Assembly of Protocell-like Vesicles in Micro-scale Hydrothermal Pores via Chaotic Thermal Convection

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A key unanswered question in the origin of life involves identifying mechanisms that explain how very dilute concentrations of lipid precursors could spontaneously assemble to form protocells under prebiotic conditions. The small pore networks that permeate mineral formations near underwater hydrothermal vents have emerged as potential hot spots for these processes. But so far, the physical machinery needed to drive macromolecular synthesis and packaging in these settings remains unclear. Here we show how micro-scale chaotic thermal convection under conditions that naturally exist in hydrothermal pores [1] can drive assembly of vesicles formed by phosphatidylcholine, a representative phospholipid membrane constituent. Using coordinated experiments and computational simulations, we have quantitatively explored thermally-driven convective flows across an ensemble of different pore geometries to establish a parametric map of the flow field and size distribution of vesicles produced after 24 h of incubation (determined by nanoparticle tracking analysis).

These data indicate a locus of flow conditions coinciding with a chaotic flow regime where vesicles 1 μm or larger emerge, supporting the ability of the convective flow to mediate assembly of vesicles in the protocell size range. Further analysis reveals that an interplay between the strength of the chaotic flow, its speed (quantifiable in terms of either the maximum or average velocity within the simulation domain), and its rotational component plays a crucial role. Chaotic motion drives enrichment of lipid species from the bulk to targeted locations within the pore, resulting in the production of vesicles larger than 1 μm under flow states that embed localized circulation capable of trapping the chemical precursors. These new insights lay a foundation to link the flow field inside a pore network to the size distribution of vesicles produced, ultimately making it possible to rationally identify conditions likely to favor protocell formation in hydrothermal systems.

[1] Priye, *et al*. (2017) *PNAS* **114**, 1275-1280.