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Extended Abstract

The Origin of Information and Value Selection: Investigate the Laws of the Generation of Living System

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Introduction

The value selection of information and its threshold-relationship are the basic principles of the origins of life and information. Based on scientific experiments, Manfred Eigen raises selective value as the quantitative evaluation of the evolutionary level of information through unified mathematical expression and verifies that the ultimate foundation of natural evolution is value selection. It reveals the dialectic relationship between creation and stability in the process of system evolution, and shows the possibility and limitation of the evolution of information. These works provide important scientific foundation and inspiring philosophical insights for us to investigate the laws of the generation of living system, and objectively evaluate the potentiality and level of system evolution.

Part I

In order to investigate the origin of biological information and life, and reveal the mechanism of how biological macromolecules emerge from non-living to living, Eigen defines nucleic acid as information and protein as function. He thinks that the basic principle of evolution can be understood as self-organization on the level of molecule and then provides a mechanism of autocatalytic hypercycle. Obviously, in the self-organization processes with teleological feedback, information has intimate relation with function. Information has no significance or value until it is maintained to the moment being read out. Hence, we should go beyond Shannon's objective information and a priori probability, and deep into subjective aspect of information and its value as well as whole signal system.

"Information originates or gains value by selection." (Eigen, M., 1971, 469) Eigen argues that "an understanding of the basic principles of evolution as self-organization at the molecular level does not require 'new physics', but rather a derivable principle which correlates macroscopic phenomena with elementary dynamical behavior" (ibid, 516) . This principle is the principle of selection.

How to provide a unified mathematical expression? Beginning with the phenomenological rate equations of the generation and transformation of quasi-species (准种, molecular-species), Eigen drives a selection advantage parameter expressed by molecular terms as selective value.

The three parameters occur as a combined term:

$$W_i = A_i Q_i - D_i \qquad (1)$$

Ai: rate parameter, Qi: quality factor, Di: rate parameter of decomposition. (Eigen, M., 1973, 613)

Although what these three parameters express is a property of the carrier of information, the property is intimately relative to the information state of carrier. It is carrier through which Eigen gives information value that makes information get capacity to intrinsically evolve. Through these three new variables which connecting with the concept of information, Eigen expresses the evolutionary level of molecules and provide the criterions for selection. The gain of information depends on the proceeding evaluation of selection which regards to selective value.

Further researches show that the processes of natural evolution always tend to select higher selective value. In other words, selective value always evolves towards the direction on higher level: $\Delta W \succ 0$. With the evolution of a system, the average productivity of the system $\bar{E}$, namely threshold, will be optimized.

Taking selection parameter as the criterion of evaluation and the improvement of selective value as selection advantage, this process can be expressed by the principle of optimization:

$$W_{m1} < W_{m2} < \cdots < W_{\mathrm{opt}}. \qquad (2)$$

$$\bar{E} \to W_{\max} \qquad (3)$$

Wm represents a relative maximum among a population of competitors. (Eigen, M., 1971, 517-518)

Therefore, the principle of selection can be expressed as the principle of extremum or the principle of optimization. It shows that selective value should be as high as possible for optimized selection. That is to say, parameters of value, namely generation rate, lifetime and precision, are as large as possible. The optimal $\bar{E}$ means that ensemble tends to highest selective value as a whole. The evolution of a system is manifested as the act towards highest selective value as a whole.

I think that Eigen's principle of selection not only breaks through thermodynamics and unifies information theory and evolution theory, but also further develops classical information theory and self-organization theory with which providing a new interpretation of Darwinian evolution theory.

According to the principle of selection, evolution may involve an increase in selective value as well as utilization of larger information content (or utilizing information content cost-optimally . "The use of information associated with a high 'selective value', rather than economization with respect to the consumption of free energy, is the decisive factor in evolution." (Eigen, M., 1971, 517) This breakthrough not only goes beyond the conclusion that "information is negative entropy", but also beyond past self-organization theories.

According to the theory of dissipative structure, there is only entropy being produced inside of system; system generates order depending on absorbing negative entropy from environment through

open. The evolution of such system is passive without intrinsic foundation. Hence, it cannot get rid of the dilemma that the entropy of universe tends to maximum. However, the principle of selection reveals the inner mechanism of the generation of information and evolution. It proves that natural evolution is "once-forever" inevitable if there is value selection though beginning with stochastic event. The general principles of selection and evolution, which is on molecular level, uncover the inner foundation of biological information and the origin of life on the one hand, run through and be intrinsic to all the processes in the whole universe on the other hand.

