BP 31: Cell Mechanics III

Time: Friday 10:00–12:00 Location: BAR 0106

BP 31.1 Fri 10:00 BAR 0106

Viscoelastic properties of cells under influence of drugs — •Henrik Siboni[1,2], Ivana Ruseska[1], Leonhard Grill[2], and Andreas Zimmer[1] — [1]Pharmaceutical Technology & Biopharmacy, University of Graz, Austria — [2]Single Molecule Chemistry, University of Graz, Austria

Nanoscale Drug Delivery Systems are an increasingly popular type of pharmaceutical treatment with the recent vaccines against COVID-19 being prime example. Here, we present out latest results in characterising preadipocyte cells when treated with protamine-miRNA nanoparticles. We employ Atomic Force Microscopy to perform force-indentation experiments in order to spatially resolve the elastic properties before and after drug treatment. Going further, we use force clamping and creep-relaxation in order to map the viscous properties as well. We then discuss the potential conclusions that can be drawn from this study and the pharmaceutical implications.

BP 31.2 Fri 10:15 BAR 0106

A mechano-osmotic feedback couples cell volume to the rate of cell deformation — Larisa Venkova[1,2], •Amit Singh Vishen[3], Sergio Lembo[4], Nishit Srivastava[1,2], Baptiste Duchamp[1,2], Artur Ruppel[5], Alice Williart[1,2], Stéphane Vassilopoulos[6], Alexandre Deslys[1,2], J. M. Garcia Arcos[1,2], Alba Diz-Muñoz[4], Martial Balland[5], J.-F. Joanny[3], Damien Cuvelier[1,2,6], Pierre Sens[3], and Matthieu Piel[1,2] — [1]Institut Curie, PSL, CNRS, UMR 144, Paris, France — [2]IPGG, PSL Research University, Paris, France — [3]Institut Curie, PSL, CNRS, UMR 168, Paris, France — [4]Cell Biology and Biophysics Unit, EMBL, Heidelberg, Germany — [5]Laboratoire Interdisciplinaire de Physique, Grenoble, France — [6]Sorbonne Université, Paris, France

Mechanics has been a central focus of physical biology in the past decade. In comparison, how cells manage their size is less understood. Here, we show that a parameter central to both the physics and the physiology of the cell, its volume, depends on a mechano-osmotic coupling. We found that cells change their volume depending on the rate at which they change shape, when they spontaneously spread or when they are externally deformed. Cells undergo slow deformation at constant volume, while fast deformation leads to volume loss. We propose a mechanosensitive pump and leak model to explain this phenomenon. This mechano-osmotic coupling defines a membrane tension homeostasis module constantly at work in cells, causing volume fluctuations associated with fast cell shape changes, with potential consequences on cellular physiology.

BP 31.3 Fri 10:30 BAR 0106

Viscoelastic characterization of biological cells in hyperbolic microfluidic channels — •Felix Reichel[1,2] and Jochen Guck[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Max-Planck-Zentrum für Physik und Medizin, Erlangen, Germany

Research over the last decades revealed that single-cell mechanical properties can serve as label-free markers of cell state and function and that mechanical changes are a sign of alterations in the cell's molecular composition. This led to the development of a number of microfluidics tools to rapidly measure the deformability and also the viscoelastic properties of cells. The quantification of the stresses, that cause the deformation of the cells in these channels, is often challenging and with that the derivation of a stress-strain relation for such a system becomes complex. Here, we used hyperbolic channels to create an extensional flow field where the acting stresses can be measured using calibration particles and yield a simple relationship between acting stress and resulting cell strain. We then used the setup to measure the Young's modulus and bulk viscosity of HL60 cells and blood cells over a wide range of time scales. Drug induced changes to the cell state could be measured by a change in cell mechanical properties. Our simple setup offers a straightforward measurement of the viscoelastic properties of cells and microscale soft particles.

BP 31.4 Fri 10:45 BAR 0106

Pancreatic cancer metastasis: mechanics and adhesion — •Shruti G. Kulkarni[1], Malgorzata Lekka[2], and Manfred Radmacher[1] — [1]Institute of Biophysics, University of Bremen, Otto-Hahn Allee 1, 28359 Bremen, Germany — [2]Institute of Nuclear Physics PAN, Radzikowskiego 152 , 31-342 Krakow, Poland

