BP 28: Poster Session II

Time: Thursday 18:00–20:00 Location: P2/EG

BP 28.1 Thu 18:00 P2/EG

X-Ray Phase-Contrast Tomography Imaging of Single Cells Using an Optical Stretcher — •Jan-Philipp Burchert[1], Roland Stange[2], Madleen Busse[3], Tim Salditt[1], and Sarah Köster[1] — [1]Institute for X-Ray Physics, University of Göttingen — [2]RS Zelltechnik GmbH, Schöllnach — [3]Department of Physics and Munich School of Biomedical Engineering, Technical University of Munich

X-rays penetrate deep into matter and allow us to image structures with high spatial resolution, which makes them attractive for investigating individual biological cells. Here, we combine x-ray phase-contrast tomography with an x-ray compatible optical stretcher to image single cells in solution, thus in their physiological environment, and avoid the need for freezing, drying or embedding of the samples. The cells are trapped in a contact-free manner in a fixed position by the optical stretcher and are probed by the x-ray beam. The microfluidic flow sets the cells in slow rotational motion, which enables tomographic imaging. We apply this combination of techniques to unfixed and fixed NIH3T3 fibroblasts, which are partially stained with an x-ray contrast agent. The experimental data show that we can acquire images of these cells with our setup. Moreover, the comparison of the different preparations and two beam energies will improve the image quality in future experiments.

BP 28.2 Thu 18:00 P2/EG

Scanning small angle x-ray scattering of hydrated, keratin-rich cells in flow environment — •Boram Yu[1], Sophie-Charlotte August[1], Peter Luley[1], Manfred Burgerhammer[2], and Sarah Köster[1] — [1]Institute for X-Ray Physics, University of Göttingen, Germany — [2]European Synchrotron Radiation Facility (ESRF), Grenoble, France

Intermediate filaments (IFs), one of the three main components of the cytoskeleton, form a network that contributes to cell mechanics. Thus, collecting structural information about IF networks in their physiological setting, i.e., in whole living cells, is crucial. We study mammalian cells expressing cytokeratin, which forms bundle structures. To obtain this information, we use scanning small angle x-ray scattering (SAXS), as it provides both real space overview images with moderate resolution and reciprocal space information with a high resolution. X-ray imaging of cells in aqueous state is challenging as their electron density contrast is low, and pronounced radiation damage and radiation-induced gas formation occurs. For this reason, we used a dedicated flow sample chamber that minimizes the thickness of liquid layer in the beam path and serves to exchange liquid continuously during scanning. Despite weak contrast and short exposure times, we are able to retrieve the local main orientation of subcellular structures, thus demonstrating how scanning SAXS offers valuable information from fixed-hydrated cells in liquid flow.

BP 28.3 Thu 18:00 P2/EG

Comparative investigation of differently prepared porcine retinal pigment ephitelium (RPE) cells using mid-IR photo-induced force microscopy (PiF-IR) — •Jesvin Joseph[1,2], Robin Schneider[1], Rowena Simon[3], and Daniela Täuber[1,2,4] — [1]Heintzmann Lab, Leibniz Institute of Photonic Technology, Jena — [2]Institute of Physical Chemistry & Abbe Center of Photonics, Friedrich-Schiller-University Jena — [3]Department of Ophthalmology, University Hospital Jena — [4]Institute of Solid State Physics, Friedrich Schiller University Jena, Germany

Age-related loss of sight caused by macular degeneration (AMD) is monitored in clinical health care using fundus autofluorescence, which investigates variations in the autofluorescence signal stemming from the retinal pigment epithelium (RPE)[1]. Nanolocal chemical characterization of RPE cells and pigment granules could deepen the understanding of involved cellular processes. Nano-infrared imaging methods can provide chemical information at a lateral resolution below 10 nm[2]. We used PiF-IR to investigate externally grown porcine RPE cells, which were dried in varied conditions. First results show spectral variations obtained from cells dried at room temperature and at 37°C. We compare these spectra to PiF-IR and conventional FTIR spectra obtained from plain retinal pigment chemicals. Funding by Profil Line Light, project pintXsum, FSU Jena, is acknowledged. [1] Schultz, R., Schwanengel, L., Klemm, M., Meller, D. & Hammer, M. Acta Ophthalmologica (2021). [2] Luo, X. Xue, Y.; Wu, J.; Cai, W.; Täuber, et al. Applied Physics Letters DOI: 10.1063/5.0128850.

BP 28.4 Thu 18:00 P2/EG

Redirecting the early embryogenesis of *Caenorhabditis elegans* by altering mechanical cues — •Vincent Borne and Matthias Weiss — Experimental Physics I, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

During early development, somatic and germline precursor cells of the model organism *Caenorhabditis elegans* undergo an apparently predetermined and robust division scheme, suggesting early embryogenesis to run on autopilot. While the role of biochemical signaling in embryogenesis has long been recognized, the influence of mechanical forces for proper cell arrangement has been revealed only recently. Aiming at challenging the robustness of the organismal development mechanically, we have flattened the embryo to induce altered positioning and division timing of cells. Indeed, upon a controlled squeezing between two coverslips, the outer boundary of the embryo remained intact but cytokinesis was seen to be compromised, i.e. normal development came to a full stop. Surprisingly, nuclei still underwent division, resulting in multinucleated cells or even a syncytium-like state with up to 60 nuclei. In this state, we have monitored the growth of nuclei and their division timing. Despite the total failure of cell division, both observables are in line with experimental data and theoretical descriptions obtained from unperturbed embryos. Our results highlight how some key features for correct embryonic development prevail even under mechanically stressful conditions.

BP 28.5 Thu 18:00 P2/EG

Microfluidics-based analysis of the mobility and migration pattern of *Trypanosoma brucei* — •Hannes Wunderlich[1], Lucas Brehm[2], Jana Ritschar[2], Sebastian Krauss[1], Klaus Ersfeld[2], and Matthias Weiss[1] — [1]Experimental Physics I, University of Bayreuth, Germany — [2]Molecular Parasitology, University of Bayreuth, Germany

Trypanosoma brucei is a unicellular parasite that causes the African sleeping sickness after entering the human bloodstream via the bite of an infected tsetse fly. Active spiral movement of trypanosomes, mediated by the beating of a microtubule-driven cell-body attached flagellum, is crucial to evade the hosts immune response, i.e. swimming is a matter of survival for trypanosomes. Beyond the flagellum, microtubules also form a highly ordered, subpellicular array beneath the cell membrane, hence determining the effective elasticity of the parasite and its propulsion via the flagellum. Using soft lithography to produce well-defined two-dimensional chambers and using a temperature controlled environment, we have optimized cell tracking, shape determination, and subsequent analyses. As a result, we find that wild-type and mutant strains with altered post-translational modifications of microtubules not only feature different phenotypes but also show distinct mobility patterns, e.g. a strain-dependent swimming velocitiy and intermittency of swimming (run-and-tumble phases).

BP 28.6 Thu 18:00 P2/EG

2D polarization fluorescence imaging (2DPOLIM) - Evaluation of depolarization artifacts in fixed four channel detection — •Yunhao Mei[1,2], Asad Hafeez[1,2], Yutong Wang[1,2], Mohammad Soltaninezhad[1,2], Rainer Heintzmann[1,2], and Daniela Täuber[1,2] — [1]Heintzmann Lab, Leibniz Institute of Photonic Technology, Jena — [2]Institute of Physical Chemistry & Abbe Center of Photonics, Friedrich-Schiller-University Jena, Germany

Fluorescence polarization and anisotropy measurements are widely used in Diagnostics and Imaging in the Life Sciences. Most common is the use of linearly polarized excitation together with two-channel detection of linear polarization parallel and perpendicular to the polarization in excitation. However, when applied to anisotropic samples, the result may depend on the lab frame in respect to structural alignments within the sample, which can be preventend by collecting the sample fluorescence in more polarization angles[1]. We designed a four-channel detection for evaluating Förster Resonance Energy Transfer between similar fluorescence labels, the so-called homo-FRET or em-FRET. The quantitative discrimination of FRET via tiny changes in polarization resolved fluorescence intensities requires highly sensitive

cameras and well-designed and calibrated detection channels. Wire grids provide high-quality polarization properties when used in normal incidence in transmission but may introduce depolarization when implemented tilted in respect to the optical axis. We studied several possible arrangements and compared the introduced depolarizations. [1] R. Camacho et al. Adv. Mater. 2019, 1805671.

BP 28.7 Thu 18:00 P2/EG

Monitoring actomyosin flows in early Caenorhabditis elegans embryos by lightsheet microscopy — •Ivana Jeremic and Matthias Weiss — University of Bayreuth, Bayreuth, Germany

Symmetry breaking, i.e. the formation of body axes, is crucial for embryonic development as it guides the formation of highly organized tissues and consequently assures proper maturation of the organism. A convenient model system for studying such events is Caenorhabditis elegans since all body axes are fully defined already in the 8-cell stage of the embryo. Confocal fluorescence imaging on C. elegans has revealed that chiral mechanical forces, generated by the actomyosin cortex, play an important role in the left-right symmetry breaking. Confocal imaging, however, requires a gentle flattening of the embryo to allow for a full three-dimensional assessment of the embryo. Yet, even a gentle squeezing of the embryo can already delay cell divisions and subsequently lead to altered cell positions, suggesting that also the symmetry-breaking action of the actomyosin cortex can be affected. Using a custom-made lightsheet microscope that does not require any squeezing of the embryo, we have monitored actomyosin flows in the early embryo in three dimensions over time. Preliminary data from these experiments suggest that the previously observed chiral forces are even enhanced under these unconfined conditions.

