Molecular Biomechanics:
Phase transitions in Lipid Multilayers under shear and pressure

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In this talk I will discuss the first experiments to study the phase behavior of lipid multilayers in pure water, and in a model synovial fluid under pressure and shear typical in human joints. The data were taken on the new Neutron Reflectometer "Bioref" at the Helmholtz Center Berlin for Materials and Energy (HZB), which was build in a collaboration with the University of Heidelberg. "BioRef" combines neutron reflectivity and IR Reflection Spectroscopy to probe the mechanical and temperature effects on the stability and phase transitions in lipid multilayers. This allows for the first time to correlate molecular conformations in the lipid molecules with mesoscopic phase changes in the multi-lamellar system. The phase behavior of 1,2-Dimyristoyl-sn-Glycero-3-phosphocholine (DMPC) multilayers was studied both for the pure lipids, and with addition of Hyaluronic Acid (HA) to mimic the synovial fluid in a joint. Addition of HA leads to swelling of the multilayers into the micrometer thickness range and stabilizes them against temperature, pressure and shear. We find that the gel-liquid transition in the lipid layers as probed by the frequency of the methylene vibrations in the alkane chains of the DMPC molecules are not effected by the addition of HA. To explain the observation that the swollen multilayers are stable against a appreciable osmotic pressure, we speculate that tethering of HA polymers and mechanically connecting the bilayers leads to the surprising stability. At a shear frequency below 3 Hertz the lamellar system is stable, whereas at higher shear frequency the multilayers are destroyed. Extrapolating our model experiments to the human knee, this means: walk-don´t run.