BP 9: Posters - Cell Mechanics

Time: Monday 17:30–19:30 Location: P3

BP 9.1 Mon 17:30 P3

Characterization of the power and thermic behaviour of an ultrasonic probe — •Tobias Löffler[1], Mike Huwer[1], Julia Kristin[2], and Mathias Getzlaff[1] — [1]Institute of Applied Physics, University of Düsseldorf — [2]Hals-Nasen-Ohrenklinik, Universitätsklinikum Düsseldorf

We want to use an ultrasonic probe to transfer energy to biological samples in liquid. For a better understanding of the influence of the ultrasound, we need a detailed characterization of its properties in the liquid environment.

In order to determine the temperature-profile in the vicinity of our ultrasonic probe, measurements of the temperature at different distances in direction of oscillation and additionally as a function of time have been performed. The displacement of the probe head was measured with an optical microscope.

The characterization of the output energy was performed with calibrated ultrasonic-power-detectors at different distances in the direction of propagation.

BP 9.2 Mon 17:30 P3

Development of a mechanically stable cell stretcher for measuring the influence of external strain on cell mechanics with the AFM — •Fabian Port, Patrick Paul, and Kay-E. Gottschalk — Institute of Experimental Physics, Ulm University

In the last few decades the correlation between cell mechanics and different physiological or pathophysiological conditions, like stem cell differentiation [1] or cancer [2], has been a growing aspect of biophysical research. To understand the underlying mechano-chemical feedback cycles, it is important to understand the mechanical properties of cells under varying conditions. Such conditions could be the effect of strain on cells, which is particularly important for a variety of cell types like endothelial cells in the lung, in arteries or in the bladder. The impact of such conditions on the cell mechanics is not yet well understood on the cellular and subcellular level. For a detailed analysis of the cells response to stretch, we present here a self-developed cell stretching device, which is compatible with correlative AFM and FLIM Measurements.

[1] Suresh, S., Spatz, J., Mills, J. P., Micoulet, A., Dao, M., Lim, C.T.,and Seufferlein, T. (2005). Connections between single-cell biomechanics and human disease states: gastrointestinal cancer and malaria. Acta Biomaterialia, 1(1), 15-30.

[2] Sokolov, I. (2007). Atomic force microscopy in cancer cell research. Cancer Nanotechnology, 1-17.

BP 9.3 Mon 17:30 P3

Cooperative microtubule dynamics in closed elastic compartments — •Jonas Hegemann and Jan Kierfeld — TU Dortmund, 44221 Dortmund, Germany

Microtubules are an essential part of the cytoskeleton and interact mechanically with cell cortex and membrane. Since local polymerization forces on the cell boundary can affect its global shape, this generates a coupling between different microtubules. We propose a model, which describes the polymerization dynamics of a microtubule ensemble confined in a closed elastic compartment in two dimensions and growing radially outwards. This serves as a simple model for microtubules in an elastic cell cortex, which can change its shape. Microtubules are coupled via their growth velocities, which depend on local forces derived from an elastic energy functional. The cell cortex dynamically reacts to stochastic displacements produced by the microtubules. We investigate synchronization effects and polarization mechanisms.

BP 9.4 Mon 17:30 P3

Adhesive dynamics of Plasmodium falciparum-infected red blood cells — •Anil K. Dasanna, Christine Lansche, Michael Lanzer, and Ulrich S. Schwarz — Heidelberg University

The clinical symptoms of the malaria disease appear when healthy red blood cells (RBC) are invaded by the malaria parasites during the blood stage of the life cycle. The whole infection of RBC takes about 48 hrs and proceeds through the three stages of ring, trophozoite and schizont. During these stages, infected RBC increasingly develop adhesive protrusions, so-called knobs, on their surface. These knobs cause iRBCs to adhere to endothelial cells in the microvasculature, preventing their clearance by spleen and liver, but also leading to capillary obstruction. We first present how exactly the shape of iRBCs change during the time course along with their geometrical features such as volume and surface area using confocal microscopy and image processing. We then discuss how these changes in shape and knob details through out the blood stage affect the rolling adhesion of iRBCs on endothelial cells using flow chamber experiments. Results from these flow chamber experiments are complemented with adhesive dynamics of deformable RBC simulations. Hydrodynamics is implemented with multiparticle collision dynamics (MPCD). In particular using simulations, we will discuss how does the combination of iRBC shape or different infectious stage cell along with different knob density give rise to different adhesive dynamics such as flipping motion or stable rolling. We will show how does membrane elasticity play role in adhesive dynamics.

