. Metaphase I is when tetrads line-up along the equator of the spindle. Spindle fibers attach to the centromere region of each homologous chromosome pair. Anaphase I is when the tetrads separate, and the homologous chromosomes move to opposite poles of the cell. During the telophase I, the chromosomes gather into nuclei, and the original cell divides. Some animal cells have division of the cytoplasm; this process of division is called cytokinesis. Thus Meiosis I reduces the ploidy level from 2n to n. In prophase II, the chromosomes condense again, following a brief interphase in which DNA does not replicate. Kinetochores of the paired chromatids line up across the equator of each cell in metaphase II. During anaphase II, the centromeres split and the former chromatids (now chromosomes) are segregated into opposite sides of the cell. During telophase II, the chromosomes gather into nuclei, and the cells divide and cytokinesis separates the cells. In this process the cells are evenly divided to two cells in the meiosis I and four cells in the meiosis II, which can be entangled with each other, it means daughter cells are EPR pairs. Thus we can generate the Bell states with a Hadamard gate and a CNOT gate. In meiosis I, the process of synapsis with cooperation of metaphase I and anaphase I can be simulated based on a Hadamard gate. A CNOT gate has been used to simulate the operation of cytokinesis during telophase I. In the meiosis II, the separation the chromatids of the new chromosomes during anaphase II with cooperation of prophase II and metaphase II act like a Hadamard gate. The operation of cytokinesis during telophase II can be simulated using a CNOT gate. The EPR gate describes cell division in the meiosis I and II too.

**4- Simulation of gametes**

Forming the gametes requires cells to undergo a special type of cell division called meiosis, which is really two cell divisions happening one after the other. A mature male (sperm) or female (egg or ovum) germ cell usually possessing a haploid chromosome set, and capable of initiating formation of a new diploid individual by fusion with a gamete of the opposite sex.

4-1- Simulation of female gamete

Oogenesis is the process of forming an ovum (egg) by meiosis in specialized gonads known as ovaries in the females. The primary oocyte gives the secondary oocyte and the first polar body that they can not be entangled together; they are not EPR pairs, in female meiosis I. because the cytoplasm is unevenly divided. In the meiosis II, an ootid and secondary polar bodies is created that are not entangled together too (meiosis II only occurs if and when fertilization occurs by a sperm cell). On the other hand, the development of the egg cell involves an unequal cell division thus in this division there are no entanglement and no EPR pairs. We can not simulate mechanism of the meiosis I and II with EPR gate in

the females; because there is not CNOT gate that describes the operation of cytokinesis (cytoplasm is unevenly divided).

4-2- Simulation of male gamete

Male gamete produces by male individual of the species and is smaller than egg, called sperm. Each primary spermatocyte duplicates its DNA and subsequently undergoes the meiosis I to produce two haploid secondary spermatocytes and secondary spermatocytes produced earlier rapidly enter meiosis II and divide to produce haploid spermatids. During spermiogenesis, the spermatids begin to grow and spermatozoa forms. In this process, cells are evenly divided to two secondary spermatocyts in the meiosis I and four spermatides in the meiosis II, which can be entangled with each others thus they are EPR pairs. Since the cytoplasm is evenly divided, the CNOT gate can describe the operation of cytokinesis, in the meiosis I and II. We can simulate the meiosis I and II with EPR gate in the male. This gate describes secondary spermatocytes division and spermatides division in the meiosis I and II, respectively.

**5. Discussion and Results**

Using quantum gates we can stimulate the mitosis and meiosis with EPR gate for the first time. In EPR gate, the qubits are passed through a Hadamard gate and then both qubits are entangled by a CNOT gate. It means that the CNOT gate tangles quantum states of both qubits into a single bipartite quantum state, such bipartite state stores information within the entanglement. There are also direct connections between entanglement and information transmission discovered by Bennett et al. (1990).The sperms can swim several millimeters each second and the muscular movement of the wall of the uterus and the tubes helps its mobility. There is also evidence that they respond to a chemical attractant produced by the egg or the tissues surrounding it, so there is communication for the accurate transmission of information between sperm and egg. In any case, sperm may reach the egg within 15 minutes of ejaculation. Thus there is interaction between the sperms and the environment in this the long journey. The sperms are EPR pairs and the interaction of entangled particles with the environment causes decoherence, so that the resulting EPR pair will not be maximally entangled. In order to decrease interaction of the sperms with the environment, many entangled EPR pair need it means the male's cycle occurs with several hundred million sperms cells being produced daily. The trip is also fraught with heavy mortality they are EPR pairs that entanglement between them are destroyed in reach to egg. An average human ejaculate contains over one hundred million sperm, but only a few dozen reach the uterus, they are pure entangled EPR pairs. But successful fertilization requires a sperm with complete information and only one breaks the egg for accurate transmission of information to form zygote. We have used qubits, because the beauty of treating qubits gives us the freedom to construct a general theory of quantum computation and quantum information which does not depend on a specific system for its realization. If sperms are present in the oviduct at the time of ovulation, fertilization takes place in the oviduct. Zygote forms as a result of fertilization. Let us consider, three states, the spermatozoon without interaction with the egg $|0\rangle$, the ovum without interaction with the sperm $|1\rangle$ and combination the sperm and the egg $|\psi\rangle = a|0\rangle + b|1\rangle$. $|a|^2$ and $|b|^2$ represent probability of participation the sperm and the egg in formation zygote, respectively. In fertilization, the egg nucleus unites with the sperm nucleus it means a mature human sperm and a mature human oocyte are products of gametogenesis. Each of them has only half of the required number of chromosomes for a human being. They cannot singly develop further into human beings. Therefore

