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A Theory of Bio-Quantum Genetics

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Abstract

The physical mechanism of heredity or inheritance of genes is a quantum mechanical and/or quantum computational process. A theory of bio-quantum genetics is established in this paper. Principle of Bio-quantum Genetics is suggested. I propose and define the soft-genes of genetics controlling the processes of heredity or inheritance of genes. This research deals with the quantum mechanisms of Mendel plant heredity and family inheritance as examples of bio-quantum genetics, deepening our understanding of heredity or inheritance. I believe that more contributions will be made to promote researches of bio-quantum genetics or quantum biology at large.

Keywords

Bio-Quantum Genetics, Quantum Mechanics, Genes, Soft Genes, Quantum Mechanism of Mendel Plant Heredity, Quantum Mechanism of Family Inheritance

1. Introduction

In 1866, Mendel published his outstanding paper "Experiments on Plant Hybrids" dealing with genetic information [1] [2] [3] [4]. In 1909, Johannsen introduced the word "gene" for the fundamental unit of genetic information [3] [5]. The post-World War Two discovery launched a revolution in Genetics. Watson, Crick, Wilkins and Franklin solved the three-dimensional structure of DNA [3] [4] [6] [7] [8]. Following 1900 there accumulated a body of information concerning the Mendelian inheritance in man. Farabee and others studied the cases of Mendelian differences between families [3]. Gobineau and others studied Mendelian differences between races [3]. Galton suggested the possibility of the genetic improvement of human populations [3].

Many authors made researches on relationships between family histories and risks of genetic diseases [9]-[21]. Some authors noticed atavism and its importance [22]-[28].

Application of quantum mechanics to life science results in development of quantum biology. The origin of quantum biology is often traced back to Schrödinger's publication "What is Life" [3] [29]. Quantum biology is a field of study that applies the theory of quantum mechanics to understand biology, and has unique contributions to life science. Researchers made contributions to quantum biology [29]-[39], problems of genetics are concerned [38] [39].

We understand heredity or inheritance by understanding genes, fundamental units of genetic information [3]-[8]. Genes are micro-entities, ruled by laws of quantum mechanics, the physical science of the micro-world [40] [41] [42]. Quantum states of genes obey the fundamental principles of quantum mechanics, superposition, uncertainty and entanglement, and its mathematical inference rules. Also, genes are bio-quantum bits, whose states are controlled and transformed by quantum computation. Therefore, the underlying physical mechanism of genetics is quantum mechanical and/or quantum computational processes. Logically, establishing a bio-quantum theory of genetics is reasonable. The study of bio-quantum genetics may result in a deeper understanding of genetics and open up a new territory of fruitful enquiry.

In this paper, I establish a system of bio-quantum genetics. I suggest the principle of bio-quantum genetics: heredity or inheritance is a quantum mechanical and/or quantum computational process.

I suggest a bio-quantum model of plant heredity, derive the results of Model's experiments, explaining the reappearance of the recessive character, deriving Model Ratio, proving the general formula of Model Ratio.

I suggest a bio-quantum model of human genetics, give a bio-quantum mechanism of the inheritance of the family genes, resulting in the solutions of normal inheritance, reversion and atavism, by quantum computation.

I propose and define the soft-genes: the fundamental principles of bio-quantum mechanics, the inference rules of quantum mechanics, the bio-quantum entangling and de-entangling program and the quantum computational algorithms.

The soft-genes control the processes of heredity or inheritance of the genes.

2. System of Bio-Quantum Genetics [40]-[45]

The system of bio-quantum genetics consists of the following elements:

1) Principle of Bio-quantum Genetics: Heredity or inheritance is a quantum mechanical and/or quantum computational process;

2) Fundamental principles of bio-quantum mechanics: superposition, uncertainty and entanglement;

3) Principle of uncertainty of bio-quantum mechanics:

For any bio-quantum state,

$$p_d + p_r = 1 \tag{1}$$

$$p_d p_r = 0 \tag{2}$$

where p_d is the probability of the measurability of the dominant gene, p_r is the probability of the measurability of the recessive gene.

4) Rules of mathematical inference in quantum mechanics;

5) Quantum measurement;

6) Wave packet collapse;

7) Genes: bio-quantum bits, fundamental units of bio-quantum genetic information;

8) Quantum-genes or soft-genes: the fundamental principles of bio-quantum mechanics, the mathematical inference rules of quantum mechanics, the bio-quantum entangling and de-entangling program and the quantum computational algorithms.