BP 28.8 Thu 18:00 P2/EG

Organelle organization and dynamics in cells on soft substrates — •Paula Girones Paya, Florian Rehfeldt, and Matthias Weiss — Experimental Physics I, University of Bayreuth, Germany

The interior of eukaryotic cells features a highly organized and dynamically evolving set of compartments (organelles), e.g. mitochondria, the endoplasmic reticulum, or the nucleus. How these organelles self-organize to arrive at an arrangement that is beneficial for a cell is still poorly understood. Numerous studies have monitored organelle morphologies and dynamics in well-characterized culture cells grown on rigid substrates, e.g. glass coverslips. In real life, however, cells are situated in soft tissues with an elastic modulus that is five to six orders of magnitude lower. On soft substrates, actin-based stress fibers are less pronounced, and consequently cell morphologies are considerably less flattened by tensile forces, suggesting that also organelle arrangement and dynamics is altered. Here, we compare results of mitochondrial dynamics, cell nucleus volumes, and the exchange kinetics for diffusively driven transport between the nucleoplasm and the cytoplasm of cells on soft and rigid substrates.

BP 28.9 Thu 18:00 P2/EG

Quantifying Molecular Mobility, Abundance and Interactions by Fluorescence Correlation Spectroscopy — •Jana Sütterlin[1], Katharina Reglinski[1,2,3], Francisco Páez Larios[1,2], and Christian Eggeling[1,2] — [1]Institut für angewandte Optik und Biophysik, Friedrich-Schiller Universität Jena, Jena, Deutschland — [2]Leibnitz-Institut für photonische Technologien e.V., Jena, Deutschland — [3]Universitätsklinikung Jena, Jena, Deutschland

Since many biological functions rely on molecular interactions, knowledge about molecular mobility and diffusional processes are key to understand cellular signalling. To gain the desired insights, it is of utmost importance to develop and apply live-cell compatible approaches for diffusional investigations. Fluorescence Correlation Spectroscopy (FCS) is a powerful technique that enables the quantification of these dynamics.

This poster will provide an outline on how to utilise parameters acquired from FCS and dual-colour Fluorescence Cross-Correlation Spectroscopy (DC-FCCS) to quantify diffusion characteristics of particles in aqueous environments. This way, an examination of diffusional behaviour influenced by various binding conditions can be carried out.

FCS study about the peroxisomal import receptor PEX5 in live HEK cells is shown to elucidate its molecular interaction dynamics within the cytosol. Thereby the potential of FCS is exploited, highlighting its non-invasive, live-cell compatible properties. Ensuring proper function of organelles and cells, PEX5 transports cargo proteins featuring a targeting sequence, which need to be imported into peroxisomes.

BP 28.10 Thu 18:00 P2/EG

Evolution of the crowded state of cells as seen by FRET — •Avijit Kundu and Mattias Weiss — Experimentalphysik I, Universität Bayreuth, Universitätsstraße 30 95447 Bayreuth

Cells are the basic units of all living organisms. Somewhat surprisingly, however, virtually all cells feature very similar and high degrees of macromolecular crowding, with total concentrations of more than 100 mg/ml, irrespective of the species from which the cell is taken. Macromolecular crowding plays a key role in many biophysical processes and it can even alter biochemical cues by changing the binding kinetics or the steady-state frunction of associated states, suggesting that cells need to actively maintain their crowding state. Using a FRET sensor that reports on the local crowdedness in living cells, we have explored how individual cells can re-adapt their crowding state after a perturbation. Using a stepwise change of the osmotic pressure, we find that cells react rapidly to the external perturbation but aim at a relaxation back to the native state over time scales of minutes to hours.

BP 28.11 Thu 18:00 P2/EG

3D light-sheet microscopy of contracting skeletal muscle tissue — •Laura Strampe, Arne Hofemeier, Paul Maier, Jan Huisken, and Timo Betz — Third Institute of Physics - Biophysics, Georg August Universität, Göttingen

Skeletal muscle makes up the majority of human muscle tissue. Its contraction allows for controlled movements of the body, as well as being essential for maintaining posture. To understand the global and local forces at play during such contractions, occurring on the time scale of seconds, a 3D high-speed, high-resolution imaging method is necessary. We present a protocol for raising biomimetic muscle tissue anchored between two flexible mm-sized post. A full contraction cycle can be recorded through the synchronization of periodic electric stimuli and image acquisition using a custom build Flamingo light-sheet microscope. This enables us to study a wide range of questions including the influence of local contractile forces on muscle stem cell activation and contractile sarcomere dynamics.

BP 28.12 Thu 18:00 P2/EG

Screening for Pharmacologically Enhanced Tissues for Optical Microscopy. — •Venkat Raghavan Krishnaswamy, Susan Wagner, Rico Barsacchi, and Moritz Kreysing — Max Planck Institute of Molecular Cell Biology and Genetics. Dresden. Germany.

Our ability to observe the complexity of a living tissue under a light microscope is heavily impeded by the inherent light-scattering properties of the biological tissues. But remarkably some living tissues are highly transparent in nature, e.g., human retina, certain deep-sea creatures, etc. Comprehending and replicating the mechanisms by which tissue transparency is attained would unleash the full capabilities of optical microscopes. Here, we propose to unravel the molecular basis of tissue transparency in three-dimensional tissues using the immense potential of high-throughput screening and large-content image analysis tools. Specifically, we used active pharmacological compounds to screen for pathways that impact light-scattering properties in spheroids of human colorectal carcinoma cell line (HCT116). Randomly integrated multi-fluorescent beads within the spheroids served as an extrinsic readout factor and a conventional chemical-based clearing method was used as a positive control for assessing the optical properties of the tissue. The image analysis pipeline constructed to measure the intensities of the beads through the Z-sections clearly distinguishes cleared from uncleared spheroids. Overall, a robust assay was developed which would be employed on larger screens, to rapidly identify compounds and, further, signaling pathways that regulate the molecular mechanisms of tissue transparency.

BP 28.13 Thu 18:00 P2/EG

Imaging of vital mitochondria using Scanning Ion Conductance Microscopy (SICM) and electron microscopy methods — •Eric Lieberwirth[1], Christian Völkner[1], Regina Lange[1], Anja Schaeper[2], Magdalena Otte[2], Marcus Frank[3], Kevin Oldenburg[4], Ingo Barke[1], Simone Baltrusch[2], and Sylvia Speller[1] — [1]University of Rostock, Institute of Physics — [2]Rostock University Medical Center, Institute for Medical Biochemistry and Molecular Biology — [3]Rostock University Medical Center, Medical Biology and Electron Microscopy Center — [4]University of Rostock, Center for Interdisciplinary Electron Microscopy MV

Mitochondria are enclosed by a double membrane. While the inner

membrane with many insertions creates a large surface for the respiratory chain complexes, the outer one mediates fusion, fission and degradation of the organelles in the network. In this process, pole-like interaction sites develop, which impact the surface of the outer membrane. Scanning Ion Conductance Microscopy (SICM) allows the outer membrane of immobilized vital mitochondria to be measured in a buffer solution with a spatial resolution of about 50 nm and a height resolution of a few nanometers. The outer membrane shows dynamic height fluctuations as well as spatial height variations depending on the medium. Transmembrane proteins can be made visible when labelled with nanoscopic gold particles. A complementary study of SICM topographies, Scanning Electron Microscopy (SEM) and in situ liquid Transmission Electron Microscopy (TEM) images gives insight into the spatial distribution of internal and membrane-bound structures.

BP 28.14 Thu 18:00 P2/EG

Imaging Soft-Landed DNA-Aggregates — •Isabelle Legge, Jovana Pepic, Tim Esser, Márkó Grabarics, and Stephan Rauschenbach — Department of Chemistry, University of Oxford, Oxford, United Kingdom

Deoxyribose nucleic acid (DNA) is involved in important biological processes including replication, encoding information and gene expression. The helical structure of DNA double strands is well known but the superstructure of more complex assemblies such as DNA origami can be challenging to characterise by averaging techniques. Therefore, a versatile, yet practical, sample preparation technique is needed to make DNA-based molecules accessible to high-resolution, single-molecule imaging by atomic force microscopy (AFM) or transmission electron microscopy (TEM). Here, we use electrospray ion-beam deposition (ESIBD) to produce clean samples of single- and double-stranded DNA or DNA origami to enable AFM and TEM imaging, providing information on structure, conformation and revealing the mechanical properties. We discuss the advantages and limitations of this approach to improve the understanding of the function of these molecules.

