

The Origin of Life from the Perspective of Information

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Abstract

Plato placed great importance on the natural number one. Plato stated that the three properties of Plato's one are indivisible, invariable, and equal and that an ideal one has no physical properties. If we regard differences among lives as differences among genes and gene products and life as the container of genes, then life has properties similar to Plato's one. Furthermore, life has properties of multiplying when it survives and disappearing when it dies. These properties of life are prerequisites for natural selection. Natural selection makes DNA become digital information, enabling accurate copies of DNA. Furthermore, DNA bases, essential for survival, become close to Plato's one by natural selection. In addition, the information content of life must be sufficiently large for death to be irreversible, and the irreversibility of death is a prerequisite for natural selection.

Keywords

Plato's one, Life, DNA, Darwinian Evolution, LUCA, Natural Selection

1. Introduction

Let us consider the origin of life. Darwin's theory of evolution is the starting point for thinking about the origin of life. According to Darwin, life evolved from simple to complex. Phylogenetic trees were built on this idea. However, the root of the tree of life remained unknown for a long time.

In the 20th century, Watson and Crick's discovery of the double helical structure of DNA opened the path to solving this problem (Watson & Crick, 1953). By analyzing the genetic information in DNA, creating a phylogenetic tree of life became possible. In particular, because ribosomal RNA genes were well conserved in all life, Woese classified life into three domains based on the base sequence of

ribosomal RNA genes (Woese, Kandler, & Wheelis, 1990). Furthermore, according to Woese (Woese, 1998), all current life is believed to have evolved from the last universal common ancestor called LUCA. Research on LUCA is still progressing, but the idea of LUCA remains.

Life evolved from LUCA is subject to natural selection, so life must have two states: life and death. According to Schrödinger (Schrödinger, 1992a), life escapes the law of entropy at first glance. Living organisms maintain order within their bodies much longer than ordinary matter, and when they die, they rapidly decay into an equilibrium state. He said that life obtains negative entropy from food (Schrödinger, 1992b). In more conventional terms, life maintains order using the Gibbs free energy from food (Avery, 2022c). Life transports this energy through adenosine triphosphate (ATP) to maintain order, similar to how modern civilization uses oil to maintain civilization. To summarize Schrödinger's argument, maintaining order means life is alive, except for exceptional cases such as spores. Life in the form of cells always maintains order using Gibbs free energy, but when life dies, it suddenly moves toward an equilibrium state.

Schrödinger lectured on "What is Life?" at Trinity College in Dublin in 1943, while Shannon presented information theory in 1948 (Shannon, 1948). Thus, he was unaware of the concept of information. We shall consider his "What is life?" from the information perspective. He cites clocks as the epitome of order (Schrödinger, 1992c). He says "Nevertheless the fact remains that 'physical clock-works' visibly display very prominent "order-from-order" features, the type that aroused the physicist's excitement when he encountered them in the organism." Meanwhile, watchmakers need information to make watches that keep time accurate. Thus, the blueprint of a clock is a mass of information. In other words, order, according to Schrödinger, is synonymous with information.

Similarly, when life is healthy, the proteins made from genes remain intact, and the entire organism has much information. However, when life is stressed, proteins denature and decompose, the amount of information in the organism decreases, and if it becomes irreparable, it leads to death. Furthermore, looking at thermodynamics from an information perspective, entropy can be paraphrased as uncertainty (Adami, 2015) or missing information (Avery, 2022a). Additionally, we can calculate the Gibbs free energy information content (Avery, 2022b).

The ability of life to maintain biological order comes from information. However, how does life store information? According to the second law of thermodynamics, information will deteriorate and be lost no matter how well it is stored. The key to solving this problem is natural selection. We shall consider how natural selection preserves information.

2. The Importance of Plato's One

The ancient Greeks placed the most significant importance on the natural number one. They considered the number one a fundamental concept. In particular, Plato placed great importance on the number one. Plato stated that the three properties

of one are indivisible, invariable, and equal to each other and that an ideal one has no physical properties (Plato, 2000). In this paper, let us call one with these properties Plato's one. The real one inevitably has physical properties, so it is a degraded copy of Plato's one. Similarly, life is incomplete compared to Plato's one, but as we will see later, it is possible to think that life recognizes the world by natural numbers.

