BP 24: Posters: Physics of Cells

Time: Wednesday 17:30–19:30 Location: Poster C

BP 24.1 Wed 17:30 Poster C

Induced changes in spatio-temporal oscillations of the cell thickness in response to conflicting stimuli — •Mario Breitkopf and Marcus J. B. Hauser — Abteilung Biophysik, Otto-von-Guericke-Universität Magdeburg, Magdeburg, Germany

Plasmodia of the unicellular slime mould *Physarum polycephalum* form a vascular network where protplasma is pumped to and fro through the cell. The pumping is associated with differences in the thickness of the veins (and hence the thickness of the cell). To ensure effective pumping, certain domains of the cell oscillate in phase. The spatial coherence of these thickness oscillations can be affected by external stimuli, which allows this slime mould to make decisions.

Here we study the self-organized, spatiotemporal pattern of cell thickness oscillations that arise when the cell is exposed to two conflicting stimuli. This is realized by presenting the cell a mixture of a chemoattractant and a chemorepellant. We analyze the changes in thickness oscillations in order to unravel whether changes in the signal transduction pathways also translate into the macroscopic patterns of cell thickness oscillations.

BP 24.2 Wed 17:30 Poster C

Causes of retrograde flow in fish keratocytes — •Thomas Fuhs[1,2], Michael Goegler[1], Claudia A. Brunner[1], Charles W. Wolgemuth[3], and Josef A. Kaes[1] — [1]Division of Soft Matter Physics, Department of Physics, University of Leipzig, Leipzig, Germany — [2]Paul Flechsig Institute of Brain Research, University of Leipzig, Leipzig, Germany — [3]Departments of Physics of Molecular and Cellular Biology, University of Arizona, Tucson, AZ, United States of America

Confronting motile cells with obstacles doubling as force sensors we tested the limits of the driving actin-and-myosin-machinery. We could directly measure the force necessary to stop actin polymerization as well as the force present in the retrograde actin flow. Combined with detailed measurements of the retrograde flow velocity and specific manipulation of actin and myosin we found that actin polymerization and myosin contractility are not enough to explain the cells behavior. We show that ever-present depolymerization forces, a direct entropic consequence of actin filament recycling, are sufficient to fill this gap, even under heavy loads.

BP 24.3 Wed 17:30 Poster C

Spatio-temporal dynamics of plasmodial migration of the slime mould *Physarum polycephalum* — •Beatrice Rodiek[1], Tetsuo Ueda[2], and Marcus J. B. Hauser[1] — [1]Abteilung Biophysik, Otto-von-Guericke-Universität Magdeburg, Magdeburg, Germany — [2]Research Institute of Electronic Science, Hokkaido University, Sapporo, Japan

Spatio-temporal self-organization of large amoeboid plasmodial cells of the slime mould *Physarum polycephalum* was studied in relation to cell locomotion. During locomotion, the slime mould shows rhythmic contraction and expansion waves. We observe distinct patterns in wild-type strain and in one behavioural mutant. The pseudopodium extended either in a periodic back-and-forth manner or in a forward-stop fashion. Correspondingly, the propagation of the contraction waves either reached the vicinity of the front or left a stationary, non-oscillatory region near the front. Thus, the genetic differences in the cells of the same species may translate into different physical patterns of locomotion.

BP 24.4 Wed 17:30 Poster C

Investigation of the protoplasmic flow in veins of *Physarum polycephalum* — Sebastian Weise and •Marcus J. B. Hauser — Abteilung Biophysik, Otto-von-Guericke-Universität Magdeburg, Magdeburg, Germany

The plasmodium of the *Physarum polycephalum* forms a characteristic, extended vascular network, which is used to transport the protoplasm through the giant cell. The transport is driven by peristaltic pumping and it reverses its direction periodically. The flow in the veins of *P. polycephalum* is always laminar, however, it is known that protoplasmic particles are effectively and rapidly distributed within the cell. To elucidate how an effective transport can be achieved in a system with laminar flow, we performed particle tracking velocimetry experiments. The flow of inserted particles is analyzed, and the role of vascular ramifications is addressed.