We use Atomic Force Microscopy (AFM) to characterise the mechanical properties of Pancreatic ductal adenocarcinoma (PDAC) cell lines from the primary tumour site (PANC1), and from liver (CFPAC1) and lymph node (Hs766T) metastases. AFM measures forces using the optical lever system. To measure their stiffness, cells were probed using a rectangular cantilever with a three-sided pyramidal tip. Apparent Young's modulus (E) and power-law exponent (α) can be calculated from the force curves. To probe the adhesive properties of the cells, a single cell was attached to functionalised triangular tipless cantilevers, and then pressed against a confluent layer of cells. When the cell-cantilever is retracted, the contact of the attached cell with the cell layer is broken. The detachment exerts force on the cantilever, and this signal is also recorded by and characterised from the retract curve. The adhesion of cancer cells was measured with self-cells (the same cell line) as well as with endothelial cells (EA.hy926). CFPAC1 cells soften in confluent layers, and have increased cell-cell interaction with endothelial cells as compared to self-cells. Hs766t have similar stiffness as both single cells and as a confluent layer, and have higher cell-cell interaction with self-cells than with endothelial cells.

15 min. break

BP 31.5 Fri 11:15 BAR 0106

Dynamics of confined cell migration in 3D micro-dumbbells — •Stefan Stöberl[1], Johannes Flommersfeld[2], Maximilian M. Kreft[1], Chase P. Broedersz[2], and Joachim O. Rädler[1] — [1]Faculty of Physics and Center for NanoScience, Ludwig-Maximilians-University, Munich, Germany — [2]Department of Physics and Astronomy, Vrije Universiteit Amsterdam, 1081 HV Amsterdam, The Netherlands

Cell migration plays a key role in physiological processes such as wound healing, cancer metastasis and immune response. In previous work we have studied the non-linear dynamics of single cells migrating between two surface-patterned adhesion sites guided by a bridging line. Here, we study the dynamics of MDA-MB-231 cells captured in three dimensional (3D) dumbbell-like micro cavities. The structures formed by photolithography of PEG-Norbornene hydrogels provide a soft and hence deformable frame, while cells attach and migrate on a fibronectin-coated bottom. We find that the dwell time of cells before transitioning is retarded when the width of the dumbbell constriction is narrowed below 10 um. In this limit, deformation of the nucleus determines the time course of the repeated stochastic transitions. We measure the forces exerted by the nucleus parallel and perpendicular to the dumbbell channel walls using the displacement field of beads embedded near the 3D constriction. At the same time, the nuclear deformation is followed by confocal 4D imaging revealing an elongation and temporary decrease in nuclear volume during migration through confinement.

BP 31.6 Fri 11:30 BAR 0106

Geometry sensing by active flows: how the cell cortex can feel its shape — •Jonas Neipel and Frank Jülicher — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Morphogenesis often involves chemical patterns, e.g. defined by the concentration of signalling molecules, that specify the shape of a cell or tissue. The robustness of such processes with respect to perturbations can be enhanced by feedbacks where the generated shape impacts back on the formation of the chemical pattern. Here, we show that such shape sensing can result from the same forces that drive shape changes. We consider sheets of active matter, such as the cell cortex or a developing tissue layer, that behave as active fluid surfaces on long time scales. In these systems, forces drive flows within the surface that inevitably depend on the surface geometry of the surface. When molecules are advected by this flow, a pattern arises, reflecting the symmetries of the geometry. In particular, we show that viscous shear forces result in an effective friction force being proportional to the Gaussian curvature, such that patches of contractile stresses are advected towards regions of minimal Gaussian curvature. On a surface with spherical topology but elongated shape, this implies that a contractile ring such as the cytokinetic ring aligns perpendicularly to the long axis of the surface. Hence, the actomyosin cortex can drive align-

ment of the division axis with the long axis of the cell by a rotation of the entire cell, consistent with recent experiments.

BP 31.7 Fri 11:45 BAR 0106

Large area automated structural and mechanical analysis of developing cells and tissues — •Joerg Barner, Tanja Neumann, André Körnig, Dimitar R. Stamov, and Heiko Haschke — JPK BioAFM Business, Bruker Nano GmbH, Am Studio 2D, 12489 Berlin, Germany

Active forces in biological systems define the interactions between single molecules, growing cells and developing tissues. Atomic force microscopy (AFM) can be successfully applied for comprehensive nanomechanical characterization of such samples under near physiological conditions. Currently, the trend is to extend this by studying the mechanobiology of living cells while evaluating their structure and the interaction with their cell culture substrates.

We will demonstrate how cell spreading and migration in living KPG-7 fibroblasts and CHO cells, can be studied with high-speed AFM and associated with spatially resolved cytoskeletal reorganization events. We will further extend this with high-speed mechanical mapping of confluent cell layers, which in combination with optical tiling can be applied to automated analysis of large sample areas. As a tool for analyzing the complex cellular mechanobiology, we went beyond purely elastic models, and performed sine oscillations (up to 500 Hz, amplitude 5-60 nm) in Z while in contact with the surface to probe the frequency-dependent response of living fibroblasts.