3. Bio-Quantum Genetic Model of Plant Heredity [1] [2] [3] [40] [41] [42]

I define $|1\rangle$ to be the bio-quantum state of the dominant gene or character, where 1 is the bit of the dominant gene or character A. I define $|0\rangle$ to be the bio-quantum state of the recessive gene or character, where 0 is the bit of the recessive gene or character a.

I find that the process to produce plant generations is iteration of bio-quantum entangling and de-entangling program.

3.1. Bio-Quantum States of Hybrids

The bio-quantum state of a hybrid is a bio-quantum entangling state of $|1\rangle$ and $|0\rangle$,

$$|0\rangle \otimes |1\rangle = |01\rangle. \tag{3}$$

According to the uncertainty principle of bio-quantum genetics, one bio-quantum de-entangling inference of $|01\rangle$ is

$$|01\rangle \to |1\rangle \tag{4}$$

for measurement to display the dominant character. Another bio-quantum de-entangling inference of $|01\rangle$ is

$$|01\rangle \to \frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right). \tag{5}$$

We will see that the de-entangled state of Equation (5) is effective for producing the first generation of the hybrid.

3.2. The First Generation of the Hybrid

The first generation of the hybrid is the bio-quantum entangling of the state of Equation (5) with itself

$$\frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right) \otimes \frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right) = \frac{1}{2}\left(|00\rangle + |01\rangle + |10\rangle + |11\rangle\right) \tag{6}$$

where $|00\rangle$ is the homozygous state of the recessive gene, $|11\rangle$ is the homozygous state of the dominant gene, $|01\rangle$ and $|10\rangle$ are the heterozygous states of genes.

From Equation (6), the ratio between the number of the dominant states, the number of the hybrid states and the number of the recessive states (A:Aa:a Ratio or Mendel Ratio for short) is

$$1:2:1. \tag{7}$$

In other words, the probability of the dominant state, the hybrid states and the recessive state is $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$ respectively.

The bio-quantum de-entangling of $|00\rangle$ is

$$|00\rangle \to |0\rangle \text{ (for measurement of the recessive character)}, \tag{8}$$

explaining the "reappearance" of the recessive character described by Mendel,

$$\text{and } |00\rangle \to \frac{1}{\sqrt{2}}\left(|0\rangle + |0\rangle\right) \text{ (for producing the second generation)}. \tag{9}$$

The bio-quantum de-entangling of $|11\rangle$ is

$$|11\rangle \to |1\rangle \text{ (for measurement of the dominant character)} \tag{10}$$

$$\text{and } |11\rangle \to \frac{1}{\sqrt{2}}\left(|1\rangle + |1\rangle\right) \text{ (for producing the second generation)}. \tag{11}$$

The bio-quantum de-entangling of $|01\rangle$ is

$$|01\rangle \to |1\rangle \text{ (for measurement of the dominant character)} \tag{12}$$

$$\text{and } |01\rangle \to \frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right) \text{ (for producing the second generation)}. \tag{13}$$

The bio-quantum de-entangling of $|10\rangle$ is

$$|10\rangle \to |1\rangle \text{ (for measurement of the dominant character)} \tag{14}$$

$$\text{and } |10\rangle \to \frac{1}{\sqrt{2}}\left(|1\rangle + |0\rangle\right) \text{ (for producing the second generation)}. \tag{15}$$

3.3. The Second Generation of the Hybrid

The production of the second generation is a series of bio-quantum entangling.

From Equation (9),

$$\frac{1}{\sqrt{2}}\left(|0\rangle + |0\rangle\right) \otimes \frac{1}{\sqrt{2}}\left(|0\rangle + |0\rangle\right) = \frac{1}{2}\left(|00\rangle + |00\rangle + |00\rangle + |00\rangle\right). \tag{16}$$

From Equation (11),

$$\frac{1}{\sqrt{2}}\left(|1\rangle + |1\rangle\right) \otimes \frac{1}{\sqrt{2}}\left(|1\rangle + |1\rangle\right) = \frac{1}{2}\left(|11\rangle + |11\rangle + |11\rangle + |11\rangle\right). \tag{17}$$

From Equation (13),

$$\frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right) \otimes \frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right) = \frac{1}{2}\left(|00\rangle + |01\rangle + |10\rangle + |11\rangle\right). \tag{18}$$

From Equation (15),

$$\frac{1}{\sqrt{2}}\left(|1\rangle + |0\rangle\right) \otimes \frac{1}{\sqrt{2}}\left(|1\rangle + |0\rangle\right) = \frac{1}{2}\left(|11\rangle + |10\rangle + |01\rangle + |00\rangle\right). \tag{19}$$