BP 28.15 Thu 18:00 P2/EG

A backward-mode optical-resolution photoacoustic microscope for functional 3D imaging — •Elisabeth Baumann[1,2], Ulrike Pohle[3], Thomas Allen[4], Holger Gerhardt[1,2], and Jan Laufer[3] — [1]MDC, Berlin, DE — [2]Charite, Berlin, DE — [3]MLU, Halle, DE — [4]UCL, London, UK

Optical-resolution photoacoustic microscopy (OR-PAM) is a biomedical imaging technique with great potential for preclinical studies of the vasculature. It can be used to obtain spatially resolved information on parameters like the blood flow speed and blood oxygen saturation. However, for many in vivo applications, backward-mode operation of the OR-PAM system is required for which conventional piezoelectric ultrasound sensors are at a disadvantage as they need to be placed far away from the signal source. Here, we present an all-optical, backward-mode OR-PAM system that fulfils the requirements for functional imaging of the vasculature. The system incorporates a novel planar Fabry-Pérot (FP) ultrasound sensor, which is transparent to the excitation light and can be placed immediately adjacent to the sample.

To demonstrate the morphological imaging capabilities of the system, we performed 3D imaging in vitro of a leaf skeleton phantom and in vivo of a zebrafish embryo in raster-scanning mode. To be able to resolve blood flow, a fast continuous-scanning mode was established and validated in imaging phantoms. To show the capabilities of the system to image blood oxygen saturation, a Raman laser was set up for multi-wavelength excitation OR-PAM of ink phantoms.

BP 28.16 Thu 18:00 P2/EG

Imaging Symmetry-Dependent Behavior of Orbital Angular Momentum Entangled States — •Juan Nicolas Claro Rodriguez[1,2] and Roberto Ramirez Alarcon[1] — [1]Centro de Investigaciones en Óptica, 37150 León-Guanajuato, México — [2]Paderborn University, 33098 Germany

Orbital angular momentum (OAM) is a degree of freedom of photons, promising for many high-dimensional quantum applications. By tuning the symmetry of OAM states using dove prisms and measuring spatially resolved interference properties, we find that fringes are produced depending on the type of the state symmetry and propose an application to achieve twice the contrast in quantum optical coherence tomography. This technique also permits high-resolution microscopy of photo-sensitive tissue.

BP 28.17 Thu 18:00 P2/EG

Quantitative imaging of Caenorhabditis elegans dauer larvae during cryptobiotic transition — •Kyoohyun Kim[1], Vamshidhar R. Gade[2,3], Teymuras V. Kurzchalia[2], and Jochen Guck[1] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany — [3]Institute of Biochemistry, ETH Zürich, Zürich, Switzerland

Caenorhabditis elegans can survive harsh environments by entering dauer diapause with reduced metabolic activity and distinct structural changes. We employed optical diffraction tomography (ODT) to quantitatively measure the transitions of mass density distribution inside living C. elegans larvae in the reproductive and diapause stages. ODT revealed that the mass density of C. elegans larvae increased upon entry into dauer diapause, and surprisingly, the harshly desiccated dauer larvae exhibited very high refractive index values (n ~ 1.5). Moreover, mutants that are sensitive to desiccation displayed structural abnormalities in the anhydrobiotic state that were not observable by conventional microscopy. Our findings open a door to quantitatively understanding the importance of material properties of an organism on the verge of life and death.

BP 28.18 Thu 18:00 P2/EG

Shaping the embyo: blastoderm stress maps reveal early mechanical symmetry breaking — •Alejandro Jurado Jiménez, Leon Lettermann, Bernhard Wallmeyer, and Timo Betz — Drittes Physikalisches Institut, Georg-August-Universität Göttingen

In this work we present a hydrodynamical analysis of early Zebrafish development which aims to understand the mechanical state of the tissue leading to its first symmetry breaking during epiboly: the shield formation. A full mechanical characterization of the blastoderm is achieved using a combination of Light-Sheet microscopy and state-of-the-art cell tracking of the cells nuclei, viscosity measurements and polyacrylamide beads as force sensors. The extraction of stress maps in the tissue is possible thanks to a custom-made software for the analysis of the bead deformation, which is presented here a versatile tool for similar stress analyses in other biological samples.

Our experimental analysis of the mechanical state of the embryo is supported and expanded by a model-driven extraction of the stress fields using NeuronalODEs. The NODEs system only necessitates the velocity field on the blastoderm to solve the hydrodynamic problem, optimizing up to 10^5 parameters and retrieving a full dynamical description of the embryo. Both the experimental and numerical analyses expose a stress asymmetry prior and during the shield formation, from which we can learn more about the mechanical origin of the first embryonal symmetry breaking.

BP 28.19 Thu 18:00 P2/EG

Radial growth and the impact of stress on the cell division plane in the hypocotyl — •Mathias Höfler and Karen Alim — School of Natural Sciences, Technical University of Munich, Germany

The morphogenesis of plant tissue is a reliably stable and efficient process, yet individual cell shape and growth underlie high variance. Theory and experiment show that there is a mechanical and biochemical feedback loop for plant tissue development. In fact, mechanical stresses have a pronounced effect on microtubule orientation in the tissue, thereby changing the mechanical properties and leading to anisotropic cell growth. Here, we study the effect of cell mechanics, stress patterns and feedback mechanisms on the bidirectional radial growth of the plant hypocotyl. We furthermore study the connection between mechanical stresses and the choice of cell division plane orientation. We seek to unveil the minimal biophysical requirements and relevant forces to achieve the experimentally observed morphologies. Our results show that inhomogeneous growth generates distinct stress patterns in the tissue . Introducing cell division along the direction of maximum stress furthermore gives us a first perspective on how radial growth morphologies emerge.

BP 28.20 Thu 18:00 P2/EG

3D Traction Force Microscopy on engineered blood vessels — •Karim Ajmail, Fatemeh Mirzapour, and Karen Alim — School of Natural Sciences, Technical University of Munich, Germany

The endothelium lines the walls of every blood vessel the human body. By virtue of their strategic position the endothelium has to withstand a plethora of mechanical cues including shear stress, circumferential strain as well as pressure exerted by the blood flow. Therefore, the

mechanobiology of endothelial cells is a particularly pivotal part for the functionality of this tissue. However, the immense complexity of the vasculature necessitates in vitro systems that can uncouple and measure these various effects. Although in vitro approaches greatly enhanced our understanding of endothelial complexity, a mechanical characterization of endothelial systems is missing so far. Here, we employ 3D Traction Force Microscopy (TFM) as state-of-the-art method to measure cellular forces in physiologically relevant environments. In particular, we use 3D TFM to measure forces in a perfusable engineered blood vessel embedded in a fibrin hydrogel. Further, the effect of different stationary as well as pulsatile flow patterns on the mechanical response of the cells is investigated. We propose 3D TFM as an additional readout parameter in future human-on-a-chip applications for a quantitative mechanical characterization of the tissue.

BP 28.21 Thu 18:00 P2/EG

Tissue tension during zebrafish development — •Ming Hong Lui[1,2], Alejandro Jurado[1], Leon Lettermann[1,3], and Timo Betz[1,2] — [1]3rd Institute of Physics - Biophysics, University of Göttingen — [2]Max Planck School Matter to Life — [3]Institute for Theoretical Physics, Heidelberg University

Understanding the morphogenesis during development is one of the emerging fields where the interaction between developmental and tissue biology with biophysics has provided a series of new insights into nature's physical working principles. In particular, during embryonic development of zebrafish, cells in the blastoderm exhibit collective migration towards the yolk in a process known as epiboly, while simultaneously shield formation and gastrulation break symmetry preceding tissue differentiation. These elegantly robust processes are facilitated by both biochemical and mechanical interactions.

To determine how mechanical tissue stresses contribute to these interactions, we use photoablation to externally break symmetry by severing connections in the enveloping layer and record the subsequent population redistribution using light sheet microscopy of the whole embryonic volume. From the analysis of the nuclei trajectories, we noted that the epiboly process is highly robust and mostly unaffected by the damage, during which there is a convergent motion of cells towards an azimuthal angle (orthogonal to the direction of epiboly) that forms the future spine. Ablations can transiently disrupt this convergence dependent on the developmental time at which the damage is introduced.

BP 28.22 Thu 18:00 P2/EG

A 3D Voronoi vertex model for fluid transport in lumenogenesis — •Anne Materne[1], Charlie Duclut[1,2], Quentin Vagne[1,3,4], Pietro Incardona[3,5,6], Ivo F. Sbalzarini[3,5,7,8], and Frank Jülicher[1,3,8] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Laboratoire Physico-Chimie Curie, Paris, France — [3]Center for Systems Biology Dresden, Germany — [4]Department of Genetics and Evolution, Université de Genève, Switzerland — [5]Faculty of Computer Science, TU Dresden, Germany — [6]Institute for Genomic Statistics and Bioinformatics, Universität Bonn, Germany — [7]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany — [8]Cluster of Excellence Physics of Life, TU Dresden, Germany

In many systems, cells collectively organise to build complex structures. In particular, in certain developmental processes the formation of a fluid-filled cavity called a lumen plays a crucial role. Various mechanisms, for example programmed cell death, are known to initiate lumen formation. However, in order to sustain lumenogenesis, cells must collectively transport water and ions into the newly forming cavity. Here, we present a 3D Voronoi vertex model to study this collective transport process at cellular resolution. Our approach involves a substantial extension of the typical Voronoi work function minimisation procedures to account for the hydraulic and mechanical mechanisms in cell volume regulation and for pressure-driven flows. Fully-parallelised and efficient for systems with many cells, our procedure allows us to study the dynamics of lumenogenesis in complex geometries.

