ENERGY FLUCTUATIONS DROVE THE SELECTION OF INFORMATION VARIANTS AND THE ORGANIZATION OF PREBIOTIC NETWORKS

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Modern life is exceedingly complex and deploys sophisticated mechanisms for protecting, using and evolving internal information. The origin of life is hard to justify because, apparently, life cannot be simple, yet we cannot explain lengthy evolution toward increasing complexity in abiotic networks until life can actually begin. How did information content became streamlined in systems with high chemical diversity and large information capacity? If such evolution is normal, we should be able to observe it in natural and experimental dynamic systems (such as chemical reaction networks, energy dissipative phenomena and computer based automata).

We hypothesize that bio-molecular networks that support life today were preceded by simpler, yet self-controlled dynamic systems, called *prebiotic networks*. Such networks have most likely emerged from simple chemical systems, with added features that have allowed evolution toward increased complexity, adaptation to environmental stress and competition for resources. In abiotic conditions increase in order (i.e. decrease in entropy) of dynamic systems is at odds with the 2nd law of thermodynamics, and this contrast increases with the information capacity of a system. In modern life this problem is resolved by mutualism between energy dissipative mechanisms and information preservation mechanisms. But such "high tech" molecular interactions do not exist in simple chemical automata. We can make the assumption that prebiotic networks have evolved in an environment with sufficient energy to build up disequilibrium. Yet, information content within primitive networks was little, inefficient and hard to preserve. Key to understanding the evolution of protobiotic networks is identifying network architectures and natural factors that drove such systems toward increased complexity. Throughout this evolution however the "main physical purpose" of prebiotic networks had to persist: i.e. "dissipation of energy gradients" (the "*raison d'âtre*" for modern life as well).

We have analyzed naturally occurring controllers of evolution in simple reaction networks with variable architecture using the artificial life simulator BiADA (Biotic Abstract Dual Automata). We explain the principles of BiADA modelling and range of applications. We explain how BiADA models quantify and correlate parameters such as diversity, order, complexity, energy dissipative potential, fitness and competition between information variants.

We show results concerning the role of key factors in the evolution of network organization: (1) energy availability, (2) autocatalytic efficiency, (3) fluctuation in energy availability; (4) diversity of information competitors and (5) dead-end network branching.

We found that if sufficient energy is available, the competitiveness of internal information is correlated with the efficiency of autocatalysis. The minimum threshold for autocatalytic efficiency is positively and linearly correlated with the number of information variants and thus with the antilog of Shannon's Information Capacity. The amount of energy needed to streamline the internal information varies from one system to another, because many factors control it: the free energy content per unit of information, information stability, the quality of free energy available, temperature, the energy uptake efficiency and a system's ability to dissipate heat.

Energy fluctuations lead to changes in a system's thermodynamic equilibrium and favor networks with dead-end branches (acting as temporary reserves of energy and building blocks). The relationship between transformation kinetics and energy fluctuation profiles is also very important and in creating a Goldilocks' prebiotic evolution zone. I.e. extensive energy deprivation wipes out valuable information content, while high energy availability favors diversification of information. We found positive correlation between energy fluctuation and increase in network complexity.

We hypothesize that during the origin of life, increase in order and complexity in prebiotic networks was strongly correlated with the evolution of energy availability stress. Our results support that prebiotic networks have evolved in biosynthetic direction and in environments were energy was non-copious and evolving in periodicity. Because energy periodicity and predictable changes in energy availability contain information, it can be interpreted that during the origin of life part of the organization gained by prebiotic networks came from environmental information.

References:

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