Electric field excitation and non-equilibrium dynamics of polypeptide/DNA protocells

With the support by the National Natural Science Foundation of China and the National Basic Research Program of China, the research team led by Prof. Liang Dehai (梁德海) at Beijing National Laboratory for Molecular Sciences, MOE Key Laboratory of Polymer Chemistry and Physics, College of Chemistry and Molecular Engineering, Peking University, uncovered a dynamic non-equilibrium behavior in synthetic protocells, which was published in *Nature Communications* (2016, doi: 10.1038/ncomms10658).

Although life emerged on our planet about 3.5—4.0 billion years ago, it still remains a mystery that how the first cells emerged in a world devoid of biological evolution. Numerous strategies are now available to generate rudimentary forms of synthetic cell-like entities (protocells), among which, with or without the membrane, most models are based on the static assembly of molecules. However, life is dynamic: every life activity occurs under a flux of energy. The cell dies if the energy flux is stopped. The hydrogel environment and the compartmentalization responsible for the origin of life should be maintained under energized and non-equilibrium conditions.

The main energy form of life is chemical energy. However, an electric field, which exists extracellularly and intracellularly and can be as high as 10^7 V cm^{-1}, is essential for regulating appropriate cell behaviors during tissue morphogenesis and regeneration. Regarding this, Liang's group demonstrates that the electric field energization of coacervate micro-droplets comprising polylysine and short single strands of DNA generates membrane-free protocells with complex, dynamical behaviors. By confining the droplets within a microfluidic channel and applying a range of electric field strengths, they produced protocells that exhibit repetitive cycles of vacuolarization, dynamical fluctuations in size and shape, chaotic growth and fusion, spontaneous ejection and sequestration of matter, directional capture of solute molecules, and pulsed enhancement of enzyme cascade reactions. These findings in *Nature Communications* highlight new opportunities for the study of non-equilibrium phenomena in synthetic protocells, provide insights into the mechanism of life-like behavior in inanimate active matter, and could be of interest to the origin of life scenarios of prebiotic organization.

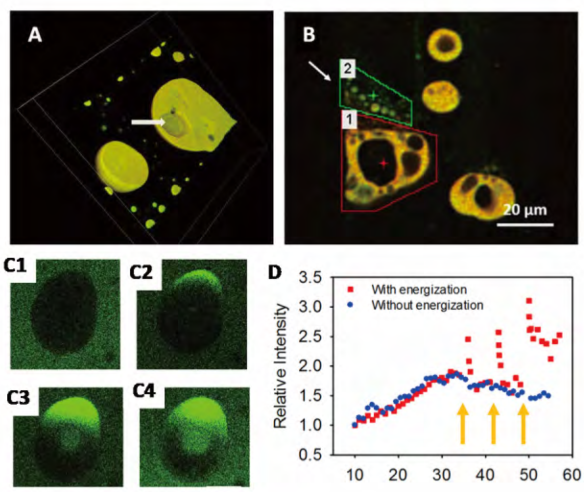

Figure Vacuole formation and protocell dynamics in electric fields. (A) 3D reconstruction of inner compartment; (B) ejection of micro-particles from large protocell; (C) time-dependent uptake of calcein under energization; (D) enhancement on enzyme cascade reaction.