BP 24.5 Wed 17:30 Poster C

Collective cell migration in tumor colonies — •Janina Lange[1], Claus Metzner[1], Julian Steinwachs[1], Patrick Krauss[1], Pamela Strissel[2], and Ben Fabry[1] — [1]University of Erlangen-Nuremberg, Department of Physics, Biophysics Group — [2]University of Erlangen-Nuremberg, Department of Gynaecology and Obstetrics

Many tumor cells proliferate despite a lack of interaction with the extracellular matrix and without cell-contact inhibition that normally prevents cells from proliferating beyond confluency. This gives tumor cells the advantage to grow into a dense 3-dimensional tissue. As the tumor grows, mechanical stresses arise that depend on proliferation speed, cell contractility, substrate adhesiveness, and cell cohesiveness. They are organized by cells migrating between regions of different mechanical stresses. Here we study how proliferation, adhesiveness and cohesiveness influence the migration of individual tumor cells in rapidly growing 3-dimensional tumor colonies initiated on a 2D substrate. Colonies of highly and weakly adhesive and cohesive cell lines are compared. We also study colonies of embryonic mouse fibroblasts in which focal adhesion kinase was knocked out, which leads to changes in both adhesiveness and cohesiveness involving E-cadherin. In weakly adhesive cell lines, cells close to the border migrate rapidly and persistently in the radial direction. Interestingly, in the central tumor region we also find highly persistent cell migration but in random directions with a spatially and temporally highly correlated migration pattern. Collective cell migration, however, was absent in colonies of high adhesiveness and low cohesiveness.

BP 24.6 Wed 17:30 Poster C

Cell visco-elasticity measured with AFM and optical trap at sub-micron deformations — •Paula Sánchez, Weixing Li, Marie Zeiss, Carina Wollnik, Kai Bodensiek, Florian Rehfeldt, and Iwan Schaap — III. Physikalisches Institut, Faculty of Physics, Georg-August Universität Göttingen, Germany

The elastic properties of cells are widely used as an indicator for differentiation, response to drug treatment, or the effects of the supporting matrix on cell development. We use vertical optical trapping and AFM to measure the cell's visco-elastic response at deformations of 0.2 to 1.2 um. To perform the optical trapping experiments at different speeds we implemented an FPGA based fast force feedback to control the vertical movement of the piezo at speeds up to 50 um/s. We use this combined approach to quantify the visco-elasticity at small and large deformations on both stiff and soft substrates. Deformations up to 0.2 um showed a reversible, thus truly elastic response that was independent of the rate of deformation. At higher indentations, the apparent Young's modulus increased a multifold due to viscous effects that followed a weak power law. Both AFM and optical trapping indentation experiments give consistent results for the cell elasticity. Optical trapping has the benefit of a lower force noise, which allows a more accurate determination of the absolute indentation.

BP 24.7 Wed 17:30 Poster C

Elasticity measurements of fibroblastic cell nuclei by atomic force microscope for characterizing Lamin and TMEM43 mutations — •Tamara Münnich[1], Volker Walhorn[1], Helene Schellenberg[1], Astrid Kassner[2], Hendrik Milting[2], and Dario Anselmetti[1] — [1]Experimental Biophysics, Bielefeld University, Germany — [2]Erich und Hanna Klessmann-Institut, Herz- und Diabeteszentrum Bad Oeynhausen, Germany

Arrhythmogenic right ventricular cardiomyopathy (ARVC) is an inherited heart muscle disease associated with cardiac arrhythmia. It is a major cause of sudden cardiac death in the young and athletes. Mutations of the intermediate filament Lamin and the transmembrane protein 43 (TMEM43) are connected to ARVC. Both proteins are located at the nuclear envelope. As the cell nucleus has to resist strong mechanical stress caused by the contraction of the heart muscle, we suppose that the mutations affect functional mechanical properties of the nucleus. The elastic moduli of the cell nuclei were measured with the atomic force microscope and estimated by the Hertz-model. The measurements were performed with fibroblasts, which serve as a model

system for cardiomyocytes. We analyzed a set of Lamin and TMEM43 mutated cells and compared them to a control group consisting of wild type fibroblasts and mutations not associated with ARVC. The TMEM43 mutant showed much higher and widespread elastic moduli, whereas the elasticity of the Lamin mutant is similar to the control group. In the future we will analyze modified fibroblasts expressing no Lamin and TMEM43 respectively.

