BP 4: Membranes and Vesicles (joint session BP/CPP)

Time: Monday 9:30–13:00 Location: ZEU 250

BP 4.1 Mon 9:30 ZEU 250

Regulated ensembles and lipid membranes — •Martin Girard and Tristan Bereau — Max-Planck-Institut für Polymerforschung

Cellular membranes are composed of lipid bilayers, amphiphilic molecules with polar headgroups and hydrophobic tails. Their composition is highly complex, involving hundreds of different lipid types and the regulation mechanism is still the subject of intense research. A recent experiment [1] has shown that cholesterol concentration increases with temperature in zebrafishes, as well as the demixing temperature, two results which appear to be contradictory results since cholesterol promotes mixing. Here, we show that many aspects of the zebrafish experiments can be replicated if one assumes a chemical reaction network for regulation of acyl tails. Effectively, this would mean that acyl tail saturation is loosely regulated by cells and mainly directed by cholesterol fraction. This view also explains trends seen along the secretory pathway between cholesterol concentration and acyl tail saturation.[1] M. Burns, K. Wisser, J. Wu, I. Levental, S. L. Veatch, "Miscibility transition temperature scales with growth temperature in a zebrafish cell line" Biophysical Journal 113 (2017)

BP 4.2 Mon 9:45 ZEU 250

Effect of reactive oxygen species on phospholipid monolayers — •Florian Gellert, Heiko Ahrens, and Christiane A. Helm — Institute of Physics, University of Greifswald

Oxidative degeneration of lipids can lead to severe damages of the biological cell membrane. The phenomenon is initiated by reactive radicals, such as certain reactive oxygen/nitrogen species (ROS/ RNS). To investigate this behaviour, we use monolayers at the air/ water interface of unsaturated lipids as model membranes and measure isotherms. ROS induce an oxidation of the double bond. The double bond turns hydrophilic, thus increases the molecular area per lipid at the same surface pressure. This is demonstrated by using phosphocholines with the same head group, but either one or two double bonds in one alkyl chain and no double bond in the other alkyl chain. In another series of experiments, both alkyl chains contained a double bond. We conclude that the ROS/ RNS attacks mostly the unsaturated alkyl chains and has little effect on the head group of the lipid.

BP 4.3 Mon 10:00 ZEU 250

From UV to Near Infrared Optical Control of Photolipid Vesicles — •Theresa S. Kehler[1], Stefanie D. Pritzl[1], Alexander F. Richter[1], David B. Konrad[2], Dirk Trauner[2], and Theobald Lohmüller[1] — [1]Chair for Photonics and Optoelectronics, Nano-Institute Munich and Department of Physics, Ludwig-Maximilians-Universität (LMU), Königinstr. 10, 80539 Munich, Germany — [2]Department of Chemistry, New York University, Silver Center, 100 Washington Square East, New York 10003, United States

Photoswitchable azobenzene phospholipids or "photolipids" can be employed as molecular reagents in bilayer membranes to control a variety of characteristic membrane properties such as lateral fluidity, permeability or stiffness. A general drawback of the azobenzene photoswitch, however, is that illumination with UV light is required to trigger trans-to-cis isomerization, which limits the wider applicability of photolipids in biological systems.

Here, we report on the photophysical properties of a new group of halogenated azobenzene photolipids, where the wavelengths required to control photoisomerization are shifted to the visible and near-infrared range. The isomerization dynamics of red-shifted photolipid vesicles are characterized by absorption measurements, fluorescence microscopy and membrane fluctuation analysis. Notably, we observe a wavelength dependence of the switching rates, which can be harnessed to reversibly control the membrane rigidity up to a factor of two.

BP 4.4 Mon 10:15 ZEU 250

Structural and dynamical changes of biomimetic myelin membranes induced by myelin basic protein — •Benjamin Krugmann[1], Andreas Stadler[2], Aurel Radulescu[1], Alexandros Koutsioumpas[1], Marie-Sousai Appavou[1], Martin Dulle[2], Laura Stingaciu[3], and Stephan Förster[2] — [1]FZJ JCNS-1, 52428 Jülich, Germany — [2]FZJ JCNS-MLZ, 85748 Garching, Germany — [3]ORNL, Oak Ridge TN 37831, USA

A major component of the saltatory nerve signal conduction is the multilamellar myelin membrane around axons. In demyelinating diseases like multiple sclerosis, this membrane is damaged. In literature different values for the lipid composition of healthy myelin sheath and myelin with experimental autoimmune encephalomyelitis - the standard animal model for multiple sclerosis - have been found. In this work we try to elucidate the interaction mechanism of myelin basic protein - the structural protein responsible for the cohesion of the cytoplasmic leaflets of the myelin sheath - with membranes mimicking both compositions. As samples we use unilamellar vesicles and supported bilayer systems. With neutron and x-ray small angle scattering methods combined with cryo-TEM we can follow the rapid aggregation which leads to a slow process in which different structures are formed depending on the lipid composition. Those structural information can be associated with the bending rigidity of the respective membrane measured with Neutron Spin Echo. Neutron reflectometry gives insights on how the interaction mechanism between membrane and protein functions and reveals how modified membranes are destabilised by the protein.

