BP 22: Cell Mechanics

Time: Thursday 10:30–11:45 Location: PC 203

BP 22.1 Thu 10:30 PC 203

Shear Rheology of a Cell Monolayer — Pablo Fernandez[1], Lutz Heymann[2], •Benjamin Tränkle[3], Albrecht Ott[3,4], Nuri Aksel[2], and Pramod Pullarkat[5] — [1]E22 Biophysik, Technische Universität München, D-85748 Garching — [2]Technische Mechanik und Strömungsmechanik, Universität Bayreuth, D-95440 Bayreuth — [3]Experimentalphysik I, Universität Bayreuth, D-95440 Bayreuth — [4]Biologische Experimentalphysik, Universität des Saarlandes, D-66041 Saarbrücken — [5]on leave from Experimentalphysik I, Universität Bayreuth, D-95440 Bayreuth

We report a systematic investigation of the mechanical properties of fibroblast cells using a novel Cell Monolayer Rheology (CMR) technique. The new technique provides quantitative rheological parameters averaged over $\sim 10^6$ cells, making the experiments highly reproducible. Using this method, we are able to explore a broad range of cell responses not accessible using other present day techniques. Within the explored strain rates (10^{-3}–$1\,s^{-1}$) and strain amplitudes (1%–100%), nonlinear behaviour is only revealed by the effect of a nonzero average stress on the response to small, fast deformations. The response becomes linear at long timescales as well as large amplitudes. This counterintuitive linear behaviour is due to the dynamic nature of the cell cytoskeletal crosslinks and/or filaments, since it can be abolished by making them permanent with a fixation agent. These experiments provide a broad framework for understanding the mechanical responses of the cytoskeleton to different imposed mechanical stimuli.

BP 22.2 Thu 10:45 PC 203

Manipulation of stretch-activated calcium channels with the optical stretcher — •Markus Gyger and J. A. Käs — Universität Leipzig, Institut für Experimentelle Physik I, Linnéstr. 5, 04103 Leipzig

Cellular response to deforming forces can be measured with the optical stretcher. Cells are trapped by two anti-parallel laser beams. By increasing the laser power the momentum transfered to the cell surface causes visible deformations. This can be used to probe the global mechanical behaviour of single cells in suspension. For low stresses and small deformations most of the cells deform viscoelasticly. However, for higher stretching powers the cells start to counteract the deformations. Sometimes this active response to deformation results in a contraction of the cell relative to its initial, undeformed state. This raises interesting questions regarding the mechanisms by which cells register and respond to the applied forces. Under physiological conditions many must react to mechanical stimuli. As a prominent example, hair-cells in the Cochlea of vertebrate ears are known to open transmembrane calcium channels upon mechanical stresses. Calcium is one of the most important secondary messengers and is involved in most of the known mechano-activated cell responses. Since its normal concentration in the cell soma is very low and increases only by influx from outside the cell or release from intracellular calcium stores upon stimulus, the influx can be made visible by appropriate fluorescent dyes. The aim of this work is to investigate the dependence of calcium influx on the forces applied to the cell surface in order to gain insight into the mechanisms of active responses to stretching.

BP 22.3 Thu 11:00 PC 203

Dynamic states of rolling adhesion: dependance on rates for formation and rupture of molecular bonds — •Christian B. Korn and Ulrich S. Schwarz — University of Heidelberg, Im Neuenheimer Feld 267, D-69120 Heidelberg, Germany

Motivated by rolling adhesion of white blood cells in the vasculature, we study how cells move in linear shear flow above a wall to which they can adhere via specific receptor-ligand bonds. We perform computer simulations based on a Langevin equation accounting for hydrodynamic interactions, thermal fluctuations and adhesive interactions. In contrast to earlier approaches, we resolve both receptor and ligand positions. We identify five different dynamic states of motion in regard to the translational and angular velocities of the cell. We express these states in a state diagram for the parameter subspace spanned by the dynamic rates for bond formation and rupture. In particular, we show that if on- and off-rates are sufficiently balanced the cell's translational and angular velocities become sychronized. This corresponds to rolling in a macroscopic sense while otherwise the cell is slipping.

In order to analyze the generic interplay between bond formation and rupture, we also define and analytically solve a simple model system based on a one-step master equation. The analytical results show qualitative agreement with the mean velocity data obtained from the computer simulations.

BP 22.4 Thu 11:15 PC 203

Stress relaxation, stiffening and fluidization of adherent cells — •Philip Kollmannsberger and Ben Fabry — Physics Department, University Erlangen-Nuremberg, Henkestr. 91, 91052 Erlangen

The linear rheology of adherent cells is characterized by a wide distribution of relaxation times, as seen by a creep or stress relaxation response that follows a weak power law over several time decades. However, stress relaxation of living cells in the non-linear range where stress stiffening occurs has been poorly characterized and are not well understood. We used a magnetic tweezer setup with real-time force control to apply forces of more than 20 nN to beads bound to the cytoskeleton of adherent cells. Deformations in response to stepwise increasing and repeated force application were analyzed using a nonlinear superposition model that allowed us to dissect stress relaxation processes from stiffening responses. Results show that the creep modulus becomes nonlinear and decreases with increasing force. In addition, stresses relaxed in most beads according to a power-law in time with a slope between 0.2 and 0.3 independent of the stress magnitude. Force-induced fluidization and yielding leads to an increase in the power-law exponent. This was indicative either of a disruption of the beads when the force was further increased, or of a substantial plastic deformation after the force was removed. We interpret our results in terms of a model where dynamic stability and turnover of molecular interactions carrying the mechanical stress are determined by an energy landscape with a wide distribution of energy well depths and associated trap stiffnesses.

BP 22.5 Thu 11:30 PC 203

The use of scanning probe techniques and laser micromanipulation to isolate and mechanostimulate highly potent adult mesenchymal stem cells — •Karla Müller[1], Matthias Zscharnack[2], Jörg Galle[3], and Josef Käs[1] — [1]Inst. for Soft Matter Physics, University of Leipzig — [2]Applied Stem Cell Biology, Center for Biotechnology and Biomedicine, University of Leipzig — [3]Interdiciplinary Centre for Bioinfomatics, University of Leipzig

Degenerative joint diseases due to rheumatism, joint dysplasia or traumata are particularly widespread in countries with high life expectancies. Today hyaline cartilage and bone defects resulting from joint destruction can be treated by appropriate transplantations from (and thereby destroying) intact joint areas. An alternative approach is the use of adult mesenchymal stem cells. These cells have the potential to differentiate into various cell types, such as osteoblast-like cells and chondrocyte-like cells. The aim of MS CartPro is to develop a closed, aseptic bioreactor for the production of autologous grafts for cartilage regeneration. We establish the sorting of most potent cells out of a heterogeneous cell sample by exploring the phase space of viscoelastic properties and relating these to the individual cells ability to differentiate into the desired tissue type. In order to non-invasively probe the mechanical properties of suspended cells, the Optical Stretcher is a highly adequate tool. Mechanostimulation is achieved by indenting adherent stem cells with a modified AFM tip in order to push them towards a chondrocyte like differentiation.