BP 28.23 Thu 18:00 P2/EG

Dystrophin as a tension regulator in human skeletal muscles — •Mariam Ristau[1], Arne Hofemeier[1,2], and Timo Betz[1] — [1]Third Institute of Physics - Biophysics, Georg-August-University Göttingen, Germany — [2]ZMBE - Institute of Cell Biology, University of Münster, Germany

Skeletal muscles are associated with contraction, movement and force generation. They are important for maintaining posture and maintaining bone and joint stability. Muscular dystrophies such as Duchenne muscular dystrophy (DMD) result in progressive weakening of skeletal muscles. DMD is caused by the loss of the protein dystrophin which is thought to stabilize and protect muscle fibers from injury. In the progression of the disease, damaged muscle fibers degrade, muscle mass is lost and greater functional impairments develop. We have studied the contractile potential of myoblasts and reconstituted tissue derived from healthy and DMD patients, and found that they were mechanically different in muscle tension and contractility. DMD derived myoblasts exhibited an overall weaker contractility compared to healthy derived myoblasts. In contrast, DMD derived myoblasts showed an overall higher muscle tension, suggesting that dystrophin may function as a tension regulator in skeletal muscles. In order to rule out the possibility that these findings are due to patient variability we intend to establish a genetic model in which we knockout dystrophin with the CRISPR/Cas9 system in healthy myoblasts and rescue dystrophin in DMD myoblasts by integrating micro-dystrophins(μDys).

BP 28.24 Thu 18:00 P2/EG

Influence of vimentin intermediate filaments on microtubules in cells — •Anna Blob[1], Roman David Ventzke[1,2], Thomas Giacomo Nies[2], Axel Munk[2], Laura Schaedel[3], and Sarah Köster[1] — [1]Institute for X-Ray Physics, University of Göttingen — [2]Institute for Mathematical Stochastics, University of Göttingen — [3]Center for Biophysics, Saarland University

The cytoskeleton in eucaryotic cells is an intricate network of three different filamentous proteins: microtubules, actin filaments and intermediate filaments. They are essential for the mechanical properties of a cell as well as intracellular transport and division. Each filament type has its own unique features, and, in particular, microtubules, can withstand large compressive forces and show characteristic buckling and bending behavior that is still not fully understood. There is evidence for important interactions between cytoskeletal filaments: vimentin intermediate filaments stabilize microtubules in vitro and can template the microtubule network in migrating cells. Following up on this idea, we are interested in the influence of vimentin networks on microtubule mechanics. Investigating how the bending of microtubules depends on both the microtubule network itself and the vimentin network will improve our understanding of the mechanical consequences of the interaction within and between these filament systems. We compare microtubule networks in vimentin-knockout and wildtype mouse fibroblasts on micropatterns. We find that the local curvature of microtubules depends on the cellular region and increases with both increasing microtubule density and increasing vimentin density.

BP 28.25 Thu 18:00 P2/EG

Interactions between synaptic vesicles and cytoskeletal filaments — •Tiago Mimoso, Tizian Schmidt, and Sarah Köster — Institute for X-Ray Physics, University of Göttingen, Germany

Signal transmission of neurons occurs both electrically and chemically. The chemical signal is transported by synaptic vesicles(SVs) from one cell to another via the synaptic cleft to the adjacent neuron. Thus, these SVs are found in the synapse, within the so-called synaptic bouton. Here, the SVs are surrounded by cytoskeletal filaments, including dynamic microtubules that undergo rapid assembly and disassembly. There are studies that suggest an interactions between SVs and the cytoskeletal filaments, however the exact mechanisms remain unknown. Therefore, we now ask the question of whether SVs and microtubules interact and what influence the presence of SVs has on the growth rate, disassembly rate, catastrophe frequency and rescue frequency of the microtubules. We employ a reconstituted *in vitro* system and image the dynamic microtubules by total internal reflection fluorescence (TIRF) microscopy. We use a novel and fast data analysis technique based on a neural network to segment the microtubules in the microscopy pictures. This method provides the advantage of being applicable also curved microtubules and yields results that are comparable to the commonly used manual analysis method.

BP 28.26 Thu 18:00 P2/EG

Burst Mode Characteristics of an Ultrasonic Transducer for Treatment of Cancer Cells — •Rebecca Kampmann[1], Birte Sehlmeyer[1], Claus Scheidemann[2], Tobias Hemsel[2], and Mathias Getzlaff[1] — [1]Institute of Applied Physics, Düsseldorf University — [2]Dynamics and Mechatronics, Paderborn University

Head and neck squamous cell carcinoma cells and oral keratinocytes have different cell mechanics and because of that they have different natural frequencies. This characteristic is used to selectively destroy

cancer cells.

For this purpose, ultrasonic waves at a resonant frequency of 90kHz were used in burst mode to achieve the largest possible deflection of the ultrasonic transducer. The ultrasonic actuators were electrically excited using a flexible ultrasonic generator developed by ATHENA Technologie Beratung GmbH, Paderborn. Investigation of the active current, which is proportional to the transducer tip velocity, showed that the active current depends on the set active time. If the active time is too low, the active current is not able to reach the desired target current. The longitudinal deflection of the ultrasonic probe in burst mode is comparable to the one in continuous mode. The set-point current amplitude and the active time are decisive parameters. In addition, the transverse deflection was investigated, showing that this vibration is larger than the longitudinal one.

BP 28.27 Thu 18:00 P2/EG

Burst Mode of Ultrasonic Resonant Oscillations for Stimulation and Destruction of Tumor Cells — •Birte Sehlmeyer[1], Rebecca Kampmann[1], Claus Scheidemann[2], Tobias Hemsel[2], and Mathias Getzlaff[1] — [1]Applied Physics, Düsseldorf University — [2]Dynamics and Mechatronics, Paderborn University

Different types of cancer, such as prostate carcinomas, are nowadays already treated with the ultrasound-based therapy HIFU (high intensity focused ultrasound). The healthy cells, which are located in the irradiation field, cannot be spared in this process. The elasticity differences between cancer cells and healthy cells strongly influence their stimulation frequency. LIPUS (low intensity pulsed ultrasound) is used to selectively stimulate and destroy cancer cells close to their own natural frequency, while sparing locally adjacent healthy cells.

Here we report new findings on the maximum oscillation amplitude of an ultrasound unit in burst mode. In burst mode, there is only a signal output during the active times.The ultrasonic actuators were electrically excited using a flexible ultrasonic generator developed by ATHENA Technologie Beratung GmbH, Paderborn. The excitation of the ultrasonic unit was varied by setting the targets current amplitude and the active time. Regarding the characteristic stimulation frequency of tumor cells, the frequency spectrum and frequency filters are discussed. In addition to the longitudinal deflection amplitude, an oscillation in the transverse direction was observed. Finally, the transverse oscillation behavior is investigated in relation to half-wave synthesis.

BP 28.28 Thu 18:00 P2/EG

Cytoskeletal Networks in Cells Under Strain — •Ruth Meyer[1], Anna V. Schepers[1], Peter Luley[1], Jonathan Bodenschatz[2], Amaury Perez Tirado[2], Andreas Janshoff[2], and Sarah Köster[1] — [1]Institute for X-Ray Physics, University of Göttingen — [2]Institute for Physical Chemistry, University of Göttingen

The cytoskeleton of eukaryotes consists of three types of filaments: F-actin, microtubules and intermediate filaments (IFs). In contrast to microtubules and actin filaments, IFs are expressed in a cell-type specific manner, and keratins are found in epithelial cells. In certain cell types, the keratin filaments form a layer close to the membrane which may be referred to as an "IF-cortex". Furthermore, it is hypothesized that this IF-cortex arranges with radial spokes in a "rim-and-spokes" structure in epithelia. Based on this hypothesis, IFs and actin filaments might add complementary mechanical properties to the cortex. It was previously shown that single IFs remain undamaged even at high strains. We now ask the question of whether this unique force-extension behavior of single IFs is also relevant in the filament network within a cell. We designed an equibiaxial stretcher that can apply high strains to the cells. This setup is combined with fluorescence and atomic force microscopy enabling simultaneously imaging of the cells and measuring their stiffness during stretching. By quantitatively analyzing the force indentation curves and the microscopy images, we analyze the structure and the mechanical properties of actin and IF networks close to the cell membrane.

BP 28.29 Thu 18:00 P2/EG

Exploring cell-cell interactions inferred from trajectories in two-site arrays — •Emily Brieger[1], Tom Brandstätter[2], Georg Ladurner[1], Chase P. Broedersz[2], and Joachim O. Rädler[1] — [1]LMU, Munich, Germany — [2]VU Amsterdam, Amsterdam, Netherlands

Collective cell migration is a fundamental aspect to a variety of physiological processes. The migratory dynamics of these collective processes rely on cell-cell interactions that are depending on complex molecular mechanisms, such as cadherin dependent pathways. In previous work we studied the interaction behavior of two cells migrating on dumbbell-like micropattern. This geometry enforces repeated head-to-head collisions of cells and allows the distinction of interacting and noninteracting events. In this framework non-cancerous MCF10A cells and cancerous MDA-MB-231 cells clearly differ in their effective adhesion and friction terms derived from quantitative theoretical analysis. Here we use this data-driven approach to study how specific molecular alterations of surface proteins change cell-cell interactions in different cell lines. Blocking of E-cadherin and Ephrin A2 via antibodies yield distinct shifts in cell behavior space. Likewise knockouts that prevent cells from using their usual communication pathways alter the adhesive and frictional interactions. We show that the analysis yields insight into the role of E-Cadherin and Ephrin A2 in frictional and adhesive interactions as well as repulsive response known as contact inhibition of locomotion.