BP 24.8 Wed 17:30 Poster C

Photo-induced switchable cell adhesion on nanostructured surfaces — •Laith Kadem[1], Qian Li[1], Michelle Holz[2], Rainer Herges[2], and Christine Selhuber-Unkel[1] — [1]Christian-Albrechts-University Kiel, Institute for Materials Science — [2]Christian-Albrechts-University Kiel, Otto Diels-Institute of Organic Chemistry

Cell adhesion (CA) relies on the specific binding of transmembrane proteins to their extracellular ligands. The spacing between individual integrin binding sites in mammalian RGD-integrin CA system controls CA forces and reinforcement as well as cell elasticity. We aim to develop nanostructured surfaces where light-driven switchable CA is feasible. Using Diblock Copolymer Micelle Nanolithography, these nanostructures are introduced on the surface as nanometer-sized monodispersed gold particles ordered in a quasi-hexagonal pattern. The spacing between gold dots can be varied from 20 to 200 nm with nanometer precision. Moreover, we can apply this technique to surfaces with a structured microtopography. Regular microtopographies on surfaces can be obtained with photolithography followed by an etching step. Subsequently, we create patterns of the gold nanodots within the micro-domains. With this protocol, we are able to generate different spacings of gold dots on one single substrate in a single step. The gold dots are functionalized with photoswitchable azobenzene molecules incorporated with RGD peptides in order to mediate specific CA to surfaces through integrins. Using the photoswitching properties of azobenzenes, we aim at switching CA in a spatially and temporally defined fashion.

BP 24.9 Wed 17:30 Poster C

A systems-level model for focal adhesions — •Max Hoffmann[1,2] and Ulrich S. Schwarz[1,2] — [1]BioQuant, Heidelberg University, Heidelberg, Germany — [2]Institute for Theoretical Physics, Heidelberg University, Heidelberg, Germany

Focal adhesions are cell-matrix contacts, which transduce and integrate mechanical as well as biochemical cues from the environment. They are large supra-molecular assemblies with more than 170 types of proteins and more than 700 types of interactions collectively known as the "adhesome". Due to their association with the plasma membrane, focal adhesions are spatially organized in three layers of adhesion receptors, connector and signaling molecules, as well as cytoskeletal proteins. The exact composition and function of focal adhesions is strongly regulated by signaling (including the effect of the small GTPases from the Rho family) and the impact of mechanical force.

Here we present theoretical models, which account for all of these features by describing the assembly process of a generic set of core components. First we introduce a kinetic model that allows us to predict the effect of RNA-interference studies on focal adhesions. Depending on the specific knockdown, focal adhesions can get up or down regulated, in good agreement with recent experimental findings. The impact of force on the assembly and maturation process is investigated for different force models (slip and catch bonds) that can lead to markedly different phenotypes. Second we address the maturation of focal adhesions in spatial detail with a particle-based simulation reflecting the spatial-temporal coordination close to the leading edge of the cell.

BP 24.10 Wed 17:30 Poster C

Measuring viscoelasticity in the extracellular space upon particle binding — •Felix Jünger and Alexander Rohrbach — Lab for Bio- and Nano-Photonics, University of Freiburg, Georges-Koehler-Allee 102, 79110 Freiburg, Germany

The cytoskeleton is a highly dynamic structure present in all cells, consisting of various kinds of filaments. It is responsible for movement, shape and division of cells as well as for particle uptake and transport processes inside the cell. Still, many principle questions remain open about the mechanics of particle uptake and the driving forces. What is the role of the membrane, the actin network, the myosin motors and the interplay among them?

Macrophages are essential components of the mammalian immune system, responsible for internalizing pathogens via phagocytosis. In our work we perform micro-rheological experiments on J774 mouse macrophages to investigate the viscous and elastic properties of the extracellular space prior to phagocytosis - parameters that the cell can actively control by reorganizing its actin cytoskeleton. We use photonic force microscopy (PFM) to analyse the temporal fluctuations of an optically trapped bead, which is approached to a cell membrane. The motion of the bead is tracked interferometrically in three dimensions with nanometer precision and on a microsecond time scale. The viscous modulus $G''(\omega)$, but also the elastic modulus $G'(\omega)$ can be obtained by analyzing the fluctuation data on a broad spectral bandwidth ω. We have measured several bead-cell arrangements and developed first simple theoretical models that help explain our experimental findings.

