BP 27: Physics of Cells III

Time: Thursday 14:00–17:00 Location: ZEU 250

Invited Talk BP 27.1 Thu 14:00 ZEU 250

Inelastic Mechanics of Biopolymer Networks — •Klaus Kroy — Intstitut für Theoretische Physik, Universität Leipzig

Live cells have ambiguous mechanical properties. They were often described as either elastic solids or viscoelastic fluids and have recently been classified as soft glassy materials characterized by weak power-law rheology. Nonlinear rheological measurements have moreover revealed a pronounced inelastic response indicative of a competition between viscoelastic stiffening and inelastic fluidization. It is an intriguing question whether these observations can be explained from the material properties of much simpler in-vitro reconstituted networks of cytoskeletal biopolymers. I will summarize some recent theoretical advances in this direction.

BP 27.2 Thu 14:30 ZEU 250

Buckling instability of motor driven rotating bacterial flagella — •Reinhard Vogel and Holger Stark — TU Berlin

Many types of bacteria, such as *E. coli* and *Salmonella*, swim by rotating a bundle of helical filaments also called flagella. Each filament is driven by a rotary motor. When its sense of rotation is reversed, the flagellum leaves the bundle and undergoes a sequence of configurations characterized by their pitch, radius, and helicity (polymorphism). Finally the flagellum assumes its original form and returns into the bundle.

The bacterial flagellum consists of three parts; the rotary motor embedded in the cell membrane, a short proximal hook that couples the motor to the third part, the long helical filament. The helical shape of the filament converts rotational motion into a thrust force that pushes the bacteria forward.

In our contribution, we demonstrate how the hook, which transfers the motor torque to the filament, can be modeled. We then investigate how the flexible filament reacts on the applied motor torque. For small torques and a resulting thrust force pushing the bacterium forward, the helical axis is approximately parallel to the motor torque and the helical filament is only slightly compressed. However, when the torque is increased, the straight helical form becomes unstable and we observe a buckling instability or Hopf bifurcation when the compression becomes too strong. We analyze how the mobility of the cell body and thermal noise influence the instability and discuss its biological implications, in particular, for the formation of the bundle.

BP 27.3 Thu 14:45 ZEU 250

Novel micro-analytical techniques for diagnostics of malaria infected red blood cells — •Jakob Mauritz, Clemens Kaminski, Teresa Tiffert, and Virgilio Lew — Universität Cambridge, Vereinigtes Königreich

We report on the application of advanced microanalytical techniques for the study of Plasmodium falciparum infected red blood cells. Using confocal microscopy, volume and shape changes of living red blood cells can be measured at femtolitre resolution throughout the intraerythrocytic infection cycle of the parasite. The cytomechanical properties are studied using a novel optical stretcher device constructed by the authors, which enables individual infected cells to be trapped and manipulated optomechanically in microfluidic channels. Finally, novel results of X-ray microanalysis and fluorescence lifetime imaging for the quantification of haemoglobin and ion content and concentrations are reported on. In their combination, these methods offer unique insight into the homeostatic behaviour of malarial blood cells, providing an unprecedented wealth of information. The data are compared to predictions from a detailed physiological model of the homeostasis and volume regulation during the infection cycle of the red blood cell.

BP 27.4 Thu 15:00 ZEU 250

Friction Modulated Traction Force in Cell Adhesion — •Tilo Pompe[1], Stefan Glorius[1], Stephanie Johne[1], Maria Kasimir[1], Martin Kaufmann[1], Lars Renner[1], Manfred Bobeth[2], Wolfgang Pompe[2], and Carsten Werner[1,3] — [1]Leibniz Institute of Polymer Research Dresden, Max Bergmann Center of Biomaterials, Germany — [2]Technische Universität Dresden, Institute of Materials Science, Germany — [3]Center for Regenerative Therapies Dresden, Germany

The force balance between the extracellular microenvironment and the intracellular cytoskeleton controls cell fate decisions. We report a new mechanism of receptor force control in cell adhesion originating from friction between cell adhesion ligands and the supporting matrix. Myosin motor activity in conjunction with assembly of fibronectin ligands non-covalently coupled to polymer surfaces of graded physicochemistry is shown to result in modulated traction forces of adherent cells. By using a diffusion process for the description of ligand reorganization with the growing fibronectin fibrils acting as local sinks, the determined ligand mobility is correlated to traction force measurements. We conclude that the modulation of the ligand-support anchorage allows to tune cellular traction forces at adhesion receptors in the pN range by a frictional mechanism. Hence, adhesion-ligands friction has to be considered to be highly relevant in studying mechanotransduction and cell development of adherent cells.

BP 27.5 Thu 15:15 ZEU 250

Elastic interactions with the substrate can guide spatial re-organization during myofibril assembly — •Benjamin M. Friedrich[1], Amnon Buxboim[2], Dennis E. Discher[2], and Samuel A. Safran[1] — [1]Department of Materials and Interfaces, Weizmann Institute of Science, Rehovot, Israel — [2]Group of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania, USA

Myofibrils are the force generating units in striated muscle cells and represent a crystal-like state of acto-myosin organization with characteristic, sarcomeric architecture. The assembly of these myofibrils is a multi-step process that starts with the formation of stress fiber-like, sarcomeric premyofibrils near the cell-substrate interface. A prerequisite for the subsequent fusion of neighboring premyofibrils into nascent myofibrils is the inter-fiber registry of their respective sarcomeric periodicity. Here, we propose that substrate-mediated elastic interactions drive neighboring premyofibrils into registry. Elastic interactions may thus guide myofibril assembly and provide a link between acto-myosin organization and mechanical properties of an extra-cellular substrate. Our theory can account for the non-monotonic dependence of myofibrillogenesis on substrate rigidity that was observed in recent experiments (Engler et al., J. Cell Biol. 166, 2004).