"Persistent alterations between Yin and Yang are Dao". The principle of selection and principle of entropy increase are symmetry: their forms are same while directions are opposite. These two principles， just like two forces of Taiji, draw a brand new picture of the world generating without ending. The evolution of things in the universe is a not linear, monotonous development but an everlasting process of birth and death, rise and fall, advance and retreat. Hence, cosmological paradox is solved.

The principle of selection is the most basic principle of evolution theory. It proves that the ultimate basis of natural evolution is value selection. It is the first time that value is introduced into science through selection. This brings important scientific foundation and insights for us to investigate different levels of living system.

Part II

Eigen argues that "evolution represents further optimal program". Because molecules evolution requires "possibility of correct replication" on the one hand, on the other hand, the mutant in the process of evolution comes from error of replication, "replication error is the main source of new information". Therefore, "the process of optimization may sometimes involve contradictory requirements" (Eigen, M., 1971, 481)

He obtains an important threshold- relationship for the maximum information content of a quasi-species through combining selection criterion and quality factor:

$$\gamma_{\max} = \frac{\ln \sigma_m}{1 - \bar{q}_m} \qquad (4)$$

In the equation: $\gamma_{\max}$, maximum character sequence of a message, namely maximum information content of the quasi-species.

σ_m, threshold, it must be larger than 1 to make $\ln \sigma_m \succ 0$.

$\bar{q}$, quality factor, namely precision parameter, expresses the probability of a message being replicated，correctly.

$1 - \bar{q}$, the average error rate per symbol of the quasi-species. (Eigen, M., 1979, 14)

As showing in the equation, the maximum information content of quasi-species is in direct proportion to threshold σ_m. Larger the threshold is, larger the quantity of information content the system can contain. If the quantity of maximum information content is invariant, error rate is larger with larger threshold. It means that larger inclusion of system will lead to more creativity. The potentiality of the evolution of the new order generated by the system also will be larger. While if threshold is less than 1, the quantity of information content will be negative. It means that the entropy in the system will increase leading to thermal equilibrium (heat death) and decline.

However, at the same time, "the number of molecular symbols of a self-reproducible unit is restricted, the limit being inversely proportional to the average error rate per symbol: $1-\bar{q}_m$." (Eigen, M., 1979, 15) "There is a threshold-relationship for the rate of mutation, at which evolution is fastest, but which must not be surpassed unless all the information thus far accumulated in the evolutionary process is to be lost." (Eigen, M., 1979, 8)

"For optimal selection, the required precision of information transfer has to be adjusted to the amount of information to be transferred." (Eigen, M., 1971, 518) Optimal threshold must correspond to largest selective value. Researches show that self-organization system can modulate its threshold by itself. At the point of catastrophe, threshold always is the largest. Threshold (value) will increase stably as the result of growing. System will select its largest selective value every time the threshold value changes.

I think, Eigen reveals chaos property of evolution information. The error of replication is not external disturbs but the very intrinsic evolution mechanism of the system, namely the inevitable result of self-iteration. Hence, every "dominated copy" always has a "comet tail" of error copy. It is this error which provides selectivity and adaptability the system needs to evolve. It is also the essential feature that distinguishing natural generation from mechanic motion and communication system.

The threshold-relationship deeply uncovers the dialectic relationship between innovation and stability in the process of the evolution of living system, vividly showing its characteristics: it is not new system wiping out and replacing old system but self-renewal and self-transcendent. System optimizes its structure continuing to live and grow through mutation. Therefore, there is no simple replacement between old and new, but complex threshold-relationship between precision and error, conservation and innovation, inheritance and reformation, competence and cooperation, etc. With threshold-relationship equations , we can quantitatively asses the potentiality of the evolution of a system given by replication mechanism. In certain sense, threshold-relationship provides us a scientific method to look for the point at which we can regulate the system properly and find dynamic equilibrium in the selection-evolution process which is full of contradictions. It provides rich insights for us to understand and acquire the evolutionary laws of the wholeness or group of system and brings new light on the methodologies of reformation and innovation.

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