Next, we will consider how similar life is to Plato's one. We will consider the three properties of Plato's one: indivisibility, invariability, and equality. First, if the unit of life is a cell, it is indivisible, as mentioned above. Life has evolved from unicellular organisms, and even among multicellular organisms, individuals of higher animals are indivisible in principle.

We continue to consider two points: invariability and equality. At first glance, it would seem that even unicellular organisms are neither equal nor invariant, as they vary and mutate from one individual to another. However, Craig Venter has succeeded in completely replacing the DNA of bacteria with artificial DNA and culturing them successively (Gibson, Glass, Lartigue, Noskov, Chuang, & Algire et al., 2010). After many generations, the bacteria would consist almost entirely of the product of the artificial DNA. Furthermore, turning to eukaryotes, the cloned sheep Dolly was born. In the future, similar experiments with artificial DNA may be possible in eukaryotes. Therefore, all life consists of genes and their products; abstract life would be a vessel without these components.

However, cells have a significant role to play. Genes need living cells to function, so life can only come from life. At present, we cannot make cells from scratch. In other words, life can only come from life. If we accept the LUCA (last universal common ancestor) hypothesis, all current lives are descendants of the LUCA. Then, every existing cell is a copy of only one cell. If we attribute life's differences to gene variations, then lives remain invariable and equal as vessels for genes. In essence, life has properties that are close to Plato's one (Kotani, 2017).

Next, life is subject to natural selection. The following properties of life are prerequisites for natural selection. First, because a cell has properties similar to Plato's one as a container for genes and gene products, the differences between cells are due to genes. Second, when lives are alive, they multiply. Third, when lives die, they disappear. They are prerequisites for natural selection.

Finally, each base in DNA is subject to natural selection. For example, suppose that a single base in the DNA of a bacterium is mutated. If the mutation is lethal, the bacterium will die, and the original base will be preserved. If the mutation is advantageous for survival, the bacterium will multiply, and the bacteria with the original base will decrease. In this way, bacteria evolve as each base in their DNA is subjected to natural selection. Furthermore, the single base in bacteria has properties close to those of Plato's one: for example, one adenine must be the same as another, must not change spontaneously, and must be indivisible.

3. DNA as a Target of Natural Selection

Next, we shall consider why natural selection preserves genetic information

despite the second law of thermodynamics. An essential prerequisite for natural selection is the irreversible loss of genetic information when life dies. According to the second law of thermodynamics, information will degrade if anyone copies it repeatedly. When the copy accuracy is r and the number of copies is n , Equation (1) is established. As n increases without limit, r^n will approach 0 (Kotani, 2019). Since r is always less than 1, information will eventually be lost.

$$\lim_{n \rightarrow \infty} r^n = 0 \quad r < 1 \quad (1)$$

However, natural selection preserves information. If all mutations of a gene are lethal, then Equation (2) holds.

$$\lim_{n \rightarrow \infty} r^n = 1 \quad r = 1 \quad (2)$$

For example, natural selection has held the conserved bases of the genes of ribosomal RNA unchanged for over 3 billion years because any mutation in these bases was lethal (Alberts, Johnson, Lewis, Raff, Roberts, & Walter, 2002). In this case, each conserved DNA base in the ribosomal RNA gene has properties similar to Plato's one.

Next, we shall consider the following famous example. Natural selection conserves the amino acid sequences of crucial proteins (Kimura, 1968). The amino acid sequence of histone H4, an essential nuclear protein of eukaryotes, differs between animals and plants in only two of the 104 amino acid residues (DeLange, Fambrough, Smith, & Bonner, 1969). Mutations in genes necessary for survival are often fatal, so genes necessary for survival are ultimately preserved (Alberts, Johnson, Lewis, Raff, Roberts, & Walter, 2002). In the above example, amino acid residues in a protein are subject to natural selection because digital information is convertible. In this case, each conserved amino acid residue in histone H4 has properties similar to Plato's one.

From the two examples above, natural selection is crucial for the long-term preservation of genetic information. Life produces large numbers of copies, but there are many miscopies. Thus, it is crucial to remove lethal miscopies. Death of life is efficient for excluding lethal genes, and dead organisms are quickly degraded. Therefore, an essential prerequisite for natural selection is the irreversible loss of genetic information when life dies. Thus, life must not be revived.

