Assemblies of Liquids, Polymers and Proteins for Engineered Biological Systems

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Aqueous multi-phase systems comprising immiscible biopolymer solutions are ubiquitous in biological cells. However, the structure-to-function relationship and the physics describing the behavior of these polymer systems are, in general, not yet understood. For example, almost all proteins have a specific three-dimensional structure that maintains its specific activity in the cell. One class of phase separating proteins, which has flown under the radar for decades, do not. They are referred to as intrinsically disordered proteins (IDPs). Their role in the cell appears to be to spontaneously associate with other proteins in phase separated compartments to activate them collectively. This is an important function to include in the design of a synthetic cell and for integration with cellular regulatory systems. Our work explores how we can leverage the thermodynamic blue print provided by the cell to engineer biological systems comprising phase-separated liquids with applications spanning areas of tissue culture, gene delivery, microfluidic colloid synthesis and engineered synthetic cells. Potential advancements include understanding how these interactions affect the regulation of gene expression and cell metabolism, understanding how dysfunctional interactions are linked to neurodegenerative disorders, and the design of synthetic membraneless organelles to control a variety of biological processes at the molecular level.