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On the nature of evolution: an explicative model

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Abstract
For years, links between entropy and information of a system have been proposed, but their changes in time and in their probabilistic structural states have not been proved in a robust model as a unique process. This document demonstrates that increasement in entropy and information of a system are the two paths for changes in its configuration status. Biological evolution also has a trend toward information accumulation and complexity. In this approach, the aim of this article is to answer the question: What is the driven force of biological evolution? For this, an analogy between the evolution of a living system and the transmission of a message in time was made, both in the middle of environmental noise and stochasticity. A mathematical model, initially developed by Norbert Wiener, was employed to show the dynamics of the amount of information in a message, using a time series and the Brownian motion as statistical frame. Léon Brillouin's mathematical definition of information and Claude Shannon's entropy equation were employed, both are similar, in order to know changes in the two physical properties. The proposed model includes time and configurational probabilities of the system and it is suggested that entropy can be considered as missing information, according to Arieh Ben–Naim. In addition, a graphic shows that information accumulation can be the driven force of both processes: evolution (gain in information and complexity), and increase in entropy (missing information and restrictions loss). Finally, a living system can be defined as a dynamic set of information coded in a reservoir of genetic, epigenetic and ontogenic programs, in the middle of environmental noise and stochasticity, which points toward an increase in fitness and functionality.
Key Words: biological evolution, entropy, information, living systems, messages, noise.

Sobre la naturaleza de la evolución: un modelo explicativo

Resumen
Durante años se han propuesto vínculos entre entropía e información de un sistema, pero sus cambios en tiempo y en sus estados estructurales probabilísticos no han sido probados en un modelo robusto como un proceso único. Este documento demuestra que incrementos en entropía e información de un sistema son las dos sendas para cambios en su estado configuracional. También, la evolución biológica tiene una tendencia hacia una acumulación de información y complejidad. Con este enfoque, aquí se planteó como objetivo contestar la pregunta: ¿Cuál es la fuerza motriz de la evolución biológica? Para esto, se hizo una analogía entre la evolución de un sistema vivo y la transmisión de un mensaje en el tiempo, ambos en medio de ruido y estocasticidad ambiental. Se empleó un modelo matemático, desarrollado inicialmente por Norbert Wiener, para mostrar la dinámica de la cantidad de información de un mensaje, usando una serie de tiempo y el movimiento Browniano como estructura estadística. Se utilizó la definición matemática de información de Léon Brillouin y la ecuación de la entropía de Claude Shannon, ambas son similares, para conocer los cambios en las dos propiedades físicas. El modelo propuesto incluye tiempo y probabilidades configuracionales del sistema y se sugiere que la entropía puede ser considerada como pérdida de información, de acuerdo con Arieh Ben-Naim. Se muestra una gráfica donde la acumulación de información puede ser la fuerza motriz de ambos procesos: evolución (incremento en información y complejidad) y aumento en entropía (pérdida de información y de restricciones). Finalmente, se puede definir a un sistema vivo como la dinámica de un conjunto de información codificada en un reservorio de programas genéticos, epigenéticos y ontogénicos, en medio de ruido y estocasticidad ambiental, que tiende a incrementar su adecuación y funcionalidad.
Palabras Clave: evolución biológica, entropía, información, sistemas vivos, mensajes, ruido.

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Introduction

What is life? Technically, it could be defined as cells with evolutionary potential, make up by organic matter and getting on in an autopoyetic metabolism[1]. Organisms use energy flow gradients at different organization levels in accord with physical laws. The living systems have three principal functions as self-organizing units: a) compartmentalization, b) metabolism, and c) regulation of input and output information flux[2]. The layer between internal and external environment of organisms controls matter, energy and information flows; metabolism regulates epigenetic and autopoyetic processes; biological information is a program (and a set of programs) that operates both physiology and functionality, codified in the DNA[3].