Invited Talk BP 4.5 Mon 10:30 ZEU 250

How do lipids and proteins diffuse in cell membranes, and what do the diffusion experiments actually measure? — •Ilpo Vattulainen — Dept Physics, Univ Helsinki, Finland

There are numerous techniques able to gauge diffusion in biomembranes. For instance, quasi-elastic neutron scattering measures diffusion in a non-perturbative manner over the nanosecond time scale, yet sampling in space is in these experiments done over large distances. Meanwhile, single-particle tracking allows one to measure the dynamics of individual molecules in almost nanometer resolution, but these measurements are based on the use of markers that may interfere with the diffusion process. Here we discuss nanoscale simulation studies designed to explore the underlying molecular-scale diffusion mechanisms of lipids and membrane proteins. Also, we discuss the bases of single-particle tracking experiments by considering the effects of streptavidin-functionalized Au nanoparticle probes on the lateral diffusion. The results show that lipids diffuse in a concerted fashion as clusters of lipids whose motion is highly correlated, and membrane proteins move as dynamical complexes with tens of lipids dynamically bound to the protein. Meanwhile, lipids linked to a streptavidin-nanoparticle complex also turn out to move in a concerted manner but as a complex with the linker protein and numerous non-labeled lipids, slowing down the motion of the probe by an order of magnitude. The results highlight that prior to using any technique, it is crucial to understand the physical basis of the diffusion process that one aims to measure. Otherwise, interpretation of experimental data can be a surprisingly difficult task.

30 min. coffee break

BP 4.6 Mon 11:30 ZEU 250

Prerequisites and kinetics of lipid bilayer fusion with living cell membrane — •Justus Bednár[1,2], Anastasia Svetlova[1,2], Vanessa Maybeck[1], and Andreas Offenhäusser[1] — [1]Forschungszentrum Jülich, Institute of Complex Systems: Bioelectronic (ICS-8) — [2]Fakultät für Mathematik, Informatik und Naturwissenschaften RWTH Aachen

Fusion processes between artificial lipid vesicles and living cell membrane are studied for a variety of reasons. The delivery of anti-cancer therapeutics or the method known as lipofection are only two applications that would benefit from a detailed understanding of the prerequisites and kinetics of this fusion process.

While usually this process takes place between liposomes that have a small size relative to the cell membrane they are fusing to, an inverse approach is presented in the current work. Producing an artificial solid-supported lipid bilayer (SLB) first and letting extracts of living cell membrane fuse with it afterward allows for the application of a quartz crystal microbalance with dissipation monitoring (QCM-D). Tracking the changes in resonance frequency and energy dissipation of a quartz sensor underneath the SLB allows for real-time tracking of adhesion and fusion processes.

Using the proposed setup along with dynamic light scattering and fluorescence microscopy, the dependence of fusion efficiency and kinetics on lipid composition of the artificial lipid bilayer as well as on the concentration of cell membrane vesicles is evaluated.

BP 4.7 Mon 11:45 ZEU 250

Highly Reproducible Physiological Asymmetric Membrane with Freely Diffusing Embedded Proteins in a 3D Printed Microfluidic Setup — Paul Heo[1], Sathish Ramakrishnan[1,2], Jeff Coleman[2], James E. Rothman[2], •Jean Baptiste Fleury[3], and Frederic Pincet[1] — [1]Laboratoire de Physiqe Statistique ENS, Paris, France — [2]Department of Cell Biology Yale School of Medicine, New Haven, USA — [3]Department of Experimental Physics and Center for Biophysics, Saarland University Saarbruecken, Germany

Experimental setups to produce and to monitor model membranes have been successfully used for decades and brought invaluable insights into many areas of biology. However, they all have limitations that prevent the full in vitro mimicking and monitoring of most biological processes. Here, a suspended physiological bilayer-forming chip is designed from 3D-printing techniques. This chip can be simultaneously integrated to a confocal microscope and a path-clamp amplifier. The bilayer, formed by the zipping of two lipid leaflets, is free-standing, horizontal, stable, fluid, solvent-free, and flat with the 14 types of physiologically relevant lipids, and the bilayer formation process is highly reproducible. Because of the two channels, asymmetric bilayers can be formed by making the two lipid leaflets of different composition. Furthermore, proteins, such as transmembrane, peripheral, and pore-forming proteins, can be added to the bilayer in controlled orientation and keep their native mobility and activity. These features allow in vitro recapitulation of membrane process close to physiological conditions.