Then, from Equation (16)-Equation (19), the number of the recessive states and the number of the dominant states are the same,

$$1\times 4+2=6. \tag{20}$$

The total number of hybrid states $|01\rangle$ and $|10\rangle$ is

$$2\times 2=4. \tag{21}$$

And so, the A:Aa:a Ratio of the second generation is

$$6:4:6, \tag{22}$$

that is,

$$3:2:3. \tag{23}$$

3.4. The Third Generation of the Hybrid

Reviewing Section3.2 and Section3.3, we know that each dominant state produces 4 dominant states for its next generation; each recessive state produces 4 recessive states for its next generation; each hybrid state produces one dominant state, one recessive state and two hybrid states for its next generation.

And so, the number of the recessive states or the number of the dominant states of the third generation is

$$6\times 4+4=28 \tag{24}$$

referring to Equation (20) and Equation (21).

The number of the hybrid states of the third generation is

$$4\times 2=8 \tag{25}$$

referring to Equation (21).

From Equation (24) and Equation (25), the A:Aa:a Ratio of the third generation is

$$28:8:28, \tag{26}$$

that is,

$$7:2:7. \tag{27}$$

3.5. The Fourth Generation of the Hybrid

Calculating similarly, the number of the dominant states or the recessive states of the fourth generation is

$$28\times 4+8=112+8=120; \tag{28}$$

the number of the hybrid states of the fourth generation is

$$8\times 2=16. \tag{29}$$

From Equation (28) and Equation (29), the A:Aa:a Ratio of the fourth generation is

$$120:16:120, \tag{30}$$

that is,

$$15:2:15. \tag{31}$$

3.6. The Fifth Generation of the Hybrid

Calculating similarly, the number of the dominant states or the number of the recessive states of the fifth generation is

$$120 \times 4 + 16 = 480 + 16 = 496; \quad (32)$$

the number of the hybrid states of the fifth generation is

$$16 \times 2 = 32. \quad (33)$$

From Equation (32) and Equation (33), the A:Aa:a Ratio of the fifth generation is

$$496:32:496, \quad (34)$$

that is,

$$31:2:31. \quad (35)$$

The results of A:Aa:a Ratio obtained in Section3.2-Section3.6 are identical to those of Mendel's experiments on plant hybrids [1] [2] [3].

3.7. My Proof of Mendel General Formula of A:Aa:a Ratio

Mendel General Formula [1] [2]:

For nth generation of the hybrid, the A:Aa:a Ratio is

$$\left(2^n - 1\right):2:\left(2^n - 1\right). \quad (36)$$

Proof:

(A)The A:Aa:a Ratio of the first generation, from Equation (36), is

$$\left(2^1 - 1\right):2:\left(2^1 - 1\right), \quad (37)$$

that is,

$$1:2:1. \quad (38)$$

Ratio of Equation (38) is identical to that of Equation (7). That means that Mendel General Formula is true for $n = 1$.

(B) Suppose that Mendel General Formula is true for $n = m$:

$$\left(2^m - 1\right):2:\left(2^m - 1\right). \quad (39)$$

(C) Referring to calculations of Section 3.2 and Section3.3, the number of the dominant states or the number of the recessive states of $(m+1)$ *th* generation is

$$\left(2^m - 1\right) \times 4 + 2 = 2^{m+2} - 4 + 2 = 2^{m+2} - 2 \quad (40)$$

from Equation (39).

Referring to calculations of Section3.2 and Section3.3, the number of the hybrid states of $(m+1)$ *th* generation is

$$2 \times 2 = 4 \quad (41)$$

from Equation (39).

From Equation (40) and Equation (41), the A:Aa:a Ratio of $(m+1)$ *th* generation is

$$\left(2^{m+2} - 2\right):4:\left(2^{m+2} - 2\right), \quad (42)$$

that is,

$$\left(2^{m+1}-1\right):2:\left(2^{m+1}-1\right). \tag{43}$$

Equation (43) indicates that Equation (36) is true for $n=m+1$.

From steps (A)-(C), Mendel General Formula of A:Aa:a Ratio is proved, and is a Ratio Theorem of the Bio-quantum Genetics now.

3.8. Soft-Genes of the Plant

I find that the fundamental principles of bio-quantum mechanics, the mathematical inference rules of quantum mechanics and the bio-quantum entangling and de-entangling program control the heredity process of the plant genes, for every generation of the plant, and define them to be the soft-genes of the plant.