BP 9.5 Mon 17:30 P3

Functional analysis of chordotonal organ mechanics in vivo — •Chonglin Guan[1], Martin Göpfert[2], and Christoph Schmidt[1] — [1]Faculty für Physics, Third Institute of Physics - Biophysics, Georg-August-University, Göttingen, Germany — [2]Department of Cellular Neurobiology, Schwann-Schleiden-Centre for Molecular Cell Biology, Georg-August-University, Göttingen, Germany

Most if not all higher organisms require reliable mechanosensation for various biological processes including hearing, balance, proprioception and touch. Vertebrates and invertebrates have evolved specialized mechanosensory devices and strategies to manage this immense challenge. Vertebrates possess multiple organs, which are typically adapted to particular mechanical stimuli. In contrast, Drosophila is equipped with a polymodal sensor * the chordotonal organ (ChO) through which they are capable to perceive different mechanical stimuli including sound, touch and proprioception. Previously, I have developed a preparation to directly record from the sensory neurons of larval ChOs and managed to correlate defined mechanical inputs with the corresponding electrical outputs (Scholz et al., 2015). Our in vivo model established ChOs as interesting sites to study the molecular machinery involved in the perception of mechanical stimuli. However, genetic and functional dissection of ChO mechanics in vivo has been challenging. Here, we aim to obtain a deeper mechanistic understanding and provide new insights into the biophysics of ChOs. We correlate mechanical properties and active manipulation with neuronal activity. We focus on cytoskeleton structures and force generation.

BP 9.6 Mon 17:30 P3

A Protein Flux-based Mechanism for Midcell Sensing in Bacteria — •Silke Bergeler[1], Dominik Schumacher[2], Lotte Søgaard-Andersen[2], and Erwin Frey[1] — [1]ASC for Theoretical Physics, Ludwig-Maximilians-Universität, München, Germany — [2]Max Planck Institute for Terrestrial Microbiology, Marburg, Germany

Precise positioning of the cell division site is essential for the correct separation of the genetic material into the two daughter cells. In myxobacteria, a protein cluster is formed on the nucleoid that performs a biased random walk to midcell and positively regulates cell division there. Deletion experiments show that PomZ, an ATPase, is necessary for this cluster movement. To investigate how the cluster is positioned at midcell, we introduce a mathematical model: ATP-bound PomZ dimers can attach to and quickly diffuse on the nucleoid. At the cluster, they can hydrolyze ATP and subsequently detach into the cytosol as ADP-bound monomers. It is known that this type of particle dynamics leads to different fluxes of PomZ into the cluster from both sides along the long cell axis, if the cluster is at an off-center position. We investigate this model both numerically, using stochastic simulations, and analytically, using reaction-diffusion equations. With our model, we are able to reproduce the movement of the cluster towards midcell. We perform parameter sweeps to test the robustness of the mechanism. Furthermore, we investigate the reaction-diffusion equations in a three-dimensional geometry mimicking the cell to study geometric effects. In summary, our study provides new mechanistic insights into self-organized intracellular positioning of protein clusters.

BP 9.7 Mon 17:30 P3

The mechanical framework of cells: Modeling eukaryotic cells as thick-shell multilayer elastic materials — •Constantin D. C.

Kohl and Christoph F. Schmidt — 1Drittes Physikalisches Institut, Fakultät für Physik, Georg-August-Universität, Göttingen

Cells are complex mechanical entities. They respond passively and actively to forces exerted by their environment, and, as active materials, they probe their surroundings by exerting forces. To understand such processes, one needs a detailed quantitative model describing the mechanical properties of a cell. Components of such a model will be the external lipid bilayer, the polymeric actin cortex, and the inner cytoplasmic structures, including the microtubule network, intermediate filaments, membraneous compartments and the nucleus. An important quantity controlling cell volume is the osmotic pressure. Internal osmolyte concentration and its regulation by transport processes plays a crucial role for the mechanical properties of the cell. Most existing cell models do not consider the osmotic pressure in cells that are exposed to mechanical forces. We present finite element simulations where we model the cell as a thick-shell multiple layer object with spherical symmetry. In our model, we vary the elastic properties and the thickness of the different shell compartments and include osmotic pressure. We indent the cell by beads and investigate the resulting force curves.

