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Stability of Amphiphilic Systems in Terrestrial Hydrothermal Fields and its Implications for the Origin of Cellular Life

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Introduction: Deciphering how life would have chemically originated continues to be an intriguing mystery. Although the exact sequence of events 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 aspect is 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 different polymers. Several theories have been put forth in this regard [1, 2]. A theme common to many of these theories suggests that these uphill processes would have been chemically driven in environments that were subjected to repeated cycles of dehydration and rehydration (DH-RH) [3]. Specifically, it is thought to have been driven by condensation of relevant monomers in niches such as prebiotic tidal pools and terrestrial hydrothermal fields [4]. Furthermore, catalytic clay minerals [5], eutectic ice phases [6] and dehydrated lipid matrices [4] have been shown to assist the formation of prebiotically relevant informational molecules [7, 8].

The lipid-assisted synthesis, in particular, has important prebiotic relevance as encapsulation of functional polymers in membranous structures is thought to have been a crucial step in kick-starting evolution of early cellular life [9]. 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 [10], whose formation has been shown to occur under specific conditions of pH and temperatures [11]. However, stability of such amphiphilic systems, to repeated cycles of dehydration and rehydration, has not yet been systematically characterized to our knowledge. This is also crucial for evaluating the role of such amphiphilic systems on prebiotically relevant processes, such as the origin of informational polymers under volcanic geothermal conditions.

In this study, the stability of mixed fatty acid vesicles was characterized in DH-RH regimes. Importantly, we also carried out a "realistic" study to evaluate the stability of these systems in hot spring samples that were collected from high altitude regions in Ladakh (India) during the first Spaceward Bound India expedition in Aug 2016. This expedition was undertaken to explore Ladakh; an Astrobiologically relevant site for the study of life under extreme conditions. Our results indicate that the stability of the mixed fatty acid systems varied with repeated cyles of dehydration and rehydration. Importantly, the geochemistry of the hot springs seemed to play a crucial role in determining this stability. In conclusion, our results indicate that the origin of early cellular life would have been, both, niche and geochemical context dependent.

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