July 16-21, 2017 at UC San Diego, CA, USA

Permeability-Driven Selection in a Semi-Empirical Protocell Model: The Roots of Prebiotic 'Systems' Evolution

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Introduction: The origin-of-life problem has traditionally been conceived as the chemical challenge to find the type of molecule and reaction dynamics that could have started a process of Darwinian evolution. However, in addition to molecular kinetics and evolutionary dynamics, other physical and chemical constraints (like compartmentalization, differential diffusion, selective transport, osmotic forces, energetic couplings) could have been crucial for the functional integration and intrinsic stability of intermediate systems between chemistry and biology. These less acknowledged mechanisms of interaction might have made the initial pathways to prebiotic *systems* evolution more intricate, but were surely essential for sustaining far-from-equilibrium chemical dynamics and as a source of innovative behavior.

Results: Here we explore a protocellular scenario in which some of those additional factors are addressed, demonstrating their ‘system-level’ implications. In particular, an experimental study on the permeability of prebiotic vesicle membranes composed of binary lipid mixtures allows us to construct a semi-empirical model in which protocells are able to reproduce and undergo an evolutionary process based on their coupling with an internal chemistry that supports lipid synthesis. We show how differential permeability linked to changes in the membrane composition could become a property with selective value in those systems, modulating proto-metabolic activity and protocell division time. Thus, the endogenous production of membrane components is proposed as an early prebiotic breakthrough, key in the development of protocellular populations with increasing dynamic robustness and adaptive potential.