BP 9.8 Mon 17:30 P3

Effect of the flexural rigidity of type IV pili on the motility of *N. gonorrhoeae* bacteria. — •Maxim A. Beliaev[1], Wolfram Pönisch[1], Nicolas Biais[2], and Vasily Zaburdaev[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Brooklyn College, New York, USA

Gonorrhea is the second most common sexually transmitted disease in the world. *Neisseria gonorrhoeae* bacteria, the causative agent of the gonorrhea infection, use multiple long and semiflexible filaments, called type IV pili to move, attach to the epithelium and form colonies. These filaments assemble and elongate from the cell membrane towards its environment where they can attach to various substrates and pili of other cells. The retraction of pili can generate significant pulling forces of up to 180 pN. Although currently there exist several models of pili driven motility, they do not consider the semiflexible nature of pili filaments. In this work we explicitly analyze the effect of pili flexural rigidity on the motility of *N. gonorrhoeae* bacteria. We use two approaches to model pili. In the first one, a pilus is modelled as an Euler-Bernoulli cantilever beam with a point load at the tip whereas in the second approach, a pilus is modelled as a stiff rod connected to the cell membrane by a pivotal spring. For both models we compare the results of the numerical simulations of the moving cell to the experimental data and analyze how the flexibility of pili affects the cell persistence and orientation during motility.

BP 9.9 Mon 17:30 P3

passive and active response of bacteria under mechanical compression — •renata garces[1], samantha miller[2], and christoph f. schmidt[1] — [1]Georg-August-Universität Göttingen, Göttingen, Germany — [2]The University of Aberdeen, Aberdeen, United Kingdom

Bacteria display simple but fascinating cellular structures and geometries. Their shapes are the result of the interplay between osmotic pressure and cell wall construction. Typically, bacteria maintain a high difference of osmotic pressure (on the order of 1 atm) to the environment. This pressure difference (turgor pressure) is supported by the cell envelope, a composite of lipid membranes and a rigid cell wall. The response of the cell envelope to mechanical perturbations such as geometrical confinements is important for the cells survival. Another key property of bacteria is the ability to regulate turgor pressure after abrupt changes of external osmotic conditions. This response relies on the activity of mechanosensitive (MS) channels: membrane proteins that release solutes in response to excessive stress in the cell envelope. We here present experimental data on the mechanical response of the cell envelope and on turgor regulation of bacteria subjected to compressive forces. We indent living cells with micron-sized beads attached to the cantilever of an atomic force microscope (AFM). This approach ensures global deformation of the cell. We show that such mechanical loading is sufficient to gate mechanosensitive channels in isosmotic conditions.

BP 9.10 Mon 17:30 P3

Regulation of muscle contraction by Drebrin-like protein 1 probed by atomic force microscopy — •Peter Weist, Eugenia Butkevich, Dieter R. Klopfenstein, Renata Garces, and Christoph F. Schmidt — Drittes Physikalisches Institut-Biophysik, Georg-August-Universität Göttingen, Germany

Sarcomeres are the fundamental contractile units of striated muscle cells. They are composed of a variety of structural and regulatory proteins functioning in a precisely orchestrated fashion to enable coordinated force generation in muscles. Recently, we have identified a drebrin-like protein 1 (DBN-1) as a novel sarcomere component in the nematode C. elegans. DBN-1 stabilizes actin filaments during muscle contraction. Absence of DBN-1 results in a unique worm movement phenotype,characterized by hyper-bending. The origin of the hyper-bending is not clear yet. DBN-1 could have a regulatory role in proper muscle contraction. The phenotype of the knockout of DBN-1 protein could be caused by either enhanced contraction or enhanced relaxation of the muscles. We present here an experimental study on C.elegans muscle mechanics by atomic force microscopy. We measured the stiffness of the whole worm by gently indenting living C. elegans with a micron-sized sphere adhered to the cantilever of an atomic force microscope (AFM). Using chemical treatments in wild-type worms we probed that the degree of contraction of the muscle is directly related to the measured elastic compliance of the worm. We compared responses of wild-type and mutant C.elegans in which DBN-1 is not expressed.

