Pressure Effects on the Structure and Stability of Novel Lyotropic Mesophases of Lipids

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Lyotropic liquid crystals of 1-, 2-, or 3-dimensional periodicity spontaneously assemble when biological amphiphiles are mixed with solvent under various conditions of temperature, pressure and hydration. The mesophases formed include the 1-D fluid lamellar (L_α), 2-D hexagonal (H_I/H_{II}) and 3-D cubic phases (Q_I/Q_{II}). Although the flat fluid lamellar phase is the structure on which biomembranes are generally based, there is increasing evidence that curved structures such as the inverse cubic phases may be present in cell membranes, and/or may facilitate various cellular processes such as endo- and exocytosis, membrane budding, and fusion, as these all involve changes in membrane topology. Previous studies of lyotropic phase transitions have mainly concentrated on transformations between lamellar phases and from lamellar to inverse hexagonal structures, with little work done on transitions involving cubic phases. However, a complete understanding of the physical processes governing such transitions, including the nature of any intermediates formed, and the mechanistic routes taken, is essential if we are to further our knowledge of their possible roles in fundamental cellular processes involving membranes.

We have therefore been using high pressure and pressure-jump X-ray diffraction to investigate lyotropic phases and transitions in a range of lipid systems. The use of pressure to trigger transitions has several advantages: 1) the solvent properties are not significantly altered; 2) pressure propagates rapidly meaning that equilibrium is achieved rapidly; and 3) pressure-jumps can be both in the pressurisation and depressurisation directions. A 1 kbar change in pressure typically shifts lipid transition temperatures upwards by 20 – 30 °C, in accordance with the Clapeyron equation.

We have developed an automated high pressure cell for millisecond pressure-jump experiments, in collaboration with Dr. N. Terrill and colleagues at beamline I22, Diamond, UK (www.imperial.ac.uk/pressurecell). This is based on the Dortmund pressure cell of Professor Roland Winter, University of Dortmund. We will describe the design of this new cell, and present some of the data obtained from this cell. Looking to the future, we are keen to see a version of this apparatus installed at beamline ID02. Furthermore, there is potential to develop a microsecond pressure-jump X-ray cell, based on piezoelectric or magnetostriction actuators.

We acknowledge the very fruitful collaboration we have had over the last few years with the staff of beamline ID02, ESRF and beamline I22, Diamond Light Source.