Critical point fluctuations in supported lipid membranes

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Abstract

In order to understand the mechanisms by which membrane proteins, detergents, anti-microbial peptides and nanoparticles interact with bio-membranes, it is essential to understand the properties and dynamic behaviour of the membrane itself. We are studying the complex phase behaviour of a supported model cell membranes as a function of composition and temperature using a variety of biophysical techniques.

Although the existence of lipid rafts has been accepted for some time, their exact nature is an open question, and much of the data on them is contradictory. Many of their properties seem to be accounted for by a phase separation into 2 co-existing liquid phases, the liquid ordered phase (Lo) as the more stable raft phase domains, in a matrix of liquid-disordered (Ld) phase. The problem is that these equilibrium structures are typically microns in size, whereas the limited data available about rafts in real cells give a maximum size of 10's of nanometres, orders of magnitude smaller. Two possibilities may account for this, the first being that the rafts are actually non-equilibrium structures, formed via a constant turn-over of lipids and trafficing of particular components. Another hypothesis is that lipid rafts do not arise from a region of 2-phase co-existence, but from a single phase close to a critical point where relatively long range compositional fluctuations occur in the diffuse transition region between Lo and Ld phases. We demonstrate that it is possible to observe many aspects of critical phenomena in supported lipid bilayers using atomic force microscopy (AFM) with the aid of stable and precise temperature control. The regions of criticality were determined by accurately measuring and calculating phase diagrams for the 2 phase Ld–Lo region, and tracking how it moves with temperature. Compositional fluctuations were observed above the critical temperature (Tc) and characterised using a spatial correlation function. From this analysis, the phase transition was found to be most closely described by the 2D Ising model, showing it is a critical transition. Below Tc roughening of the domain boundaries occurred due to the reduction in line tension close to the critical point. At Tc, we have observed fluctuations on length scales greater than 10 μm. The region of critically fluctuating 10–100 nm nanodomains has been found to extend a considerable distance above Tc to temperatures within the biological range, and seem to be an ideal candidate for the actual structure of lipid rafts in cell membranes.