Origins of life and Evolutionary games: Exploring the nonlinearities in life

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Abstract

Self-organisation is at the heart of naturally occurring complex systems. The origin of life itself could be a culmination of the process of self-organisation and various theories have been postulated to that end. One of the most celebrated models of the same is the hypercycle. Hypercycles can be viewed as networks of cooperating replicators which invest in the growth of other replicators. Replicators are fundamental to such self-organising systems and in turn to the formation of life itself. However replicators have also been studied, although indirectly from the point of view of evolutionary games. Incorporating realistic non-linear interactions between the replicators, we comment on the conditions leading to the stability of such hypercycles. Along with cross-feeding experiments in *Saccharomyces cerevisiae* we plan to test these assumptions leading to stability, albeit, in an already "alive" system.

Extended summary

Replicators form the fundamental building blocks of almost all the theories of the origin of life. They have been used to define the units of evolution which multiply, have heredity, and show variation and by no means represent only biological systems (Smith, 1986). Elucidation replicators further, numerous theoretical methods have postulated their origin and evolvability (Eigen and Schuster, 1977; Stein and Anderson, 1984; Kauffman, 1986; Ohtsuki and Nowak, 2008). At the transition from "prelife" to "life" lies the emergence of replicators.

However, the definition of life is not bound only to the emergence of replicators (Saladino et al., 2012). The coming together of such infrabiological components is often attributed to chemical chaos (Szathmary, 2006). From a replication first point of view, replicators need to be available in high enough concentration so as to bring about metabolism. Thus the formation of stable hypercycles seems to be a crucial aspect entailing a stable mode of replication and metabolism. The classic hypercycle as suggested by Eigen (1971) and described in detail later (Eigen and Schuster, 1977, 1978a,b), mathematically, is a special case of the replicator equation (Hofbauer and Sigmund, 1988).

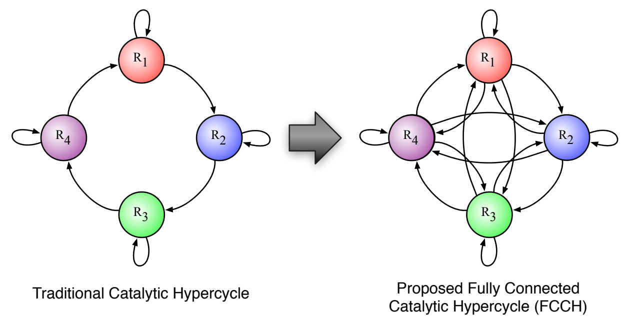

Figure 1: Going from a traditional cyclic hypercycle to a Fully Connected Catalytic Hypercycle (FCCH) where each reactant can catalyse every other reactant including itself. This generalises the interactions between the reactants. We further plan to make the reaction rates nonlinear in terms of the reactant frequencies.

The replicator equations is also a cornerstone in evolutionary game theory and thus the hypercycles can be interpreted as a game where the players are the reactants and the interactions between them dictate the nature of the game. The traditional hypercycle can be represented by a two player game where each reactant interacts with one other reactant. A generalisation of the standard hypercycle to one in which each reactants' frequency depends on every reactant in the system leads us to the Fully Connected Catalytic Hypercycle (Figure 1). Thus transferring not just the properties but the results from the theory of evolutionary games to one of the theories of the origins of life (Hofbauer, 1984). Analysing hypercycles including such extensions in evolutionary games will enable us to understand them beyond the paradigm cases. Thus inclusion of non-linear interactions, stochastic dynamics, multilevel selection and structured environments, which are all relevant scenarios for hypercycles will be studied (Traulsen et al., 2006; Traulsen and Nowak, 2006; Santos et al., 2006; Gokhale and Traulsen, 2010).

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