Life in a condensed form: Emergence of life-like properties in coacervate droplets

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Compartmentalisation of biochemical reactions into organelles is a key organizing principle in many cells. Surprisingly, an important fraction of organelles lacks a membrane boundary, and is formed instead by condensation (coacervation) of macromolecules. These membraneless compartments can readily exchange small molecules with their environment, but they selectively accumulate large molecules. In the cell, they provide unique chemical microenvironments in which biomolecules are concentrated, folded and protected, and their reactions modulated. Owing to these properties, they may also have played an important role in the origin and evolution of the first cells.

We use coacervate droplets as model membraneless compartments to study how their internal chemical environment affects the structure and reaction rates of molecules. We investigate chemical ways to create, shape and grow these compartments in a dynamic way, similar to what happens in living cells. In this colloquium, we will focus on a recently developed minimal enzymatic network that fully controls the fate of ATP-based membraneless compartments. The condensation and dissolution of compartments is dynamic and reversible, triggered by the addition of small-molecule substrates and completed within minutes. These open, crowded compartments give rise to fascinating life-like behaviour when we add proteins that can self-assemble into filaments: the filaments are shown to adapt to their environment forming spontaneously growing and dividing fibrils.