BIOLOGICAL WATER

Suzanne P. Jarvis, Takeshi Fukuma, Michael Higgins
UCD Conway Institute of Biomolecular and Biomedical Research, University College Dublin, Belfield, Dublin 6, Ireland.
suzi.jarvis@ucd.ie

Water is a prerequisite for life and by far the largest single component in the living organism. Water should therefore be considered as an integral component of biomolecular function. Virtually all cellular processes including protein folding, immune response and membrane assembly are influenced by the delicate interplay between hydrophilic and hydrophobic interactions yet hydration forces are probably the least understood of all fundamental intermolecular forces and the subject of much scientific debate.

In close proximity to a surface, water cannot be treated as a structureless continuous medium due to its unique ability to form strong and highly oriented hydrogen bonds. The morphological structure and chemical nature of the adjacent surface is critical in determining the resulting water structure in the near surface region. The surface of a biomolecule is particularly complex as it is typically covered with domains of polar and non-polar groups and is surrounded not only by water but also solvated ions. At present the influence of water and ions on such systems are not well understood, primarily due to the difficulty in experimentally accessing the local nature of the hydration force under physiological conditions.

We have combined the dynamic and quantitative detection technique of frequency modulation with a low noise atomic force microscope (AFM) capable of operation close to the theoretical noise limit [1] in order to make highly sensitive force measurements in liquid. Using this system we have explored the influence of water and ions on interactions between an AFM tip and the surface of a dipalmitoylphosphatidylcholine (DPPC) lipid bilayer under physiological conditions.

Lipid bilayers mediate numerous biological processes at the cellular level, with the initial interaction of many biochemical processes such as membrane insertion, transport and fusion occurring at the membrane-fluid interface. Thus, when a biological molecule approaches a cell membrane, it is important to consider that aqueous environment must first be displaced before the biomolecule can interact directly with the membrane.

Our findings reveal that stable intrinsic hydration layers are often present at this interface [2]. Further, the prevalence and stability of these hydration layers is highly dependent on the presence of ions in solution. We have also observed that ions can actually modify the mechanical properties of the membrane itself. Based on sub-Ånstrom resolution images of the surface of the lipid bilayer we attribute the observed change in mechanical properties to the sharing of cations between headgroups, effectively joining them together in a co-operative and mechanically stronger arrangement [3].

References:

[1] T. Fukuma and S.P. Jarvis, Review of Scientific Instruments, **77** (2006) 043701.
[2] T. Fukuma, M. J. Higgins and S. P. Jarvis, Biophysical Journal, **92** (2007) 3603.
[3] T. Fukuma, M. J. Higgins and S. P. Jarvis, Physical Review Letters, **98** (2007) 106101.