Darwinian theory of evolution by means of variation, natural selection and reproductive success of heritable variation in populations and organisms, can be defined as an ecological process that change the covariance of phenotypic traits (as expression of genetic, epigenetic, ontogenic and environmental factors) in living organisms or biological systems grouped at different organization levels[4]. Natural selection operates on biological systems that have three features: a) variability, b) reproductivity, and c) heritability; one result of natural selection is a tendency toward to an increase in fitness and functionality of biological systems in an environmental stochasticity (both biotic and abiotic). Fitness is a measure of reproductive success of changes in allele frequency of organisms on a determinate ecological noise, conditioned on the phenotype or genotype[5].

In this paper, an analogy between a biological system and a message was made; it was also considered the environmental stochasticity as the noise when a message is transmitted. Thus, the biological system is analogous to the amount of information of a message (for example: genetic information) that is transported to the next generation inside an ecological noise. This favors the use of the Norbert Wiener model of message's transmission in a telephonic line with noise[6]. In our model, it has been considered that information could be as simple as a binary unit (bit, 0 and 1), but it can grow by the additive property[7,8].

The amount of information defined by Wiener[7] (p. 62) is the negative of the quantity usually defined as statistical entropy. This principle of the second law of thermodynamics can be understood for a closed system as the negative of its degree of restrictions[9] (p. 23), i.e., its structuration level. Also, G.N. Lewis in 1930 (cited by Ben-Naim[10] p. 20) quotes: "Gain in entropy always means loss of information".

In relation to information theory, Léon Brillouin in his book "La información y la incertidumbre en la ciencia"[11] (p. 22-25) wrote that entropy is connected with probabilities as is expressed in equations by Ludwig Eduard Boltzmann and Max Planck, and suggested that information is a negative entropy[12,13] or negentropy[12]. But instead of using the term of entropy, Arieh Ben-Naim[10] (p. 21) proposes to replace it by "missing information".

Nevertheless, the second law of thermodynamics neither implies one-way time, nor has a statistical probabilities model. For this reason, in this paper it was employed a time series tool and the Brownian motion as a model to simulate the dynamics of the amount of information of a message, as an analogous of a biological system. This approach shows that biological information could be carried by "some physical process, say some form of radiation" as Wiener[7] wrote (p. 58). What wavelength? Brillouin[11] (p. 132), in his scale mass-wavelength equals a mass of 10^{-17} g to a wavelength of 10^{-20} cm; for this scales, it could be important to consider k, the Boltzmann constant, because its value is 1.38 x 10^{-16} erg/°K, in unities of the system cm, g, second. Likewise, a quantum h can be expressed as $h = 10^{-33}$ cm; this smaller length "plays a fundamental role in two interrelated aspects of fundamental research in particle physics and cosmology"[14] and "is approximately the length scale at wich all fundamental interactions become indistinguishable"[14]. Moreover, it is necessary to mention that Brownian motion is a thermic noise that implies energy of the level kT (where T is temperature) by degree of freedom[11] (p. 135). It was hypothesized that this radiation could be the wavelength of photons incoming on Earth's surface, irradiated by the photosphere of the Sun at a temperature of 5760 °K; after the dissipation of high energy photons to low energy ones, through irreversible processes that maintain the biosphere, the temperature of the outgoing photons that Earth radiates to space is 255 °K[15]. This incoming radiation support plant photosynthesis, evapotranspiration flow, plant water potential, plant growth, energy for carbon-carbon bonds (or C-H, C-O, O=O, etc.), and food of the trophic chains in ecosystems, among other energy supported processes.

The question to answer in this paper is: What is the driven force of biological evolution? The possible answer is that driven force is the dynamics of the amount of information in a biological system (genetic and epigenetic messages). Antoine Danchin[16], in a similar approach, proposes that mechanical selection of novel information drives evolution. In the next section, it will be described the mathematical model of the dynamics of message transmission, as a proposal to explain the nature of biological evolution.

The model

Shannon entropy formula is[17] (p. 291):

$$S = k \ln \Omega = k\, ln \frac{N!}{N_1!\, N_2! \ldots Nm!} \tag{1}$$