Membraneless Polyester Microdroplets as Primordial Compartments at the Origins of Life

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Abstract

Compartmentalization was likely essential for primitive chemical systems during the emergence of life, both for preventing leakage of important components, i.e., genetic materials, and for enhancing chemical reactions. Though life-as-we-know-it uses lipid bilayer-based compartments, the diversity of prebiotic chemistry may have enabled primitive living systems to start from other types of boundary systems. Here, we demonstrate membraneless compartmentalization based on prebiotically available organic compounds, α-hydroxy acids (αHAs), which are generally co-produced along with α-amino acids in prebiotic settings. Facile polymerization of αHAs provides a novel model pathway for the assembly of combinatorially diverse primitive compartments on early Earth. We characterized membraneless microdroplets generated from homo- and hetero-polyesters synthesized from drying solutions of αHA endowed with various side-chains. These compartments can preferentially and differentially segregate and compartmentalize fluorescent dyes and fluorescently tagged RNA, providing readily-available compartments that could have facilitated chemical evolution by protecting, exchanging, and encapsulating primitive components. Protein function within and RNA function in the presence of certain droplets is also preserved, suggesting the potential relevance of such droplets to various origins of life models. As a lipid amphiphile can also assemble around certain droplets, this further shows the droplets' potential compatibility with and scaffolding ability for nascent biomolecular systems that could have co-existed in complex chemical systems. These model compartments could have been more accessible in a "messy" prebiotic environment, enabling the localization of a variety of proto-metabolic and replication processes that could be subjected to further chemical evolution before the advent of the Last Universal Common Ancestor.

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