# A Conjecture of Life Evolution Based on Entropy

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**Abstract**

In this paper, we briefly describe the flows between life and environment from the perspectives of entropy, redefine the maximum entropy in biological systems based on a new conjecture, and propose a possible approach to explain the mechanism of life evolution. At the end, we point out the issues exist in this conjecture and discuss the future work required for perfecting this conjecture.

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[‡] In this revised version, we discuss the issues exist the conjecture in the previous version. These comments appear in Section.4: Comments and Summary.

# Contents

# 1 Introduction

In the classical Darwinism, the raw materials of evolution are provided by mutations, while the directions of evolution are controlled by natural and artificial selections. However, many unfriendly scientific evidences and viewpoints, such as the fossil gaps and the criticism on the role of natural selection (Raup, 1979; Hsu, 1986), were suggested in the past century. Meanwhile, there exist some ambiguous concepts and imprecise terminologies in Darwin's theory (Brooks, 2011a and 2011b), and these unclear definitions and vague explanations impede the further research on life evolution.

To interpret life evolution more accurately and quantitatively, many physical models have been suggested, and "entropy" (Schrodinger, 2012) is one of them. Based on I. Prigogine's work on energetic entropy and informational entropy, D. Brooks and E. Wiely (Brooks and Wiely, 1988) proposed the "Hierarchical Information Theory", which states that a hierarchy of information stored at the different structural scales of the genomes can be used to model the information stored in living creatures' DNA. Besides, they also suggested a hypothesis that the entropy stored in the hierarchy across a given population of some species rises at a rate predicted by the second law of thermodynamics as the population reproduces and evolves (Brooks and Wiely, 1988). This theory, however, cannot explain why the entropy and information in biological systems increase simultaneously. In this paper, we are trying to provide a possible approach to solve this "paradox" by suggesting a conjecture based on entropy.

# 2 Entropy and Information in Life Evolution

We describe the interaction between life and environment by three flows: outer matter flow ($M_{Outer}$), outer energy flow $E_{Outer}$, and outer information flow $I_{Outer}$. In Fig.1, $A$ is the whole system consists of two subsystems: life system $B$ and environmental system $C$. $D$ represents the interactions between $B$ and $C$, and $R$ represents the two ways that produce inner information in life system. We assume that an individual maintains its own degree of order of inner information $\Omega_I$ through absorbing the degree of the order of inner matter $\Omega_M$ and the degree of the order of inner energy $\Omega_E$ from outer environment. The rate of the decrease of $\Omega_I$ is larger than the rate of increase (magnitudes) of $\Omega_M$ and $\Omega_E$, therefore, the changes of these three quantities in a unit time satisfy the following inequality

$$|\Omega_I| > |\Omega_E| + |\Omega_M|. \tag{1}$$

Meanwhile, the change of total inner entropy consists of the changes of inner entropies of matter, energy and information

$$dS_{InnerTotal} = dS_{InnerM} + dS_{InnerE} + dS_{InnerI}. \tag{2}$$

Similarly, the change of total outer entropy consists of the changes of outer entropies of matter, energy and information

$$dS_{OuterTotal} = dS_{OuterM} + dS_{InnerE} + dS_{OuterI}. \tag{3}$$

We assume that $S_{OuterI}$ consists of two parts: one is the "entropy of activity information" $S_{AcivityI}$, in which "activity information" represents the information creatures use to maintain their life; and the other is the entropy of "evolution information" $S_{EvolutionI}$, which represents the information transported form creatures to their offspring. The changes of these three entropies are all positive