fertilization is complete when genetic materials (the sperm and the egg) are equal that is probability of participation of the sperm is $|a|^2 = \frac{1}{2}$(containing 23 chromosomes) and also probability of participation of the egg is $|b|^2 = \frac{1}{2}$(containing 23 chromosomes). Because each germ cell normally has 46 chromosomes, the process of fertilization can not take place until the total numbers of chromosomes in each germ cell are cut in half. It means a chromosome is formed from a single DNA molecule that contains many genes and whereas the genes play an important role in growth of the body, presence all the genes is necessary for health of the body and to avoid doubling the amount of inherited information every generation, each gamete contains only half the amount of inherited information. Until now, to the best of our knowledge, no theoretical work has been devoted to the study this detailed the mechanism of the meiosis I and II, mitosis and gametes life cycle from the view-point of quantum in human, using quantum gates. In this paper, an attempt is made to elucidate these mechanisms and to give a suitable explanation to the biology results. For the first time, we have explained the reason of several hundred sperms from the view-point of quantum in the male and we have showed fertilization will be completed when genetic materials (the sperm and the egg) equal with each other. This paper shows quantum effects in biology and the quantum concepts have been used to understand physiological phenomenon in reproduction. There are many biological phenomena that can be explained and extended by quantum theory; these explanations agree with biology results. All biological organisms must obey the laws of quantum mechanics (Hameroff, 2006). Therefore a range of phenomena can understand by quantum mechanics, any small particle can behave like a quantum particle, it means gametes have quantum behavior thus we can examine them from the view-point of quantum.

## 6- Conclusion

The state of a classical system can be specified by specifying the states of all its constituent systems. But in the quantum theory a combined system can have additional properties, in which case the constituent systems can be said to be entangled with one another. If two particles are entangled, measuring one of them will lead to a correlated result when the other is measured. While measurement of the first particle gives a random result, the state of the second particle will be fixed. Ability of the particles to be entangled gives rise to many interesting and useful applications, e.g. quantum teleportation. Before mitosis in the cell cycle, centrioles can be entangled with each other and they are EPR pairs. Since the information has to be transferred between centrioles completely in order to form daughter cells in stage of mitosis, we believe, this entanglement does not have to be destroyed by each factor. Mitosis is cell division that results in the duplication of cells, the daughter cells genetic copies from the parent cell. This cell multiplication allows for replacement of old cells, tissue repair, growth and development. These cells can be entangled together, this entanglement is important because the information should be transferred completely, in order to grow and cell replacement or repair. In the cell division process, cells divide to two cells in the meiosis I and four cells in the meiosis II, which can be entangled with each other and they are EPR pairs. In the meiosis I, the entanglement between two cells is an important object, in order to produce four cells with complete information in the meiosis II. We believe if this entanglement is destroyed by each factor; the maternal and paternal chromatids can not exchange bits of DNA to recombine their genetic material and can not increase the potential for variation. Spermatogenesis is the process of sperm cell development. Rounded immature sperm cells undergo successive mitotic and meiotic divisions (spermatocytogenesis) and a metamorphic change (spermiogenesis) to produce spermatozoa. There is entanglement between secondary spermatocytes in the meiosis I, this entanglement

does not have to be destroyed by each factor because information has to be transferred between secondary spermatocytes in order to form spermatids in the meiosis II. The entanglement between spermatids require for transmission of information to produce spermatozoa too. In this process spermatozoa can be entangled with each other and they are the EPR pairs. Consequently, this entanglement does not have to be destroyed in order to transport the information in fertilization. Because the fertilizing potential of sperm depends on the shape of spermatozoa, their motility and their ability to perform the functions necessary for fertilizing an egg and finally, the transfer of an intact genetic material (DNA) to the egg at the time of fertilization. One of fundamental and characteristic differences between classical and quantum information is the no-cloning theorem. This theorem says that copying of quantum states is prohibited. A number of different versions of the no-cloning theorem have been published (Wootters & Zurek, 1982). In according to this theory, the operator of copy transforms the superposition states into the Bell states. The centrioles division can be simulated using an operator of copy. The centrioles division produces daughter centrioles and in this process, the centrioles don't clone, however they are evenly divided to two centrioles. Since the quantum states can not be copied, there is no the same information in daughter and parent centrioles according to the no-cloning theory. The centrioles are found as a pair, composed of a mother and a daughter, which is duplicated during each cell cycle. Paintrand et al. (1992) have explained that mother centrioles have unique ultrastructural modifications and are decorated with a number of molecules not found on daughter centrioles. The cell division in the meiosis and mitosis can be simulated using an operator of copy too. In this process, the cells don't clone, however they are evenly divided to two cells in the mitosis, two cells in the meiosis I and four cells in the meiosis II. The cell division produces the daughter cells that have all the genetic material of the parent cell. Since quantum states can not be copied, there is no the same information in daughter and parent cells according to the no-cloning theory. Overall, however, one can conclude that the information in genetic material differs from generation to generation. It means that the baby doesn't have the same genetic material of its mother or father but the baby has genetic material with new properties and information.

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