BP 28.30 Thu 18:00 P2/EG

A high-throughput pipeline for morphological and functional analysis of cardiomyocytes — Daniel Härtter[1,2], •Lara Hauke[1], Wolfram-Hubertus Zimmermann[1], and Christoph F. Schmidt[2] — [1]Institute of Pharmacology and Toxicology, University University Medical Center Göttingen, Germany — [2]Department of Physics, Duke University, Durham, NC, USA

Cardiomyopathies, diseases of the heart muscle, affect 1 in 500 adults in Western countries. Nevertheless, reliable knowledge about disease onset and pathogenesis is lacking. To develop effective treatment options for patients, a dynamic and quantitative understanding of cardiomyopathies is needed. We developed an assay in which individual stem-cell derived heart cells of a fluorescent sarcomere reporter cell line grow in a heart-like environment - while allowing for automated high-resolution and high-framerate imaging - using micropatterned polyacrylamide acid (PAA) gels. We analyze the time-course of cell morphology and function upon drug-induced or genetic interventions with our deep-learning-based SarcAsM (Sarcomere Analysis Multitool) software. The resulting multiparametric functional and structural trajectories of cardiac muscle cells can be used to gain novel dynamical perspectives on the time-course and interplay of structure and function in health and disease and might contribute to the discovery of novel treatments.

BP 28.31 Thu 18:00 P2/EG

A mechanical bottom-up approach of memory formation in *Physarum polycephalum* — •Mathieu Le Verge Serandour and Karen Alim — School of Natural Sciences, Technical University of Munich, Germany

Understanding the emergence of memory in artificial or living complex systems is a considerable challenge: its origin, possibly an interplay of physics, genetics, or signaling, has not yet been elucidated. *Physarum polycephalum*, a unicellular organized as a two-dimensional tubular network, exhibits hallmarks of memory formation: its adaptive morphology encodes the location of past stimuli. We propose to investigate memory formation with a bottom-up approach focusing on the physical mechanisms of vascular morphology adaptation. First, we study the mechanical properties of *Physarum* by microrheology. We measure the viscoelasticity of the network's tubes and protrusions, and the change in stiffness or viscosity exposed to external stimuli, such as light or food. At the macroscopic scale, we study the dynamics of pruning of the network and its remodeling. We find an exponential decrease in the number of tubes reproduced by a toy model based on network hierarchy. These two complementary approaches will allow us to build a solid basis for establishing physical principles to characterize information encoding and memory emergence in *Physarum polycephalum*.

BP 28.32 Thu 18:00 P2/EG

Viscoelastic response of vimentin intermediate filament networks measured via optical tweezers-based active microrheology — •Kaan Ürgüp[1], Anna V. Schepers[2], and Sarah Köster[1] — [1]Institute for X-Ray Physics, Universität Göttingen, Germany — [2]Rosalind Franklin Institute and Kennedy Institute of Rheumatology, University of Oxford, UK

The microscale mechanics of the intermediate filament (IF) cytoskeleton are relevant for many cellular processes. The properties of the IF network have been shown to influence cell motility, migration and organelle transport. On the molecular level, an IF monomer is composed of amino acids that lead to α-helical domains in the center, flanked by

non-helical domains. Multiple monomers assemble laterally to unit-length-filaments and longitudinally to mature filaments. Vimentin is the most abundant IF protein in humans. Single vimentin filaments show a loading-rate dependent behavior, which can be attributed to the unfolding of α-helical structures into disordered structures and β-sheets when high strains are applied. What is unclear, however, is whether this nonlinear behavior is relevant in cellular vimentin networks. In this work, we measure strain and relaxation dynamics of *in vitro* vimentin networks via optical tweezers in the nonlinear regime. We use an active-passive calibration method based on the Onsager theorem. We measure the nonlinear response to different oscillation amplitudes, which correspond to different strains applied to the network. Our setup allows us to investigate whether the nonlinear behavior of the single filaments is preserved on the network scale.

BP 28.33 Thu 18:00 P2/EG

Traction force microscopy quantifies the contractility of laminopathic cardiomyocytes — •Valentina Kuhn[1,2], Christina Goss[1,3], Aiste Liutkute[2], Anna Zelena[1], Ulrich S. Schwarz[3], Niels Voigt[2], and Sarah Köster[1] — [1]Institute for X-Ray Physics, University of Göttingen, Germany — [2]Institute of Pharmacology and Toxicology, University Medical Center Göttingen, Germany — [3]Institute for Theoretical Physics, University of Heidelberg, Germany

Cardiomyocytes generate the contractile forces in the intact heart. In their nuclear lamina, cardiomyocytes express lamins A and C, a type of intermediate filament proteins that are encoded by the *LMNA* gene and are important for both genetic regulation and cytoskeletal organization. Patients with pathogenic *LMNA* mutations typically suffer from diseases characterized by altered cardiomyocyte contractile behavior, leading to high sudden cardiac death rates. So far, no detailed mechanistic explanation nor specific therapies are available. Cardiomyocytes derived from induced pluripotent stem cells (iPSC-CMs) are powerful in-vitro models to study the mechanisms underlying cardiomyopathies. We combine traction force microscopy with fluorescence imaging of the actin structures in a time-resolved manner on a single cell level. The experiment is conducted by seeding iPSC-CMs on elastic substrates featuring fibronectin micropatterns, which regularize their geometry for imaging while simulating physiological conditions. Thus, we can quantify the altered contractility of iPSC-CMs with the R331Q *LMNA* mutation in comparison with wild-type cells.

BP 28.34 Thu 18:00 P2/EG

Cell migration on micropatterns - how regular is the motion of different cell types? — •Annika A. Vogler, Sebastian W. Krauss, Radhakrishnan A. Veettil, Florian Rehfeldt, and Matthias Weiss — Experimental Physics I, University of Bayreuth, Germany

During processes like embryonic development, wound healing, or cancer metastasis, cells are often migrating in complex and obstacle-rich environments. Microstructured surfaces offer a versatile opportunity to model such environments and study cell migration under controlled conditions. Recent studies on cells that migrate in fairly simple two-state micropatterns have revealed, for example, a rich and nonlinear migration dynamics [1]. Following up on this study, we have explored the migration dynamics of non-cancerous MCF-12A cells on simple dumbbell patterns in comparison to malignant MDA-MB-231 cells. As a result, we observed that MCF-12A cells exhibit a strikingly more regular migration pattern while trajectories of cancerous cells appeared more stochastic. In particular, the path of non-tumorigenic cells was mainly focused on the edges of the pattern whereas malignant cells explored the whole available adhesion area. These results suggest differences in how the external environment is perceived by the internal biochemical state of cells.

[1] Brueckner, Fink, Schreiber et al., Nat. Phys. 15, 595 (2019)

BP 28.35 Thu 18:00 P2/EG

Cell Shape and Tension alter Focal Adhesion Structure — Carolin Grandy[1], Fabian Port[1], •Jonas Pfeil[1], Mariana Azevedo Gonzalez Oliva[2], Massimo Vassalli[2], and Kay-Eberhard Gottschalk[1] — [1]Universität Ulm, Institut für experimentelle Physik, Ulm, Germany — [2]University of Glasgow, James Watt School of Engineering, Glasgow, United Kingdom

Cells are anchored to the extracellular matrix via the focal adhesion complex. It also serves as a sensor for force transduction. We analyse the effect of tension on the location of key focal adhesion proteins vinculin, paxillin and actin. We use micropatterning on gold surfaces to manipulate the cell shape, to create focal adhesions at specific cell areas, and to perform metal-induced energy transfer (MIET) measurements on the patterned cells. We use drugs influencing the cellular motor protein myosin or mechanosensitive ion channels to get deeper insight into focal adhesions at different tension states. We show here that in particular actin is affected by the rationally tuned force balance. Blocking mechanosensitive ion channels has a particularly high influence on the actin and focal adhesion architecture, resulting in larger focal adhesions with elevated paxillin and vinculin and strongly lowered actin stress fibres. Our results can be explained by a balance of adhesion tension with cellular tension together with ion channel-controlled focal adhesion homeostasis, where high cellular tension leads to an elevation of vinculin and actin, while high adhesion tension lowers these proteins.

BP 28.36 Thu 18:00 P2/EG

Interactions of cytoskeletal elements during phagocytosis in macrophages. — •Erbara Gjana[1] and Franziska Lautenschläger[1,2] — [1]Department of Physics, Saarland University, Saarbrücken, Germany — [2]Center for Physics, Saarland University, Saarbrücken, Germany

The structure of cells is realized via their cytoskeleton - a polymer network inside cells. It is the main component of structural integrity and it shapes cells. The cytoskeleton is involved in many active cellular activities that includes cell division, migration, and phagocytosis. In macrophages, we know that actin - one protein of the cytoskeleton * plays an important role during phagocytosis. In my project, I work on understanding how actin is involved in sensing the object which needs to be phagocytosed.