Finally, we refer to the infinite monkey theorem to consider the probability of life being revived. The theorem is that if a monkey keeps making random strings long enough, eventually, the monkey will create any string. According to Anderson (Anderson, 2011), since Hamlet has 130,000 characters, the probability of a monkey randomly typing out complete Hamlet is 1 in 26^{130000} : one in 3.4×10^{183946} . Anderson said as follows:

If we took the same number of monkeys as the number of particles in the universe (10^{80}), and each type 1000 keystrokes per second for 100 times the life of the universe (10^{20} seconds), we would still find the probability of the monkeys replicating even a short book to be impossibly small.

Meanwhile, the synthetic minimal cell, JCVI-syn3A, has a 543 kb genome (Pelletier et al., 2021). The probability of randomly synthesizing bases to produce the same sequence is about one in 3.8×10^{326918} . Therefore, the probability of life returning to life is far less than that of monkeys accidentally typing Hamlet. We consider neither phenomenon possible. As a result, both become subject to natural selection.

4. Discussion

The basic form of digital information is text. In the case of the alphabet, the sequence of letters can express a vast amount of information. Similarly, DNA represents vast genetic information in base sequence. So, typical digital information is a sequence of two or more symbols. For example, binary data can be represented by two different numbers, 1 and 0, and any two different symbols can replace them. In this case, 1 and 0 have three properties of Plato's one: indivisibility, invariability, and equality. However, the significant difference between Plato's one and digital information is that digital information has physical properties, while Plato's one has no physical properties.

Two biologically essential properties of digital information are listed. First, digital information is convertible. In the case of biological digital information, DNA sequences are converted into RNA sequences, which are further converted into amino acid sequences of proteins. Second, the amount of digital information increases exponentially as the sequence of symbols extends. On the other hand, thermodynamic numbers are enormous, like Avogadro's number, but the amount of information in digital information can reach thermodynamically meaningful numbers. As a result, the death of life becomes irreversible, and natural selection is possible.

However, the ideal digital information should correspond to natural numbers, which are collections of Plato's ones. Thus, one completely equals one, and zero completely equals zero in the binary data. Nevertheless, there is no complete equality in the real world. Socrates said (Plato, 1975), "Then we must previously have known the equal, before that time when we first, on seeing the equals, thought that all of them were striving to be like the equal but fell short of it (Phaedo, 75a)." So, humans try to make real digital information closer to the ideal digital information but cannot reach it. Similarly, life has created DNA replication and repair mechanisms to preserve the DNA sequence. Notwithstanding, DNA genetic information is not ideal digital information.

Furthermore, if we accept Socrates' argument, equality is embedded in life because we know equality before birth. Tracing back to the origins of equality, we arrive at LUCA, which has properties of Plato's one. However, LUCA is so complex that there must have been pre-Darwinian evolution; we shall further expand the scope of our discussion. Viruses and viroids evolve and have properties as Plato's one (Lostro, 2019). They fulfill the prerequisites for natural selection. First, they have properties close to Plato's one. Second, they multiply if they live.

Third, they disappear if they die. Of particular note are viroids. Viroids are naked RNA but have properties similar to Plato's one due to their unique structure. Also, its amount of information is large; if it is broken, it cannot be restored.

The viroid evolves because it meets the prerequisites for natural selection. Therefore, the point at which RNA becomes viroid can be regarded as the origin of primitive life. At the same time, RNA becomes digital information and can be regarded as the origin of information and Plato's one. Naturally, the origin of life is also the origin of equality. If the RNA world hypothesis is correct, then RNA might have taken on the properties of Plato's one, at which point primitive life began and pre-Darwinian evolution began.

Current life can use Gibbs free energy to maintain order in the living organism. As a result, it can synthesize proteins, DNA, and RNA, and it can divide and multiply independently. On the other hand, viruses and viroids are parasitic organisms. Thus, they are generally regarded as intermediate between living and nonliving organisms. However, because they evolved through natural selection, they can be considered more primitive life than modern life forms.

5. Conclusion

In conclusion, we discussed the importance of the properties of life as Plato's one in initiating natural selection. Furthermore, natural selection is necessary for DNA to become digital information and be stored. In addition, the irreversibility of death, a prerequisite for natural selection, requires that life has a sufficient amount of information.

We considered the case of naked RNA to be Plato's one, using viroid as an example. As a direction for future research, what kind of sequence of RNA has stability, or is it possible to achieve both function and stability? These researches are important for considering the origin of life.

Conflicts of Interest

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

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