BP 9.11 Mon 17:30 P3

Rheology of the active cell cortex in mitosis — •Elisabeth Fischer-Friedrich[1,2], Yusuke Toyoda[2,3], Cedric Cattin[4], Daniel Müller[4], Anthony Hyman[2], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany — [3]Institute of Life Science, Kurume University, Kurume, Japan — [4]D-BSSE, Eidgenössische Technische Hochschule Zürich, Mattenstr. 26, 4058 Basel, Switzerland

The cell cortex is a key structure for the regulation of cell shape and tissue organization. To reach a better understanding of the mechanics and dynamics of the cortex, we study here HeLa cells in mitotic arrest dynamically compressed between two parallel plates. We investigate the dependence of this mechanical response on the geometry of the cell and find strong indications, that the cortical layer is the dominant mechanical element. To characterize the time-dependent rheological response, we perform step strain experiments and oscillatory cell compressions. We extract a complex elastic modulus which characterizes the resistance of the cortex against area dilation. In this way, we present a rheological characterization of the cortical actomyosin network in cells. Furthermore, we investigate the influence of actin cross-linkers and the impact of active prestress on rheological behavior. Intriguingly, we find that cell mechanics in mitosis is captured by a simple rheological model characterized by a single time scale on the order of 10 s which marks the onset of fluidization in the system.

BP 9.12 Mon 17:30 P3

Force fluctuations of suspended cells- effects of osmotic pressure and motor inhibition — •Samaneh Rezvani[1], Todd M. Squires[2], and Christoph F. Schmidt[1] — [1]Drittes Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Department of Chemical Engineering, University of California, Santa Barbara, USA

Cells communicate with their environment through biochemical and mechanical interactions. They can respond to stimuli by undergoing shape- and, in some situations, volume changes. Key determinants of the mechanical response of a cell are the viscoelastic properties of the actomyosin cortex, effective surface tension, and osmotic pressure. We use a custom-designed microfluidic device with integrated hydrogel micro-windows to rapidly change solution conditions for cells suspended by optical traps without direct fluid flow. We use biochemical inhibitors and different osmolytes and investigate the time-dependent response of individual cells. Using a dual optical trap makes it possible to probe the viscoelasticity of suspended cells by active and passive microrheology to quantify the mechanical response of the cells under the various conditions.

BP 9.13 Mon 17:30 P3

Local tubulin concentrations in the C. elegans metaphase spindle — •Johannes Baumgart[1], Marcel Kirchner[2], Stefanie Redemann[2], Jeffrey Woodruff[3], Jean-Marc Verbavatz[3], Anthony Hyman[3], Thomas Müller-Reichert[2], Jan Brugués[1], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden — [2]Experimental Centre, Medical Faculty Carl Gustav Carus, Technische Universität Dresden — [3]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden

During cell division, the mitotic spindle physically separates the duplicated chromosomes. The spindle is formed by many highly dynamic microtubules. Microtubules are stiff filaments that form by polymerization of tubulin dimers. Here we determine the concentration profile of tubulin dimers by combining electron with light microsocopy data.

Tomographic electron microsocopy is able to identify microtubules in the spindle, but cannot resolve the tubulin dimers. Therefore it provides a quantitative measure of the local concentration of tubulin within microtubules. Light microscopy data with a GFP staining of tubulin provide a relative measure of the total tubulin concentration, since both polymerized and dimeric tubulin, are stained. We calibrate the light microscopy signal using the electron microscopy data. From this quantitative analysis we determine a local enrichment of the dimeric tubulin at the centrosome. Our results suggest that the centrosome accumulates tubulin dimers which have a high affinity to the pericentriolar material and thereby facilitate localized microtubule nucleation.