Particularly, I study the effect of the physical properties such as form, size and stiffness of the objects. Therefore, I am varying the stiffness of objects, e.g. I use gelatine beads, latex beads and polystyrene beads and investigate how these are phagocytosed with the help of actin. Through different microscopy methods (epi-fluorescence, confocal) I will be able to image the process of phagocytosis. Till now, we have established phagocytosis protocols with macrophages derived from the cell line HL60. For a better biological fit I am now shifting to THP1 derived macrophages. This will help me to understand questions such as how macrophages distinguish between dead cells (ei. Dead RBCs), cell debris, and healthy cells. Also, we collaborate with theoreticians be build general mathematical model of phagocytosis.

BP 28.37 Thu 18:00 P2/EG

Micromechanics of spherical cellular aggregates — •Antoine Girot[1,2], Marcin Makowski[2], Marco Rivetti[2], Christian Kreis[2], Alexandros Fragkopoulos[1,2], Matilda Backholm[3], and Oliver Bäumchen[1,2] — [1]University of Bayreuth, Experimental Physics V, 95447 Bayreuth, Germany — [2]Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [3]Aalto University School of Science, Department of Applied Physics, 02150 Espoo, Finland

Understanding the rich dynamics of biophysical processes, such as pathogenic tissue development and morphogenesis, requires a proper mechanical characterization of multicellular aggregates. Spherical aggregates often serve as model systems, yet, they cannot be readily characterized with conventional techniques that are optimized for single cells. In this presentation, we report on *Volvox globator*, a natural cellular aggregate that is composed of hundreds of bi-flagellated cells forming a spherical monolayer filled with mucilage. We employ *in vivo* micropipette force measurements combined with optical detection to simultaneously measure the force response and the deformation of this living aggregate. We show that the micromechanics of *Volvox* can be described by a model coupling elasticity and viscosity, which allows to extract the mechanical properties. We find that the viscous component exhibits a shear-thinning behavior, that can be properly described by implementing a power-law fluid model, while the elasticity of the aggregate depends on its size.

BP 28.38 Thu 18:00 P2/EG

The influence of calcium on the structure of the actin cortex in cell monolayers and single cells — •Christoph Anton[1], Lucina Kainka[1], Sandra Iden[2], and Franziska Lautenschläger[1,3] — [1]Department of Physics, Saarland University, Saarbrücken, Germany — [2]Center of Human and Molecular Biology (ZHMB), Saarland University, Homburg, Germany — [3]Center for Biophysics, Saarland University, Saarbrücken, Germany

We recently showed that adhesion to a substrate, mediated via inte-

grins, causes significant changes to the structure, mechanics and dynamics of the cellular actin cortex. In tissues, however, cells additionally form cell-cell junctions. Therefore, we investigate how the structure of the actin cortex of healthy and cancerous epithelial cell lines is affected by the transition from single cells to cell monolayers. One important step during this transition is the formation of cell-cell junctions, such as the cadherin-based adherens junctions. These junctions are dependent on the presence of calcium ions. In our work, we varied the extracellular calcium concentration to investigate the effect of cadherin-mediated adhesion and other calcium-based cellular processes on the actin cortex. We used scanning electron microscopy (SEM) to visualize the actin cortex. We applied our filament network tracing algorithm to the SEM images to quantify the structural properties of the actin cortex, such as the mesh hole area. By comparing the cortex parameters of cells within a monolayer with the cortex parameters of isolated cells we plan to characterize the structural changes that are induced by cell-cell contacts and extracellular calcium concentrations.

BP 28.39 Thu 18:00 P2/EG

Motility of adherent cells on structured surfaces at elevated viscosities — •Radhakrishnan Adiyodi Veettil, Sebastian W Krauss, Annika A Vogler, Florian Rehfeldt, and Matthias Weiss — Experimental Physics I, University of Bayreuth, Germany

Cell motility is sensitive to the viscosity of the surrounding medium, suggesting that such external cues can trigger cells to switch gears. Indeed, it has been recently reported that elevated viscosities can induce significant changes in cell area, cell migration speed and focal adhesion turn over [1]. Here, we have followed up on these experiments by monitoring the viscosity-dependent migration of different cell types on microstructured surfaces, e.g. cell hopping of cancerous and non-cancerous cells in dumbbell patterns. Our data suggest that altering viscosity can markedly alter the migration dynamics of cells on microstructured surfaces.

[1] Pittman, Iu, Li et al., Nat. Phys. 18, 1112 (2022)

BP 28.40 Thu 18:00 P2/EG

Coordination of information in *Physarum polycephalum* — •Kaspar Wachinger[1], Johnny Tong[1], Nico Schramma[2], Siyu Chen[1], and Karen Alim[1] — [1]School of Natural Sciences, Technical University of Munich, Germany — [2]Faculty of Science, University of Amsterdam, The Netherlands

Physarum polycephalum is a network-structured, single-cell organism with thousands of nuclei that can sense and adapt to its environment. To understand how *P. polyephalum* maintains efficient gene expression, it is necessary to understand the coordinated intracellular transport of nuclei within its structure. Microinjecting several fluorescent dsDNA markers into the tubes of *P. polyephalum* allows in-vivo imaging of nuclei and their dynamics: Nuclei can either be trapped in the more solid wall cortex or follow the oscillatory cytoplasmic streaming. We investigate the flow-driven behaviours of nuclei in functionally different regions of *P. polycephalum*'s network and motivate a hypothesis of inter-nuclei communication far past the degradation distance of mRNA.

BP 28.41 Thu 18:00 P2/EG

FilamentSensor 2.0: An open-source modular toolbox for 2D/3D cytoskeletal filament tracking — Lara Hauke[1], Andreas Primessnig[1], •Emese Zavodszky[1], and Florian Rehfeldt[2] — [1]Institute of Pharmacology and Toxicology, University Medical Center Göttingen, Germany — [2]Experimental Physics I, University of Bayreuth, Germany

Cytoskeletal pattern formation and structural dynamics are key to a variety of biological functions and a detailed and quantitative analysis yields insight into finely tuned and well-balanced homeostasis and potential pathological alterations. High content life cell imaging of fluorescently labeled cytoskeletal elements under physiological conditions is nowadays state-of-the-art and can record time lapse data for detailed experimental studies. However, systematic quantification of structures and in particular the dynamics (i.e. frame-to-frame tracking) are essential. Here, an unbiased, quantitative, and robust analysis workflow that can be highly automatized is needed. For this purpose we upgraded and expanded our fiber detection algorithm FilamentSensor [1] to the FilamentSensor 2.0 [2] toolbox, allowing for automatic detection and segmentation of fibrous structures and the extraction of relevant data (center of mass, length, width, orientation, curvature) in real-time as well as tracking of these objects over time and cell event monitoring. Furthermore, we offer the Focal Adhesion Filament Cross-correlation Kit (FAFCK) [3] for automated correlation with point-like structures. [1] B. Eltzner, et al., PLoS One, 2015 [2] L. Hauke, et al., PLoS One, under review [3] L. Hauke, et al., PLoS One, 2021

BP 28.42 Thu 18:00 P2/EG

Mechanically induced Bioluminescence - from single cells to glowing sea — •Nico Schramma[1], Hugo França[1,2], and Maziyar Jalaal[1] — [1]Van der Waals-Zeeman Institute, University of Amsterdam, Amsterdam, Netherlands — [2]Instituto de Ciências Matemáticas e Computação, Universidade de São Paulo, São Carlos, Brazil

The ability of single-celled organisms to sense mechanical cues is of high importance for their migration, navigation and survival in their ever-changing environment. However, studying single-cell mechanosensing under dynamic mechanical conditions is complicated. For this reason, the bioluminescent marine algae Pyrocystis lunula is a particularly interesting organism: mechanical stimuli trigger them to release a flash of blue light, which is mostly known from the bioluminescent tide, turning the sea into a mysterious pale blue shimmering. Combining mechanical tests on single cells with dynamics of millions of bioluminescent algae in a wave impact experiment and computational fluid mechanics we find and test general relations describing macroscopic (fluid)mechanical cues with bioluminescence. Our research paves the way towards a better understanding of mechanosensation of algae and plants, but may also lead to applications of bioluminescent organisms as "living force sensors".

BP 28.43 Thu 18:00 P2/EG

Predicting optimal optogenetic control of cell migration with an active gel model — •Oliver M. Drozdowski, Falko Ziebert, and Ulrich S. Schwarz — Institute for Theoretical Physics and BioQuant, Heidelberg University, 69120 Heidelberg, Germany

Cell motility is one of the hallmarks of life and often results from flow in the actin cytoskeleton that is driven by actin polymerization at the front and myosin II motor contractility at the back. The standard model to describe such flows is active gel theory, in which myosin II contractility enters as active stress. Advancements in optogenetic tools have sparked interest in controlling these flows externally and consequently also motility.

Recently we have shown that bistability between motile and sessile states emerges in a one-dimensional active gel model if the myosin II motors are modeled as a supercritical van der Waals fluid [1]. We now incorporate optogenetic perturbations into this description and consider two experimentally accessible protocols for migration control - localized contractility perturbations and global upregulation of contraction. We find that the local protocol permits full external control. Global upregulation reliably leads to irreversible motility initiation, but does not allow for full control. Our results agree with recent experiments on cell migration in microchannels and reconcile experimental observations of local versus global regulatory mechanisms.

