STABILITY OF AMPHIPHILIC SYSTEMS IN PREBIOTIC TERRESTRIAL HYDROTHERMAL FIELDS AND ITS IMPLICATIONS FOR THE ORIGIN OF CELLULAR LIFE

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Introduction: Deciphering how life would have chemically originated on our pale blue dot continues to be an intriguing mystery for the Astrobiology community at large. Although the exact sequence of events which led to the emergence of life still remains elusive, a good body of research has narrowed down possible processes that would have been crucial for the transition from chemistry to biology. One pertinent area of prebiotic chemistry pertains to understanding the abiogenic origin of polymers on the early Earth. Formation of polymers would have been a fundamental step in the aforementioned transition as most life functions in extant biology are performed by polymers of different kinds (for e.g. DNA and RNA, perform the function of information storage and transfer; whereas, proteins act as the catalytic polymers).

Several theories have been put forth to explain the abiogenic formation of polymers and their subsequent evolution during the origin and evolution of early life [1, 2] . Importantly, a theme common to many of these theories suggests that such uphill processes would have been chemically driven (to varying extent) in environments that were subjected to repeated cycles of dehydration and rehydration, which also supported chemical fluxes [3]. Specifically, chemical polymerization is thought to have been driven by condensation of relevant monomers in niches such as prebiotic tidal pools and hydrothermal fields at the edges of volcanoes [4]. In this context, pertinent reaction schemes have been demonstrated to especially allow the emergence of early informational oligomers, by loss of water molecules that facilitate bond formation between monomers. Importantly, catalytic clay minerals [5], eutectic ice phases [6] and dehydrated lipid matrices [4] have been shown to assist the formation of informational molecules of, both, pre-RNA World and RNA Worlds [7-9]; a time in the early evolution of life where in RNA-like and RNA molecules are thought to have performed the dual role of encoding information and catalyzing reactions. The lipid-assisted synthesis, in particular, has important prebiotic relevance as encapsulation of functional polymers in membranous structures, to form protocell-like entities, is thought to have been a crucial step in kick-starting evolution of early life [10].

Although extant cellular membranes are predominantly formed from complex lipids, primitive membranes are thought to have formed from simpler amphiphiles like fatty acids and their derivatives [11]. Formation of such vesicles has been shown to occur under specific conditions of pH and temperatures [12]. However, stability of such amphiphilic systems to repeated cycles of dehydration and rehydration (DH-RH regimes), under varying pH and temperatures, has not been systematically characterized to our knowledge. This is also important for evaluating the role of such amphiphilic systems on prebiotically relevant processes like the origin of informational polymers.

In this study, we characterized the stability of a range of mixed fatty acid vesicles in DH-RH regimes, under varying conditions of pH and other relevant prebiotic parameters. Importantly, we also carried out a comparative study to evaluate the stability of these systems in hot spring samples that were collected from high altitude regions in Ladakh (India) as part of the first Spaceward Bound India expedition to this region. The expedition was undertaken in August 2016 to explore Ladakh, an Astrobiologically relevant site for the study of life under extreme conditions. Our preliminary results indicate that the stability of the different mixed fatty acid systems vary under DH-RH regimes characterized by varying pH and temperature conditions. Furthermore, the geochemistry of the hot springs also seem to play a crucial role in determining the stability of the vesicular systems in question. In conclusion, our results indicate that the origin of early cellular life would have been, both, niche and geochemical context dependent.

References:

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