BP 9.14 Mon 17:30 P3

Dynamics of single human cardiomyocytes tracked by endogenous labeling of z-lines using CRISPR/Cas9 — •Daniel Härtter[1], Til Driehorst[1,2], Malte Tiburcy[2], Kengo Nishi[1], Wolfram-H. Zimmermann[2], and Christoph F. Schmidt[1] — [1]Georg-August Universität Göttingen, Germany — [2]University Medical Center Göttingen, Germany

The dynamics of single cardiomyocytes (CM) may provide insight into cardiac function and dysfunction. The CMs' regulated and coordinated sarcomeric contractility is, however, not fully understood.

We here present a new method using endogenous labeling of the z-lines in living human stem cell-derived CMs using CRISPR/Cas9. We applied methods of micro-contact printing to shape the cells to physiological aspect ratios. Using high-speed confocal microscopy, we imaged the contractile dynamics of individual sarcomeres with high spatial and temporal resolution. We developed a method to track z-lines over time and to analyze their dynamics. We utilize approaches from nonlinear dynamic systems theory to study phase-coherence and synchronization. We could show that the phase coherence of sarcomeres strongly depends on the elastic properties of the underlying substrate. We further investigated the effects of drug interference on the sarcomeric level.

BP 9.15 Mon 17:30 P3

E-Cadherin Expression and Localization is Correlated to Cellular Softness in Cancer Development — •Erik Morawetz[1], Lars-Christian Horn[2], Susanne Briest[3], Michael Höckel[3], and Josef Käs[1] — [1]Physik der weichen Materie, University of Leipzig, Leipzig, Germany — [2]Institut für Pathologie, Universitätklinikum Leipzig, Leipzig, Germany — [3]Klinik und Poliklinik für Frauenheilkunde, Universitätklinikum Leipzig, Leipzig, Germany

The concept of the epithelial to mesenchymal transition is believed to play a crucial role in cancer development. One of its main markers is the loss of epithelial cadherin (E-Cad). The malignant transformation of cells is also linked to increased softness of the cell body. To investigate correlations between this two fundamental cellular changes, we use cell lines, as well as primary human tumor samples. In the Optical Stretcher (OS), the softness of a single cell, its reaction to the deformation, as well as the corresponding distribution of E-Cad on the cell surface can be measured simultaneously. In the cell line model we show, that the loss of E-Cad expression is linked to softer cell bodies (MDA-MB 231, MDA-M 436, MCF-10A). In addition, EMT has been induced in MCF-10A cells by cultivation under the influence of epithelial growth factor. A significant drop in the elastic modulus as well in the reaction to external forces can be observed. Primary human mamma and cervix carcinoma samples are provided by the Universitätsklinik Leipzig. The tumor samples are processed into a single cell suspension and measured in the OS. We show that a primary tumor sample can be sorted into two sub-populations of soft and stiff cells by their E-Cad level.

BP 9.16 Mon 17:30 P3

Myosin Activity in Epithelial and Mesenchymal Cells — •Enrico Warmt, Erik Morawetz, Steffen Grosser, and Josef Käs — Uni Leipzig, Soft Matter Physics, Linnéstr. 5, 04103 Leipzig

Epithelial-Mesenchymal-Transition is a critical process during cancer development. Epithelial cells are tightly junked by a complex of interlinked actin, E-cadherin and other cytoskeletal proteins. During EMT, cells decrease their E-Cadherin expression. Additionally a prestressed acto-myosin cortex is also hindering cells to migrate freely. Thus, during EMT cells might further form back their acto-myosin cortex. In Optical Stretcher experiments, we observe an active contraction of epithelial cells. That means, despite optical pulling forces cells counteract these forces, leading to cell shrinkage. These internal forces might be closely related to actin-myosin contraction, since we observe a clear loss of this contractility by inhibiting myosin activity for instance by Blebbistatin. By adding epidermal growth factor, we could induce EMT for MCF10A cells. An E-Cadherin stain was further used to determine wether cells are more epithelial- or mesenchymal like. We could directly correlate a higher contractility for cell which have more E-Cadherins expressed. These findings support strongly a down regulation of actin-myosin activity during EMT.