Identifying Habitable Environments for Prebiotic Model Protocells

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The environmental conditions under which life can emerge and evolve is one of the most fundamental parameters in understanding the origins of life on early Earth and potentially on other worlds. The cell membrane is the defining boundary between the individual cell and its environment, so the integrity of the membrane is one important measure of survival. Single chain amphiphiles (SCAs) are believed to have comprised the membranes of the earliest protocells, and hence, SCA vesicles are used as model protocells. The goal of the present study was to determine the stability of SCA vesicles in unicomponent and binary systems over a wide range of pH, ionic strength and background electrolyte type in order to identify environmental conditions for model protocell survival. The vesicle-forming ability was examined by fluorescence/phase contrast microscopy and by fluorescence spectrophotometry for five SCAs (decanoic acid, decanol, guanidine monodecanoate, decylamine and decylsulfate) with different head group charges at pHs ~ 3, 7 and 10 and at various salt conditions (200 mM NaCl or KCl or NaBr or $MgCl_2$ or $LaCl_3$).

Vesicles of different head group charges were found to be stable under different environmental conditions. In the absence of salt, more vesicle-forming systems were found at neutral and high pHs than at low pHs, for vesicles composed of only negatively charged heagroups or mixed -/0 headgroups. NaCl had the most stablizing effects whereas $MgCl_2$ and $LaCl_3$ resulted in rupture of vesicles, under most conditions. Na^+ and K^+ had similar magnitude of effect on vesicle stabilization, and Cl^- was more effective than Br^-. These results were interpreted in terms of a balance of hydrophobic, van der waals and electrostatic forces and charge screening in the presence of salts. The survival of vesicles under different conditions suggests that protocells could potentially have occupied a wide range of environmental niches. Even more interestingly, different compositions of membranes were stable under different conditions implying a potential early diversity of membrane types due to environmental selection pressure favoring survival of the fittest protocells in different conditions.