$$dS_{OuterI} = dS_{ActivityI} + dS_{EvolutionI} > 0. \tag{4}$$

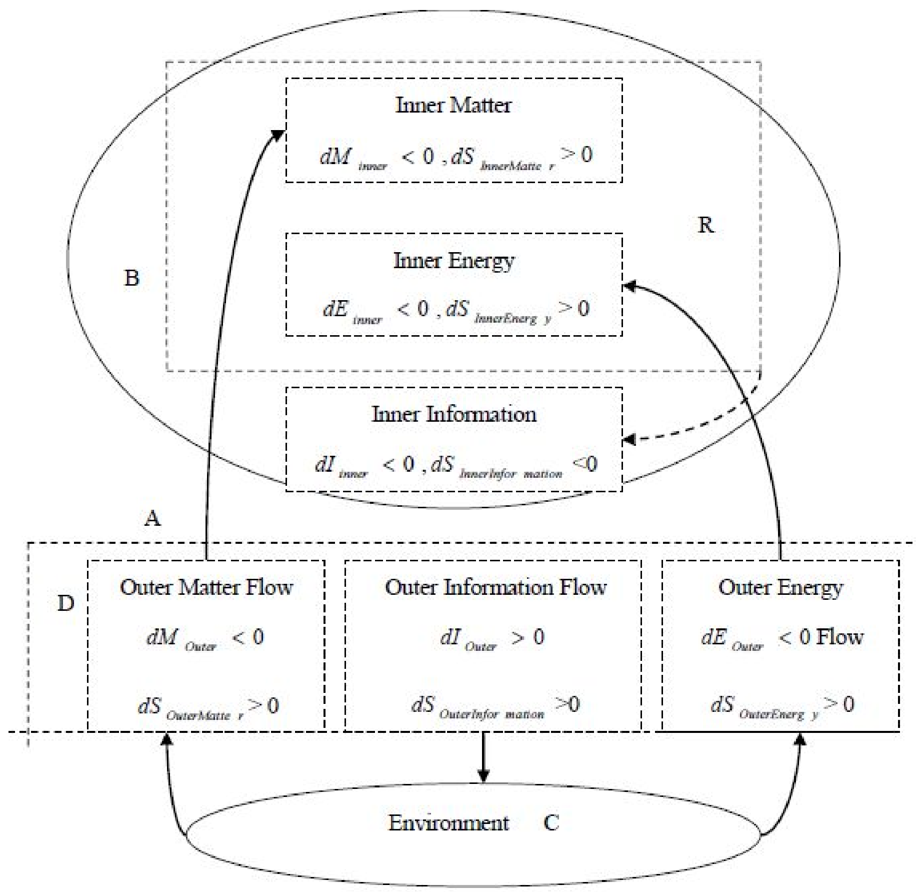


Figure 1: The Three Flows between Environment and Life.

And according to the conservation laws of mass and energy, the change of entropies associated with the changes of matter and energy should be equal:

$$dS_{InnerM} = dS_{OuterM}, \tag{5}$$

$$dS_{InnerE} = dS_{OuterE}. \tag{6}$$

Therefore, the net change of entropy in the whole biological system (i.e. the difference between the changes of outer entropy and inner entropy) is:

$$dS = dS_{OuterTotal} - dS_{InnerTotal} = dS_{OuterI} - dS_{InnerI} > 0. \tag{7}$$

Similarly, the net change of information in the whole biological system (that is, difference between the changes of outer information and inner information) is:

$$dI = dI_{OuterTotal} - dS_{InnerTotal} > 0. \tag{8}$$

Now we encounter the classical paradox, both entropy and information in the whole biological systems increase simultaneously, which contradicts the second law of thermodynamics. We will propose a new conjecture to solve this problem in **section 3**.

## 3 A Conjecture Based on Entropy

In this section, we propose a new way to solve the paradox suggested in section 2; that is, the simultaneous increase of entropy and information in the biological systems. In the past work on life evolution as a problem of entropy, the definition of the maximum entropy is

$$S_m = \int \rho_m ln \rho_m d\tau, \tag{9}$$

in which both maximum entropy $S_m$ and probability density function $\rho_m$ are time-independent. However, in modern physics theory, because of the existence of gravitational force, both maximum entropy the probability density function for the universe should not be time-independent quantities; and this causes the increase rate of the realized entropy is always less than the increase rate of the maximum entropy.

Considering the evolutionary processes of life and the universe (in the scale we have observed) are both spontaneous and irreversible, we suggest two postulates: (1) The role mutation plays in biological systems is same as the role gravitational force plays in the universe; (2) The functions of natural selection, artificial selection and ontogeny in biological systems are same as the functions of strong force, weak force and electromagnetic force in the universe. Based on these two postulates, we can assume that evolutionary processes of both life and the universe obey the same mechanism. Then we can implicitly define $S_m$ as a time-dependent quantity

$$S_m(t) = \int \rho_m(t) ln \rho_m(t) d\tau. \tag{10}$$

Based on the "similarity" assumption, we can further assume the maximum entropy $S_m(t)$ can never be achieved by the realized entropy $S(t)$.

