Biological Membranes: The Lipid Bilayer

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Lipids are small molecules which consist of a hydrophobic and a hydrophilic part which refers to them consisting of a part which prefers not to be exposed to water and another one which likes to be in contact with water. We we will draw our attention mainly to a special family of lipids so called phospholipids. They are the most common lipid species in biological membranes. They consist of a phosphate containing headgroup and usually two fatty acid chains which consist of carbon and hydrogen atoms. Fatty acid chains define the hydrophobic part of the lipid while the headgroup is hydrophilic. There are different kinds of phospholipids which differ in headgroup, chain length or the degree of saturation. The latter term refers to how many double bounds between a carbon and a hydrogen atom in one fatty acid chain can be found. If there is no double bound at all one speaks about a saturated lipid chain . If there are the lipid chain and therewith also the lipid is unsaturated. If one puts lipids into water they spontaneously form aggregates, which is because of their amphiphilic structure. The hydrophilic part tries to yield the hydrophobic one from the water. Common aggregates are micelles, hexagonal phases or the lipid bilayer. The picture added should give an easy understanding of the different possible aggregates. A very important aggregate is the lipid bilayer, where two monolayers are arranged with the fatty acid chains being exposed to each other and lipid vesicles are formed. The lipid bilayer has some interesting physical characteristics which we will discuss in the following. Further in this series of articles we will investigate in which way the physical behavior might play a role in the functioning of biological membranes and of cells in general. Here, we want to draw our attention to something which is called phase separation in physics. We all now about this from our daily experience. The phases of water are probably known to most readers. Who has not touched ice, we all drink liquid water and see water vapor rising while boiling water for tea or coffee. While phases change we talk about phase transitions. The melting of ice to water is an example of these. Boiling water also undergoes a phase shift. These effects are induced by changing temperature. One finds a similar behavior increasing temperatures of solutions of lipid suspensions. At low temperatures the lipids are arranged on a lattice structure and the lipids themselves are well ordered. Increasing temperature the lipid membrane starts to melt. The lipids become disordered and they loose their lattice ordering. Historically the two phases were called the gel and respectively the fluid phase. One still finds these expressions in the literature, but researchers more and more use the terms solid ordered and liquid disordered, which were introduced for the first time by scientists around Ole Mouritsen in 1987. Solid and liquid refer in this case to the lattice structure and ordered and disordered to the lipid chain state. During the melting process the lipid membrane changes in volume and area. A liquid disordered membrane occupies a 25% higher area and the volume grows of about 4%. At an intermediate temperature phases coexist. Solid ordered and liquid disordered phases are present and one talks about phase separation. Differential scanning calorimetry is an experimental tool which allows one to measure heat capacity differences between a sample and a reference substance. During the melting process the lipid membrane needs more energy which leads to an increase in heat capacity. This allows then to study several properties of these phase transitions. Spectroscopic techniques such as infrared spectroscopy or nuclear magnetic resonance are also used to learn more about melting phenomena in lipid membranes. In the first case vibrations of molecules give information about the melting lipids and in the second one the magnetic moment is studied. In recent years methods which allow one the visualization of phase transition processes have been widely used. These include atomic force microscopy where one scans the surface of a sample or fluorescence microscopy. Fluorescent molecules are molecules which can be stimulated by light of a given wavelength and emit light of another wavelength. This technique is then used to study the simultaneous presence of different phases. The details of these experimental approaches shall, however, not be further evaluated in this article. They will be subject to a series of following articles. On the one side other stories will explain the techniques themself, and on the other side they shall also provide additional information about the physics of the mentioned melting processes. We can already reveal that a lot of interesting physics is hidden in lipid membranes. Nowadays, it has become vivid to believe that the physical behavior is important in determining details of the function of biological membranes and therewith of cells. (To the picture on home: A liposome formed from a lipid bilayer (taken from http://courses.cm.utexas.edu/j)) Contact the author: hseeger (at) xscience.info