Does coexistence solve the prebiotic information problem?

Sergio Branciamore[1], Walter de Back[2] and Enzo Gallori[1]

[1]Department of Evolutionary Biology, University of Florence, Italy
[2]Collegium Budapest, Institute for Advanced Study, Hungary
wdeback@colbud.hu

The information problem in prebiotic evolution arises from constraints on the amount of information that can be maintained in Darwinian evolution. The error threshold limits the transmissible length of a template under high mutation load. Existing solutions to the error threshold assume that the primitive genome consisted of multiple coexisting unlinked templates. Such coexistence requires a mechanism of cooperation to counterweigh competitive exclusion. Although much attention is given to ecological coexistence properties of cooperation mechanisms, little is known about the information carrying capacity of these systems under high mutation rates. Template coexistence may escape the error threshold, but it simultaneously raises the new problem of maintaining cooperation. Cooperation is threatened by the production of parasites through mutation. This results in an additional constraint on the information content in a template ensemble, which we call the 'parasite threshold'. If the parasite threshold of cooperative system is lower than the error threshold, template coexistence does not solve the prebiotic information problem.

We study the information carrying potential in a spatial eco-evolutionary model, based on the metabolic model (Czárán and Szathmáry, 2000). We define a surface in which each site is either empty or occupied by a molecule. A genome consists of d different templates of length l=i/d nucleotides, where i is the information content of the genome. We assume that replication of a template is only possible when all d functional template types are present in the local neighborhood. Mutation in a functional template results in a nonfunctional parasitic copy, with probability m per nucleotide. Growth and decay rates of of functional molecules and parasites are equal. Every reaction step is followed by diffusion of the molecules over the surface.

Genomes with varying number of fragments (d=1,...,4) are compared under high mutation load (m=0.01). We observed the parasite numbers and the maximum maintainable genomic information. Our results show that, surprisingly, the information storage capacity is highest for unfragmented, single replicator, genomes (d=1), despite their high production of parasite. While the number of parasites decreases with the number of templates, the vulnerability of fragmented genomes to parasitism sharply increases. Because the latter effect outweighs the former, the benefit of template coexistence is lost. When the different genomic strategies are put in direct competition with each other, fragmentation can out-compete the single template genome, but only in a situation with low mutational rate, and length-dependent growth rate. Close to the error threshold, however, fragmented genomes are competitively excluded by the single template strategy.

We conclude that template coexistence by itself does not solve the prebiotic information problem, because cooperative systems are limited by the 'parasite threshold'. We demonstrate that in the metabolic model, template coexistence does not increase information content and is excluded in direct competition. Although more realistic conditions concerning catalytic specificity, length-dependent neutrality and growth may refine these results, it is clear that limitations arising from cooperation must be taken into account in solving the information problem in prebiotic evolution.