Between Mica Sheets: Better than Membranes at the Origin of Life?

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Introduction: Organelles without membranes are found in all types of cells and typically contain RNA and protein. RNA and protein are the constituents of ribosomes, one of the most ancient cellular structures. It is reasonable to propose that organelles without membranes preceded protocells and other membrane-bound structures at the origins of life. Such organelles would be well sheltered in the spaces between mica sheets, which have many advantages as a site for the origins of life. [1-3]

Discussion: Lipid bilayer membranes are fragile. Nonetheless they are a popular hypothetical environment for the origins of life. Most subcellular organelles are enclosed in lipid membranes. Some organelles, however, such as the nucleolus, are membrane-less. The nucleolus contains the components of ribosomes and is, physically, a liquid-in-liquid phase separation within the nuclear matrix. [4]

Another problem with a 'membranes-first' model for the origins of life is that membranes around living cells come in 2 basic types: Archaeal membrane lipids have ether linkages; Bacterial and Eukaryotic membrane lipids have ester linkages. [5] If there were membranes before the cellular contents within the membranes were alive, how did there come to be 2 types of membranes surrounding living cells?

The spaces between Muscovite mica sheets provide an enclosure, an environment high in potassium (K) ions, like the intracellular environment of living cells, and anionic crystal lattices with a spacing of 0.5 nm, which is also the distance between anionic phosphate groups in extended single-stranded RNA and DNA. [1] An endless energy source for the origins of life is provided by 'open-and-shut' movements of mica sheets in response to temperature changes and fluid flow. This mechanical energy (work) is arguably the fundamental form of energy in enzymatic reactions, although the obvious form of energy for enzymatic reactions is now chemical energy, typically ATP. In the 'mica world' hypothesis, mechanical energy was used directly for forming chemical bonds, rearranging prebiotic polymers, and blebbing off protocells before a transition to chemical energy such as ATP.

References:

[1] Hansma, H. G. (2010). Journal of Theoretical Biology 266(1): 175. [2] Hansma, Helen G. (2014) Origins of Life and Evolution of Biospheres 44:307. [3] Hansma, H.G. (2013). J. Biol. Struct. Dynamics 31: 888. [4] Brangwynne, C. P. (2013) The Journal of Cell Biology 203 875. [5] Woese, C.R., Microbiological reviews (1987) 51:221.

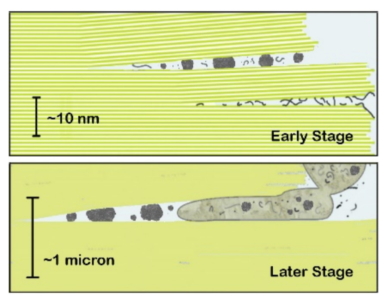

Figure 1 Diagrams of an origin of life between mica sheets under water with membrane-less organelles and other prebiotic structures. Green lines and areas represent green Muscovite mica. Potassium (K) ions in the spaces between sheets (white lines in the Early Stage) hold sheets together. The various gray structures represent extended polymers (linear structures), molecular aggregates and membraneless organelles (gray globules), and protocells (large budding structure in the Later Stage). 10-nm scale bar in the Early Stage is the thickness of 10 mica sheets. 1-micron scale bar in the Later Stage is the thickness of 1000 mica sheets. Adapted from [3].