Evolution of complexity in RNA-like replicator systems

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Background: The evolution of complexity is among the most important questions in biology. The evolution of complexity is often observed as the increase of genetic information or that of the organizational complexity of a system. It is well recognized that the formation of biological organization—be it of molecules or ecosystems—is ultimately instructed by the genetic information, whereas it is also true that the genetic information is functional only in the context of the organization. Therefore, to obtain a more complete picture of the evolution of complexity, we must study the evolution of both information and organization.

Results: Here we investigate the evolution of complexity in a simulated RNA-like replicator system. The simplicity of the system allows us to explicitly model the genotype-phenotype-interaction mapping of individual replicators, whereby we avoid preconceiving the functionality of genotypes (information) or the ecological organization of replicators in the model. In particular, the model assumes that interactions among replicators—to replicate or to be replicated—depend on their secondary structures and base-pair matching. The results showed that a population of replicators, originally consisting of one genotype, evolves to form a complex ecosystem of up to four species. During this diversification, the species evolve through acquiring unique genotypes with distinct ecological functionality. The analysis of this diversification reveals that parasitic replicators, which have been thought to destabilize the replicator's diversity, actually promote the evolution of diversity through generating a novel "niche" for catalytic replicators. This also makes the current replicator system extremely stable upon the evolution of parasites. The results also show that the stability of the system crucially depends on the spatial pattern formation of replicators. Finally, the evolutionary dynamics is shown to significantly depend on the mutation rate.

Conclusions: The interdependence of information and organization can play an important role for the evolution of complexity. Namely, the emergent ecosystem supplies a context in which a novel phenotype gains functionality. Realizing such a phenotype, novel genotypes can evolve, which, in turn , results in the evolution of more complex ecological organization. Hence, the evolutionary feedback between information and organization, and thereby the evolution of complexity.

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