4. A Bio-Quantum Genetic Model of Human Genetics [40]-[45]

4.1. Bio-Quantum State of Family Gene

The bio-quantum state of the family genes communicated to the germ cell is

$$\left|F\right\rangle=\frac{1}{\sqrt{N}}\sum_{i=1}^{n}\sum_{j=1}^{2^{i-1}}\left|F_{-i,j}\right\rangle \tag{44}$$

where $\left|F_{-1,1}\right\rangle$ is the bio-quantum sub-state of the genes of the parents (the father and the mother); $\left|F_{-2,1}\right\rangle$ and $\left|F_{-2,2}\right\rangle$ are the bio-quantum sub-states of the genes of the grandparents (the two couples of grandfather and grandmother); $\left|F_{-3,1}\right\rangle$, $\left|F_{-3,2}\right\rangle$, $\left|F_{-3,3}\right\rangle$ and $\left|F_{-3,4}\right\rangle$ are the bio-quantum sub-states of the genes of the grand-grand-parents (the four couples of grand-grand-father and grand-grand-mother); $\left|F_{-n,1}\right\rangle$, … $\left|F_{-n,2^{n-1}}\right\rangle$ are the bio-quantum sub-states of the genes of the *nth* generation of the ancestors; $N=2^{n}-1$.

4.2. Inheriting

Family inheriting is a process of quantum computing. Choosing or determining *n*, invoking and running the quantum search programs, the fetus searches the bio-quantum state of the family genes for the bio-quantum sub-state of his parents'.

4.3. Normal Inheriting

For the case of

$$n=1,$$

the bio-quantum state of family genes is reduced to

$$\left|F\right\rangle=\left|F_{-1,1}\right\rangle=\left|1\right\rangle. \tag{45}$$

The fetus inherits his parents' genes only by one search step, no matter whether the parents' genes are "good" or "bad". This is a normal inheriting. This is also the simplest and most economical inheriting.

4.4. Easy Inheriting

For the case of small *n*, inheriting is an easy search. For example, when

$$n = 10,$$

then $N = 2^{10} - 1$, the fetus inherits his parents' genes by $O\left(10^3\right)$ search steps. This is another normal inheriting.

4.5. Inheriting by Grover's Fast Quantum Mechanical Algorithm [40]-[45]

For the case of $n \gg 1$, the fetus searches $\left|F\right\rangle$ for the bio-quantum substate of his parents' genes, $\left|F_{-1,1}\right\rangle$, invoking and running Grover's fast quantum mechanical algorithm for database search [43] [44] [45].

1) Definitions [45]

$$\left|U\right\rangle \equiv \frac{1}{\sqrt{N-1}} \sum_{i=2}^{n} \sum_{j=1}^{2^{i-1}} \left|F_{-i,j}\right\rangle, \tag{46}$$

$$\left|V\right\rangle \equiv \left|F_{-1,1}\right\rangle, \tag{47}$$

then

$$\left|F\right\rangle = \sqrt{\frac{N-1}{N}} \left|U\right\rangle + \sqrt{\frac{1}{N}} \left|V\right\rangle; \tag{48}$$

$$O \equiv 1 - 2\left|V\right\rangle\left\langle V\right| \quad \text{(oracle)}, \tag{49}$$

$$D \equiv 2\left|F\right\rangle\left\langle F\right| - 1, \tag{50}$$

then

$$G \equiv DO. \tag{51}$$

2) Performing $\left|G\right\rangle$ on $\left|F\right\rangle$ for m iterations [45]:

$$G^m \left|F\right\rangle = \cos\left(\frac{2m+1}{2}\theta\right)\left|U\right\rangle + \sin\left(\frac{2m+1}{2}\theta\right)\left|V\right\rangle \tag{52}$$

where $\frac{\theta}{2} \approx \frac{1}{\sqrt{N}}$.

3) Measuring $G^m \left|F\right\rangle$ [45]

4) The general probabilities of inheriting

The general probability for the baby to inherit his parents' genes is

$$P_v = \left|\sin\left(\frac{2m+1}{2}\theta\right)\right|^2 \approx \left|\sin\left(\frac{2m}{\sqrt{N}}\right)\right|^2 \tag{53}$$

from Equation (52).

The general probability for the baby to skip his parents' genes is

$$P_u = \left|\cos\left(\frac{2m+1}{2}\theta\right)\right|^2 \approx \left|\cos\left(\frac{2m}{\sqrt{N}}\right)\right|^2 \tag{54}$$

from Equation (52)

The probabilities P_v and P_u are periodic.

