MOLECULAR DYNAMICS SIMULATIONS OF LIPID PHASE TRANSFORMATIONS

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The phase behaviour of lipid systems is very rich and complex. The cell uses the ability of lipid membranes to undergo phase separation or to adopt non-lamellar geometries in a number of fundamental biophysical processes such as raft-formation, vesicle fusion, or membrane poration and lysis. Over the past few years it has become feasible to study a variety of such phase transformation processes using molecular dynamics simulation techniques. I will give some recent examples, using coarse grained models [Marrink, S.J. et al. JPC-B 108 (2004) 750] as well as atomistic force fields [Anezo, C. et al. JPC-B, 107 (2003) 9424]. For instance, as is illustrated in the figure, the lamellar to inverted hexagonal phase in mixtures of DOPC/DOPE can be triggered by either a temperature jump or by dehydration of the multi-lamellar sample [Marrink, S.J. and Mark, A.E. Biophys. J. 87 (2004) 3894]. The simulations allow for a molecular picture of the phase transformation process, indicating stalk formation and elongation as the transformation mechanism. In another example, mixtures of saturated and unsaturated lipids are quenched into the two phase coexistence region [Faller, R. and Marrink, S.J. Langmuir 20 (2004) 7686]. The kinetics of domain formation can be followed right from the nucleation of micro-domains up to point of global phase separation. Cooling patches of pure DPPC lipids, modeled at atomistic resolution, shows the spontaneous formation of the ripple phase [de Vries, A.H. et al. Proc. Nat. Acad. Sci. U.S.A. 102 (2005) 5392]. The structure of this phase, as yet unresolved by experimental methods, is surprising, yet very elegant.

Transformation process of aDOPE bilayer from a multi-lamellar stack to an inverted hexagonal phase upon a temperature jump. Top images cut through the lamellae, showing the appearance of stalks. Lower images cut through the water layer, revealing the stalk elongation.