Interactions at the Membrane-Fluid Interface

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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. The force required to remove strongly bound water that repels two approaching surfaces is referred to as the hydration force. The nature and significance of this hydration force in biological systems has yet to be determined.

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.

Figure 1. AFM image of approximately 2 nm x 1.5 nm of DPPC lipid bilayer, showing the average distribution of ions at the membrane-fluid interface (preferentially above the two negatively charged oxygen atoms of the phosphate part of the phosphatidylcholine headgroup). Between each headgroup runs a fine web of fast moving ions. The individual ions themselves are not visible as they move much more quickly than can be seen with the AFM.

Our findings reveal that stable intrinsic hydration layers are often present at the 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 arrangement as seen in Fig. 1 [3].

References

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