4.6. Some Special Inheriting

1) Normal inheriting:

When $m \approx \left[\frac{\pi}{4}\sqrt{N}\right]$, then

$$P_v = O(1),\ \ P_u = O(0) \tag{55}$$

from Equation (53) and Equation (54).

That is, the fetus inherits his parents' genes, $|F_{-1,1}\rangle$, with a probability of $O(1)$, by searching the $|F\rangle$ in $O\left(\sqrt{N}\right)$ steps ($N = 2^n - 1$).

2) Reversion:

When

$$m \approx \left[\frac{\pi}{8}\sqrt{N}\right],$$

then

$$P_v = O\left(\frac{1}{2}\right),\ \ P_u = O\left(\frac{1}{2}\right) \tag{56}$$

from Equation (53) and Equation (54).

That is, the fetus inherits his parents' genes, $|F_{-1,1}\rangle$, with a probability of $O\left(\frac{1}{2}\right)$, if the steps of the search are of $O\left(\frac{1}{2}\sqrt{N}\right)$ until the baby is born. Or, the fetus skips his parents' genes, $|F_{-1,1}\rangle$, with a probability of $O\left(\frac{1}{2}\right)$, by $O\left(\frac{1}{2}\sqrt{N}\right)$ search steps, which is a case of reversion of inheriting. Thus, if the sub-state $|U\rangle$ collapse to its sub-state,

$$|U\rangle \rightarrow |F_{-2,1}\rangle \tag{57}$$

for example, for the measuring, the baby inherits the genes of the first couple of his grandparents.

3) Atavism:

When

$$m \approx 0,$$

then

$$P_v = O(0),\ \ P_u = O(1) \tag{58}$$

from Equation (53) and Equation (54).

The fetus inherits his parents genes with a probability of $O(0)$. That is, the fetus skips his parents' genes for his inheriting with a probability of $O(1)$.

If the sub-state $|U\rangle$ collapses to its sub-state,

$$|U\rangle \rightarrow |F_{-n,1}\rangle \tag{59}$$

for example, for the measuring, the baby inherits the genes of the first couple of his *nth* ancestors, and atavism may occur.

4.7. Soft-Genes of the Family

I find that the fundamental principles of bio-quantum mechanics, the mathematical inference rules of quantum mechanics and the quantum search algorithms control the inheritance process of the family genes, for every generation of the family, and define them to be the soft-genes of the family.

4.8. Quantum Computing Speed Estimated

Suppose n = 100, the pregnancy is 280 days, the quantum computing speed should, at least, be of $O\left(4\times10^{7}\,\mathrm{s}^{-1}\right)$ for the normal inheriting discussed in Section 4.6.

5. Discussion

Bio-quantum genetics is an interdisciplinary subject of research. The basis of bio-quantum genetics is combination of quantum mechanics, quantum information theory and genetics. Bio-quantum genetics can also be considered as application of quantum mechanics to genetics. Genes are micro-entities, so genes are ruled by quantum mechanics, the science of micro-world. Heredity or inheritance has the properties of superposition, uncertainty and entanglement. In other words, heredity or inheritance obeys the principles of quantum mechanics. Therefore, genes are quantum information in nature. Family histories determine quantum states or databases of family genes, and quantum computational database searches are processes of inheritance. The two evidences above are logical enough to support that establishment of bio-quantum genetics is natural, valid and reasonable.

Traditional genes are "hard" genetic information, while soft-genes are "soft" genetic information. Traditional genes are indicators of biological characters, while soft-genes are principles, rules, algorithms and regulations for genetics. Traditional genetics is "hard" genetics, while bio-quantum genetics is "soft" genetics, in terms of methodology.

Soft-genes control the processes of heredity or inheritance of genes (quantum states of genes exactly). The bio-quantum genetic model of plant heredity and the bio-quantum genetic model of human genetics in this paper explain, in detail, the control of the soft-genes over the genetic processes, of the two existing genetic phenomena. The two models give, respectively, their related complete experimental results. Therefore, the experiments give strong supports to the theory of bio-quantum genetics suggested in this paper.

The study of bio-quantum genetics may open up a new territory of fruitful enquiry. DNA waves can be solutions of Schrodinger equation. Mutations can result from mistakes in quantum computational search of family databases, comparing to "quantum leaps" suggested by Erwin Schrodinger. I believe that more and more results will be obtained by researches entering this field in the future.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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