Small, 2019, 10.1002/smll.201900725

BP 4.8 Mon 12:00 ZEU 250

Statistics on Red Blood Cell Flow in Microchannels — •Felix Maurer, Thomas John, and Christian Wagner — Experimentalphysik Universität des Saarlandes

Half of the human blood volume consists of erythrocytes, also refered to as red blood cells. Most of the pressure induced by the heart muscle is used for microcirculation through capillary vessels. Capillary flow is strongly characterized by the soft body physics of red blood cells often described as vesicles. We established an experimental method to record individual cells during flow through straight artificial microfluidic channels. Stationary shapes could be classified. We measured the speed as a function of position at different external pressure drops and channel geometries. The velocity distributions reveal intrinsic differences between individual erythrocytes. These have been found to be the root cause of pairing in this setup. Interaction forces have no influence on the examined flow.

BP 4.9 Mon 12:15 ZEU 250

The mechanism of vesicle-vesicle detachment under shear flow — •Mehdi Abbasi, Alexander Farutin, and Chaouqi Misbah — Univ Grenoble Alpes, CNRS, LIPhy, F-38000 Grenoble, France

Red blood cells (RBCs) suspended in plasma tend to aggregate and form rouleaux, during the aggregation they start by forming doublets of RBCs. In the physiological conditions the aggregation is reversible, the RBCs aggregate and disaggregate by the shear rate. In contrast, under some pathological conditions the aggregation becomes irreversible and once the aggregates formed they can not be dispersed again. Recently, D, Flormann et al analysed the doublet shape in the absence of applied flow in vitro and in silico. They observe that contact surface of the doublet starts by flat then sigmoid shape with the increase of adhesion energy. We performed two dimensional simulations to study the doublet dynamics under shear flow in different conditions and the effect of the doublet dynamics on the doublet suspension rheology, we also invesitigate the mechanism of vesicle-vesicle detachment.

BP 4.10 Mon 12:30 ZEU 250

Thermodynamics of caveolae formation and mechanosensing — •Niladri Sarkar[1,2] and Pierre Sens[2] — [1]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, Netherlands. — [2]Laboratoire Physico Chimie Curie, Institut Curie, CNRS, 75005 Paris, France.

Caveolae are invaginations in cell membranes formed by proteins in the caveolin and cavin family self-aggregating in the membrane to form buds. These buds also have some proteins from the EHD family aggregating at their necks. We have developed a two component equilibrium model for the thermodynamics of these bud formation process using energy considerations, where the caveolin proteins are considered as one component and the neck proteins are taken to be another. We have found that depending on the surface tension of the membrane, the line tension associated with the different proteins and the concentration of the different proteins, invaginations of different shapes and sizes can be obtained, and there can be a transition from a fully budded state to a non-budded state via a partial budded state. Also neck proteins are found to provide extra mechano-protection against disassembly due to surface tension. We also found that these buds are responsible for regulation of tension in the membrane which can give rise to activation or deactivation of different chemical signaling pathways.

BP 4.11 Mon 12:45 ZEU 250

Conformal wrapping of nanoparticles — •Piermarco Fonda[1,2] and Luca Giomi[1] — [1]Lorentz Instituut, Leiden University, Leiden, The Netherlands — [2]Max Planck Institute of Colloids and Interfaces, Potsdam, Germany

It is well-known that wrapping of nanometer-sized particles by lipid membranes can happen spontaneously for sufficient adhesion energy between the particle surface and lipid molecules. In this work we show the surprising result that, even in absence of adhesion forces, there exist solutions to the shape equation that describe a stable, spontaneous wrapping of spherical particles. Mathematically, these solutions can be found analytically thanks to the scale invariant nature of the bending energy, which allows to reduce the problem to the one of finding minimal surfaces in hyperbolic and spherical spaces. From a physical standpoint, such shapes are well-behaved since, unlike for adhesive forces, they do not require any in-plane stress at the contact points, and hence they easily preserve the liquid nature of the membrane. Finally, the relevance of these solutions to experimental and biological systems will be discussed.