FROM SCIENCE BEYOND BORDERS TO UNDERSTANDING THE BOUNDARIES OF CELLS

Cell membranes play a crucial role as the basic building blocks of cells across various organisms, ranging from simple bacteria to more intricate plants and mammals. The primary purpose of lipid membranes is to maintain the cell's structural integrity and functionality, which is accomplished by ensuring a stable state of homeostasis within the cell's interior, regardless of alterations in the intracellular space or the surrounding environment. Cell membranes are not homogenous matrices composed of evenly distributed lipids and proteins, but they are rather characterized by the presence of local heterogeneities filled with saturated lipids, cholesterol and very often enriched in proteins. The idea of lateral segregation of membrane components, driven by phase separation, is a widely embraced concept in our current understanding of membrane structural organization, encapsulated within the framework of the "fluid mosaic” model of the cell membrane. Lipid domains, composed of saturated lipids and different sterol analogs remain conserved across relatively different organisms such as eukaryotes, prokaryotes, yeasts, or plants. These highly ordered regions play a crucial role in arranging specific membrane elements, including proteins. By ensuring their proper folding they become involved in a variety of processes such as enzymatic reactions, viral binding, and entry, or penetration of bacterial toxins to the cell interior. The indisputable importance of raft-like regions in cell activity led to studies on recreating the local membrane heterogeneities in model membrane systems, determining factors that are driving the phase separation, and finally unraveling the basic requirements that have to be fulfilled to effectively manipulate the shape, size, and density of lipid domains.

In our research we endeavor to elucidate the intricate mechanisms underlying phase separation and the emergence of local membrane heterogeneities in model prokaryotic and eukaryotic cell membranes. By concentrating specifically on the manipulation of membrane lipid composition as well as the external, environmental factors (level of hydration, pH, temperature) we undertake the challenge of inducing phase separation, replicating the membrane domains within model bacterial and mammalian cell membranes and precisely mimicking their complex structural characterization. Overall, our studies shine a new light on our understanding of the formation of local membrane heterogeneities provide us with novel methods of manipulation with the size, shape, curvature and distribution of membrane domains, and explain the fascinating mechanisms behind the phenomenon of phase separation in both eukaryotic and prokaryotic cell membranes.