BP 27.6 Thu 15:30 ZEU 250

Contractile network models for adherent cells — •Philip Guthardt Torres[1,2], Ilka B. Bischofs[1,3], and Ulrich S. Schwarz[1,2] — [1]Bioquant, University of Heidelberg — [2]ITP, University of Heidelberg — [3]ZMBH, University of Heidelberg

Cells sense the geometry and stiffness of their environment by active contractility. Assuming a flat substrate, two-dimensional contractile network models can be used to understand how force is distributed throughout the cell. We show that the widely used Hookean spring networks do not correctly predict cell shape on patterned substrates. The observed circular shape feature is only predicted by actively contracting cable networks, which model both the filamentous mechanics of the actin cytoskeleton and its contraction due to myosin II motor activity. In contrast to Hookean and passive cable networks, here shape and force distribution are determined by local rather than global determinants and thus are suited to endow the cell with a robust sense of its environment. We compare our numerical results with analytical approaches and discuss an extension of this approach which considers adaptive linker mechanics.

15 min. break

BP 27.7 Thu 16:00 ZEU 250

High-Resolution Cell Mechanics with a Dual Optical Trap — •Florian Schlosser, Christoph F. Schmidt, and Florian Rehfeldt — Drittes Physikalisches Institut, Georg-August-Universität Göttingen, Germany

Cells communicate with their environment biochemically, but also through mechanical interactions. Cells can generate contractile forces through their acto-myosin network and use these forces to actively probe the mechanical response of their surroundings. This results in cellular reactions, a process called *mechano*-sensing.

Our dual optical-trap setup allows us to perform high-resolution measurements of the forces a cell generates between two fibronectin-coated beads by analyzing the fluctuations of the beads at high spatial

and temporal resolution. Simultaneously, we actively probe the viscoelastic properties of the same cell by applying oscillatory forces.

Here, we present data of contractile forces and elastic responses of 3T3 fibroblasts and use biochemical perturbations (e.g. blebbistatin, a potent non muscle myosin II inhibitor) to elucidate the contributions of the different cytoskeletal elements to the active and passive mechanical properties of a cell.

BP 27.8 Thu 16:15 ZEU 250

Influence of Calcium Signaling on Biomechanics of Single Suspended Cells in the Optical Stretcher — •Markus Gyger and Josef A. Käs — Universität Leipzig, Faculty of Physics and Earth Science, Soft Matter Physics Division, Linnéstraße 5, 04103 Leipzig, Germany

Under physiological conditions many cells must react to mechanical stimuli. This raises interesting questions regarding the mechanisms by which cells register and respond to applied forces. For adherent cells focal adhesions seem to play an important role in mechano-tranduction. Also calcium, one of the most important second messengers, is involved in a number of known mechano-activated cell responses.

In the presented study cells, artificially suspended by trypsin, were investigated to elucidate the influence of calcium signals on the mechanical properties of cells independent of focal adhesions. To this end techniques to visualize, quench, and artificially induce calcium signals were combined with the Optical Stretcher, a tool to probe global mechanical behavior of single cells in suspension. In the Optical Stretcher, cells are trapped by two anti-parallel laser beams. By increasing the laser power the momentum transferred to the cell surface causes visible deformations. Different cells such as fibroblasts, epithelial cells, myotubes and a TRPV1 transfected kidney cell line were investigated by a combination of Optical Stretching and fluorescence calcium imaging in the Laser Scanning Microscope.

BP 27.9 Thu 16:30 ZEU 250

Responses of cytoskeletal waves to stimuli and possible implications for cell behaviour — •Alexander Dreher[1], Konstantin Doubrovinski[2], and Karsten Kruse[1] — [1]Theoretische Physik, Universität des Saarlandes, Postfach 151150, 66041 Saarbrücken, Germany — [2]Department of Molecular Biology, Princeton University, Princeton, NJ 08544, USA

The crawling of eukaryotic cells on substrates is driven by the cytoskeleton. How the cytoskeleton is organized and how it responds to external stimuli during this process is still poorly understood. Spontaneous polymerization waves have been suggested to provide a means for cytokeletal organization. We theoretically investigate the response of such waves to applied forces and to local modifications of the polymerization activity. We identify conditions under which a wave is reflected and when it is captured by an obstacle. Our results suggest a possible mechanism for responses of cells encountering another cell. It might be relevant for T cells that need to decide quickly whether to kill a cell they encountered or to crawl away and search other cells.

BP 27.10 Thu 16:45 ZEU 250

The contribution of cytoskeleton networks to stretch is strain dependent. — •Kenechukwu David Nnetu, Tobias Kiessling, Roland Stange, and Josef Käs — Institut für Experimentelle Physik I, University of Leipzig, Linnéstr 5, 04103, Leipzig Germany

The interaction between the cytoskeleton filaments in a cell provides it with mechanical stability and enables it to remodel its shape. The rheological response of cells has been characterized either as viscoelastic or soft-glassy which neglects the molecular origin of cell response. In this work, by using a large amount of cells ($>$ 10,000) exceeding previous statistics by a decade, we link observed cell response to its molecular origin by showing that actin and microtubule networks maintain the mechanical integrity of cells in a strain dependent manner. While the actin network solely regulated cell deformation at small strain, the microtubule network was responsible for cell relaxation. At large strain, actin and microtubule networks dominated cell response with microtubules having a bipolar effect on cells upon stabilization. This effect explains the relapse of some cancer after chemotherapy treatment using Taxol thus providing a bridge between soft condense matter physics and systems biology.