[1] O. M. Drozdowski, F. Ziebert, U. S. Schwarz, arXiv:2206.05915 (2022).

BP 28.44 Thu 18:00 P2/EG

Nuclei trafficking dynamics in Physarum polycephalum — •Johnny Tong, Kaspar Wachinger, Nico Schramma, and Karen Alim — School of Natural Sciences, Technical University of Munich, Germany

Synthetical organism and organs house up to thousands of nuclei within a single envelope, often shaped into a complex network architecture. How are nuclei able to efficiently exchange signals over long distances? To understand how synthetia coordinate gene expression, intracellular transport within these networks is key. Physarum polycephalum is an ideal syncytia model as its network-shaped body is a single multinucleated cell which can sense and adapt to its environment in a short time scale and a long length scale. Here, nuclei are trapped in the tube walls or advected by the oscillatory cytoplasmic streaming. We investigate its flow-driven dynamics and mechanochemical behaviors using image-based methods, including particle tracking and velocimetry, to analyze the nuclei trafficking. We also utilize the thousands of nuclei to propose a new technique akin to traction force microscopy. By analyzing the fluctuations of nuclei trapped in the actomyosin cortex, we can probe the change of mechanical properties due to external stimuli, such as food, substrate stiffness, and light. Our techniques may be applied to other systems to unveil the mechanisms of long-range genetic communication within network-shaped organisms like fungi.

BP 28.45 Thu 18:00 P2/EG

Super-resolved Imaging of Cellular Traction Forces — •Armina Mortazavi, Jianfei Jian, and Benedikt Sabass — Ludwig Maximilian University of Munich, Munich, Germany

Traction force microscopy (TFM) is a well-established method that enables the measurement of forces that are exerted by adherent cells to an underlying substrate. We aim to enhance the spatial resolution of TFM by using stochastic optical reconstruction microscopy in total internal reflection mode. To measure the substrate deformations below adherent cells, we employ DNA-based FluoroCubes that each carries multiple, spontaneously blinking, fluorescent dye molecules. Grafting of these new fluorescent probes to the top surface of Polydimethylsiloxane gels and using RGD peptides as the smallest ligands representative of extracellular matrix allows us to measure the forces generated by individual focal adhesion sites. The proposed method in principle allows one to extend traction force microscopy to lengthscales below 100 micrometers and can therefore help to unravel the mechanobiology of highly localized cell-physiological processes.

BP 28.46 Thu 18:00 P2/EG

Length distributions of microtubles with a multistep catastrophe mechanism — Felix Schwietert, •Lina Heydenreich, and Jan Kierfeld — TU Dortmund University, 44227 Dortmund, Germany

Regarding the experimental observation that microtubule catastrophe can be described as a multistep process, we extend the Dogterom-Leibler model for dynamic instability in order to discuss the effect that such a multistep catastrophe mechanism has on the distribution of microtubule lengths in the two regimes of bounded and unbounded growth. We show that in the former case the steady state length distribution is non-exponential and has a lighter tail if multiple steps are required to undergo a catastrophe. If rescue events are possible, we detect a maximum in the distribution, i.e., the microtubule has a most probable length greater than zero. In the regime of unbounded growth, the length distribution converges to a Gaussian distribution whose variance decreases with the number of catastrophe steps. All results are verified by stochastic simulations.

BP 28.47 Thu 18:00 P2/EG

Bridging the gap between surface flows and motility patterns of malaria parasites — •Leon Lettermann[1], Mirko Singer[2], Falko Ziebert[1], Friedrich Frischknecht[2], and Ulrich S. Schwarz[1] — [1]ITP & Bioquant, Heidelberg University — [2]CIID, Heidelberg University

Malaria is one of the most devasting infectious diseases and transmitted from mosquitos to humans by so-called Plasmodium sporozoites, which move by gliding motility. Myosin motors move actin filaments below the plasma membrane, which leads to surface flows of adhesins that are anchored into the plasma membrane. How this surface flow is converted into the complicated motility patterns observed in experiments is not clear. Here we introduce a theoretical model that bridges this gap. The coupling between surface flow and substrate is modeled by a system of reversible adhesion bonds. We numerically solve the resulting system of ordinary differential equations and find a rich variety of motility patterns, including the circular and helical paths observed in experiments. This allows us to estimate likely patterns of surface flows, which are hard to measure experimentally.

BP 28.48 Thu 18:00 P2/EG

Stem Cell Dynamics in Tissues — •Johannes C. Krämer, Gerhard Gompper, and Jens Elgeti — Theoretical Physics of Living Matter (IBI-5/IAS-2), Forschungszentrum Jülich, Jülich, Germany

The renewal of epidermal tissue relies on a few stem cells dividing asymmetrically, and a cascade of transient amplifying cells resulting in the necessary cell mass of terminally differentiated cells. We integrated this process in the two-particle growth model, and find that this simple process results in very interesting dynamic features: Stem cells repel each other in the tissue bulk and are thus found rather isolated in the tissue.

Simulating just two isolated stem cells, we construct the probability density function to find two stem cells in a given distance, and observe a reduced probability to find stem cells close to each other. To understand this repulsive mechanism better, we apply equilibrium methods to construct an effective interaction potential. Although a massive simplification it allows us describe the repulsive interaction in a simple fashion. Thermal colloid simulations, where particles interact via the effective interaction, are consistent with simulations of bulk tissues.

Our findings may contribute to better understand the cancer stem cell hypothesis. Here, cancerous growth is assumed to emerge from few stem cell like cancer cells, which might evade being targeted by therapy. However, the cancer stem cells are difficult to observe – maybe because they get separated by this mechanism.

BP 28.49 Thu 18:00 P2/EG

On multistability and constitutive relations of cell motion on Fibronectin lanes — •Johannes Clemens Julius Heyn[1], Behnam Amiri[2], Christoph Schreiber[1], Martin Falcke[2,3], and Joachim Oskar Rädler[1] — [1]Ludwig-Maximilians-Universität München — [2]Max Delbrück Center for Molecular Medicine in the Helmholtz Association — [3]Humboldt Universität zu Berlin

Migration of eukaryotic cells is a fundamental process for embryonic development, wound healing, immune responses, and tumour metastasis. Experiments on 2d migration show a broad spectrum of morphodynamic features for many cell types. Cells exhibit distinct motile states: They are spread or moving and either steady or oscillatory and they display spontaneous transition between those states. Here, we present a study of the motion of MDA-MB-231 cells on 1d Fibronectin (FN) microlanes and group the migratory behaviour into four discrete states. A high-throughput setup allows to quantitatively analyse state transitions for a broad range of FN densities. We develop a biophysical model based on the force balance at the protrusion edge, the noisy clutch of retrograde flow and a response function to integrin signalling. The model reproduces cell states, characteristics of oscillations and state probabilities in very good agreement with our experimental data. The statistics of trajectories and theory suggests an adhesion related mechanism that not only explains multistability but also the well-known biphasic adhesion-velocity relation and the universal correlation between speed and persistence (UCSP).

BP 28.50 Thu 18:00 P2/EG

Single-molecule tracking in dense images — •Jianfei Jiang[1,2], Armina Mortazavi[1,2], and Benedikt Sabass[1,2] — [1]Institute for Infectious Diseases and Zoonoses, Department of Veterinary Sciences, LMU München — [2]Department of Physics, LMU München

Traction force microscopy (TFM) quantifies cellular traction forces on a surface. The technique is based on measuring the deformations in the substrate. A standard implementation of TFM involves using first particle image velocimetry (PIV) to measure the two-dimensional deformations. Subsequently, a force reconstruction algorithm calculates the traction field based on PIV measurements. The spatial resolution of TFM can be improved by using smaller-sized fluorescent particles embedded in the substrate. To this end, we develop a new technique that combines TFM with Stochastic Optical Reconstruction Microscopy (STORM). Using STORM, we can record the positions of FluoroCubes ($\sim$ 6nm) that are densely distributed in the substrate. Here, we propose a new single-molecule tracking algorithm to acquire fine-grained displacement fields. We first use PIV with large-sized fluorescent beads ($\sim$ 40nm) to obtain coarse-grained displacement fields, which helps us to estimate the displacement of each FluoroCube. Then, the tracking process is formulated as a linear assignment problem, where we implement the Hungarian algorithm to minimize the overall deviation from PIV estimations. The particle tracking algorithm is parallelized by dividing the image into smaller subimages to reduce computation time. The tracking results enable us to build a high-resolution displacement field for force reconstruction.

BP 28.51 Thu 18:00 P2/EG

Reconstituting a polymer hydrogel that mimics intracellular viscoelastic properties — •Dorian Marx, Bart Vos, and Timo Betz — 3. Institute of Physics, Faculty of Physics, Georg-August-University Göttingen

Throughout the years numerous models were developed that describe the mechanical response of cells to deformations. However, all models, both classic and modern, are phenomenological, that is, they lack a connection of their parameters to the real physical system, making them hard to interpret. Furthermore, the strongest argument for a particular model so far is how accurately it matches to measurements. While this is fine on a phenomenological level, a deeper understanding, e. g. why it fits, is missing. This also holds for the fractional Kelvin-Voigt model (fKVM) that is composed of two complex power-laws and was shown to fit a range of different cells very well.