Now we introduce two concepts, the volume of realized space $\Theta_{Realized}(t)$ and the volume of maximum space $\Theta_{Maximum}(t)$, which represent realized entropy and maximum entropy of a system, respectively. Note that both of these two quantities are time-dependent. Then the difference between the rates of change of these two quantities is the net change of total entropy of the biological systems is

$$\frac{\partial S(t)}{\partial t} = \frac{\partial \Theta_{Maximum}(t)}{\partial t} - \frac{\partial \Theta_{Realized}(t)}{\partial t} > 0. \tag{11}$$

Since $S_m(t)$ is "maximum entropy", based on the assumption we made above, the following inequality holds for all $t > 0$

$$\rho_m(t) > \rho(t). \tag{12}$$

And according to the two postulates, the following inequality holds for all $t > 0$ in biological systems

$$\frac{\partial \rho_m(t)}{\partial t} > \frac{\partial \rho(t)}{\partial t}. \tag{13}$$

Then the total information (now a time-dependent quantity) in biological systems at time $t > 0$ can be expressed as

$$I(t) = S_m(t) - S(t) = \int \rho_m(t) ln \rho_m(t) d\tau - \int \rho(t) ln \rho(t) d\tau > 0. \tag{14}$$

Then, by equations (12)-(14), one can readily show the following inequality holds form all $t > 0$

$$\frac{\partial I(t)}{\partial t} > 0. \tag{15}$$

So far, we have shown that in life evolution both entropy and information can increase simultaneously under the conjecture. However, there exist some issues in this conjecture, and we will discuss these problems in **section 4**.

# 4 Comments and Summary

From the discussion in **section 3**, it seems that the paradox we referred in **section 2** can be solved based on the new conjecture. However, it is necessary to point out that the work on this conjecture is far away from been completed, and there exist some resolved issues in it. In the following parts, we will discuss several problems required to be solved for building a better conjecture.

Issue 1. The principle of maximum entropy production sounds very intuitive, but it may be not consistent with biological phenomenology. In reality, all inherently irreversible processes in biological systems should follow some more complicated dynamic leading to minimum entropy production.

Issue 2. The entropy that is causal in evolution should be the entropy of information, the entropies associated with energy flow and matter flow we mentioned before may be just epiphenomena rather than the causes. Entropy and complexity can increase together due to the expansion of phase space, both through such things as mutation and selection. Based on theory of some evolutionary experts, entropy in biological systems depends on the potential and realized information: the longer the biological system evolves, the greater the difference between potential and realized information will be; and that difference is the complexity of the system itself (Brooks and Wiely, 1988).

Issue 3. Obviously, we tried to transfer some ideas from the physics to biology in this paper. However, discussion and application of these ideas in physical situations are usually much easier compared with in biological systems. Two essential reasons are that the implicit definitions of the context in physical systems have been reached a consensus in scientific community, and that the tools used in physical situations are well known from the standard models that most scientists agree with. Besides, there is usually only a single level of complexity to deal with in these physical systems (Goldenfeld and Kadanoff, 1999). Biological systems, however, have much more complexities; and the traditional ideas and classical tools in physics situations cannot be borrowed and applied to biological situations without careful thinking (Goldenfeld and Kadanoff, 1999). Therefore, unless the basic definitions of the concepts are laid down very precisely, it is hard to keep the discussion on track. Some parameters and concepts in this paper, such as "degree of order of information", "realized space", and "maximum space", require much more clear and specific definitions.

Finally, we summarize this paper as follows. The main objective of this paper is to provide a conjecture to interpret life evolution by explaining why information and entropy can increase simultaneously in biological systems. In this paper, we borrowed ideas from modern physics, suggested two postulates, and implicitly defined the maximum entropy in biological systems as a time-dependent quantity. However, the work on perfecting this new conjecture is far away from been done, and whether this conjecture is reasonable or not still requires further study.

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