To connect the fit parameters of the fKVM to the physical system we opt for a bottom-up approach by using a passive viscoelastic poly-

mer with constituents that have analogs in cells. After confirming that the fKVM accurately fits this system, we focus on finding "the most cell-like" parameter set. Varying the composition of the gel (e. g. via the cross-linker concentration) allows us to directly connect properties of the physical system to model parameters. With this, we are now able to formulate hypotheses that can be checked in live cells, giving a quantitative handle for connecting the real world biophysics to rheological models.

BP 28.52 Thu 18:00 P2/EG

Does Size Matter? Actin filament length in cell migration — •Carsten Alexander Baltes[1], Divyendu Goud Thalla[1], and Franziska Lautenschläger[1,2] — [1]Experimental Physics, Saarland University, Saarbrücken, Germany — [2]Center for Biophysics, Saarbrücken, Germany

The ability to perform cellular locomotion is crucial for a large variety of tasks. This includes the search and chase of immunecells for pathogens as well as the search for food and the reorganisation of cells in tissue developement. The cytoskeleton protein actin is particularly important for migration of eucaryotic cells. It is involved in the formation of filopodia and creates a retrograde flow from the leading edge towards the back of the cell, both of which allow them to move forward. Alteration of the actin network therefore might have an impact of the migratory behavior of cells. Here I am going to present the effects of elongated actin filaments on migrating RPE-1 cells. I will show that cells, migrating either on 1D fibronectin lines or on a fibronectin coated surface, displayed a reduction of migration speed, while keeping their persistence. They also occupy a larger area when allowed to spread freely and expres a higher amount of focal adhesions. The change in migration speed vanishes when we put those cells under confinement in PDMS microchannels. Taking those facts together we propose that the length of actin filaments is important for cell migration. However further research is needed to fully understand the importance regarding the different migration modes cells can take depending on the surrounding environment.

BP 28.53 Thu 18:00 P2/EG

From Shape to Function of Sampling Resident Tissue Macrophages — •Miriam Schnitzerlein[1], Anja Wegner[2], Stefan Uderhardt[2], and Vasily Zaburdaev[1] — [1]Department of Biology, Friedrich-Alexander-Universität Erlangen-Nürnberg and Max-Planck-Zentrum für Physik und Medizin, Erlangen, Germany — [2]Department of Internal Medicine 3 - Rheumatology and Immunology, Friedrich-Alexander-Universität Erlangen-Nürnberg und Universitätsklinikum Erlangen, Germany

Mammalian tissues are permanently subjected to various stresses - be it pathogens, dead cells and related waste products or injuries like micro-lesions - which have to be resolved properly to prevent inflammations and maintain tissue homeostasis. To detect such incidents, sessile resident-tissue macrophages (RTMs) persistently sample their surroundings by seemingly random extension and retraction of their protrusions. Quantifying these sampling dynamics over time and comparing RTM behaviour under different conditions can uncover certain patterns or strategies in RTM sampling, which will then help us to understand how RTMs ensure tissue homeostasis. In this project, we have employed a high-resolution intravital imaging protocol to generate movies of RTM sampling dynamics *in vivo*. Next we have built an image processing pipeline to assess cell dynamics via its shape, the curvature and displacement of the cell membrane as well as the movement of the cell protrusions over time. Such detailed measurements enable differentiating physiological states of RTMs, and will help to build a quantitative mathematical model for RTM protrusion dynamics.

BP 28.54 Thu 18:00 P2/EG

The energy cost of membrane-cortex deformation in phagocytosis of different sized pathogens — •Mehdi Ait Yahia and Rhoda Joy Hawkins — University of Sheffield

During their lifetime macrophages (a type of white blood cell) defend against infection in biological organisms by moving and interacting with micrometer sized pathogens. Interactions include phagocytosis which is the engulfment of pathogens by the cell deforming around the target. We model the physical description of the deformation of the membrane and cortex composition based on the energy of bending and stretching. For the bending energy we use the Helfrich energy for an elastic membrane in terms of its elastic moduli and curvature. The stretching energy is a function of the moduli and the extra surface needed to engulf the target object. We consider different methods to obtain the elastic moduli including the possibility of exocytosis modifying the surface area. The bending energy is expected to be smaller for larger objects since the curvature is inversely proportional to the radius. On the contrary the stretching energy is expected to increase for a larger object. We minimize the sum of these two energies with respect to the radius to find an optimum size for phagocytosis. We compare our theoretical predictions with data from simulations and experiments on macrophages engulfing beads of different sizes and the fungal pathogen Cryptococcus.

BP 28.55 Thu 18:00 P2/EG

We can see you think: Towards label-free imaging of action potentials — •Andrii Trelin[1], Heiko Lemcke[2], Sophie Kussauer[2], Christian Rimmbach[2], Robert David[2], and Friedemann Reinhard[1] — [1]Institute for Physics, University of Rostock — [2]Department of Cardiac Surgery, Rostock University Medical Center

The ability to directly observe neuronal communication like propagation of action potentials (AP) is crucial for the understanding of biological neural networks such as the mammalian brain. Existing methods either cannot access cells deep inside tissue (microelectrode arrays) or are not suitable for observing cells over long time periods (fluorescence). We are developing a novel method of AP imaging, based on the fact that the propagation of an AP through a neural network is accompanied by tiny movements due to various processes, including an increase of cell volume, a change of membrane tension, and others. Although movements happen on a nm scale, i.e. beyond the resolution of classical microscopy, theoretical estimates show that detection of these movements is possible by performing high-speed video recording of the cell and combining information from multiple pixels. The sensitivity can be amplified by employing a suitable optical setup, e.g. interferometric microscope. In this poster, we present the design of the experimental setup and share some of the results obtained in the project. Additionally, we will discuss the development of algorithms, capable of extracting cell movement information from high-speed videos. These include simple statistical analysis of videos, decomposition methods such as PCA, as well as machine learning approaches.

BP 28.56 Thu 18:00 P2/EG

Classifying single cells by their motion — •Anton Klimek[1], Debasmita Mondal[2], Prerna Sharma[2], and Roland Netz[1] — [1]Freie Universität Berlin, Germany — [2]Indian Institute of Science, Bangalore, India

We present a method to differentiate cells solely by their trajectories based on the generalized Langevin equation and apply it to distinguish two differently swimming types of strongly confined microalgae Chlamydomonas reinhardtii cells with an accuracy of 100 %. The model we use is suggested by the data and succeeds to describe the motion on the single cell level. By a simple fit we can extract model parameters for individual cells and subsequently perform an unbiased cluster analysis to determine the number of different cell types in the population and obtain an assignment of every cell to one of the types. Additionally, the model suggested by the data includes information on the underlying processes leading to the observed patterns of motion, which in the case of our Chlamydomonas reinhardtii data could hint towards a harmonic coupling between the cell nucleus and the flagellar propulsion apparatus. As it still remains a challenge to classify cells on the single cell level, the presented method to distinguish cells with as little information as their trajectories might have important implications in biology and medicine.

BP 28.57 Thu 18:00 P2/EG

The role of vimentin in endothelial cells under flow — •Julia Kraxner[1,2], Wolfgang Giese[1,2], and Holger Gerhardt[1,2] — [1]Integrative Vascular Biology, Max Delbrück Center for Molecular Medicine in the Helmholtz Association (MDC) — [2]German Center for Cardiovascular Research (DZHK), partnersite Berlin

Vascular endothelial cells (VECs) compose the inner layer of blood vessels where they need to be able to constantly sense, withstand and adapt to varying mechanical stresses. For the sensing and adaptation to mechanical stress cytoskeletal proteins, i.e. actin, microtubules and intermediate filaments, play an important role. Here, we focus on vimentin which is the most abundant intermediate filament in VECs. These cells are constantly exposed to shear stress and they response to the flow by polarizing and aligning in direction of flow. We investigate the role of vimentin in this flow response by exposing VECs to shear stress in vitro. Furthermore, experiments under flow reveal an increase of specific phosphorylation sites in vimentin. We study the role

of these specific phosphorylation sites on the mechanotransduction. Therefore, we want to combine traction force microscopy under flow with mutations in vimentin which inhibit phosphorylation of specific sites. Additionally, we plan on tuning the substrate stiffness to study the effect of tissue mechanics observed in aging of the vascular system and possible effects on mechanotransduction. These insights have the potential to improve our understanding of the complex mechanism of mechanotransduction in VECs.

BP 28.58 Thu 18:00 P2/EG

Optical Stretcher for Adherent Cells — •Alexander Janik, Tobias Neckernuss, and Othmar Marti — Institute of Experimental Physics, Ulm University

The characterization of cellular viscoelastic properties by utilizing the interface force arising from a laser beam shining through the cell has proven to be a valuable method for suspended cells, e.g. red blood cells.

The work presented here is based on the same phenomenon. A laser locally pulls the membrane of an adherent cell upwards, while the displacement is detected by off-axis interferometry. In proof-of-concept measurements, it is shown, that this contact-free method is sensitive enough to determine the complex shear modulus of stiff adherent NIH-3T3 cells. Laser power and wavelength are chosen to minimize heating induced softening.