BP 24.11 Wed 17:30 Poster C

Vimentin structure in human mesenchymal stem cells depends on substrate elasticity — •Jennifer Radwitz — Georg-August-Universität, Göttingen, Germany

Human mesenchymal stem cells are multipotent adult stem cells that can differentiate into several cell types, e.g. bone, muscle, cartilage. The differentiation process is usually driven biochemically by growth factors but can also be induced mechanically by changing the elasticity of the microenvironment. Structural integrity and mechanosensing of cells is sustained mainly by the cytoskeleton, which consists of acto-myosin structures, intermediate filaments (IFs) and microtubules. Contributions by microfilaments and microtubules are extensively studied but the class of IFs, in mesenchymal cells represented mainly by vimentin, is lesser explored.

By varying the Young's modulus E of the substrates we mimic different mechanical environments. Cells are transfected to express eGFP-vimentin which can be observed in a fluorescence microscope. In long-term life cell measurements we record the vimentin structure and analyze its dynamics to elucidate its contribution to the mechanical coupling of cell and matrix.

We present data showing that vimentin structure depends on substrate elasticity and develops temporally different than actin fibers, as demonstrated with co-transfected cells. Correlating the structure and dynamics with matrix elasticity will help us to dissect the contribution of vimentin filaments to the complex cytoskeletal network.

BP 24.12 Wed 17:30 Poster C

Increased Stiffness of Neutrophils after Activation by Transfusion Related Acute Lung Injury-Relavant Antibodies — •Michael Glaubitz[1], Tom Berthold[2], Christiane A. Helm[3], Mihaela Delcea[1], and Andreas Greinacher[2] — [1]ZIK HIKE - Centre for Humoral Immune Reactions in Cardiovascular Diseases, University of Greifswald — [2]Department of Transfusion Medicine, University of Greifswald — [3]Department of Physics, University of Greifswald

Transfusion related acute lung injury (TRALI) is a severe adverse effect of blood transfusion. A subgroup of TRALI is induced by antibodies directed against alloantigens on neutrophils, a subgroup of the granulocytes. TRALI is believed to occur in approximately one in every 5000 transfusions. Besides neutrophil aggregation, the neutrophils elasticity could be critical for the development of an acute lung injury, as stiffer neutrophils might get stuck in the narrow microvasculature of the lung. Using colloidal probe or tippless Atomic Force Microscopy (AFM) cantilevers to compress the cells, the influence of TRALI-relevant antibodies (HNA-3a) on the stiffness (Young's modulus E) of neutrophils is investigated. The AFM indentation measurements are fitted to the Hertz model. The stiffness of neutrophils increased after incubation with HNA-3a. The parameter incubation time was investigated and found to be relevant. These findings give insights in the etiology of TRALI.

BP 24.13 Wed 17:30 Poster C

The actin cytoskeleton of chemotactic amoebae operates close to the onset of oscillations — Christian Westendorf[1], •Jose Negrete Jr[1], Albert Bae[1], Rabea Sandmann[1], Eberhard Bodenschatz[1,2], and Carsten Beta[1,3] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), Göttingen — [2]Laboratory of Atomic and Solid-State Physics, Cornell University, USA — [3]Institute of Physics and Astronomy, University of Potsdam

The rapid reorganization of the actin cytoskeleton in response to external stimuli is an essential property of many motile eukaryotic cells. Here, we report evidence that the actin machinery of chemotactic Dictyostelium cells operates close to an oscillatory instability. When aver-

aging the actin response of many cells to a short pulse of the chemoattractant cAMP, we observed a transient accumulation of cortical actin reminiscent of a damped oscillation. At the single-cell level, however, the response dynamics ranged from strongly to weakly damped oscillations. Furthermore, in a small subpopulation, we observed self-sustained oscillations in the cortical F-actin concentration. To substantiate that an oscillatory mechanism governs the actin dynamics in these cells, we systematically exposed a large number of cells to periodic pulse trains of different frequencies. We propose a model based on a time-delay in the regulatory network of the actin system. The model was quantitatively tested with experiments performed with cells that express GFP-tagged fusion in proteins that enhance the disassembly of actin filaments and thus allow us to estimate the delay time in the regulatory feedback loop.

BP 24.14 Wed 17:30 Poster C

Spatial versus temporal gradient stimuli in eukaryotic chemotaxis — •Alexander Anielski, Eva Pfannes, and Carsten Beta — Institute of Physics and Astronomy, University of Potsdam, Germany

Chemotaxis, the directed movement of a cell in response to a chemical gradient, is a fundamental property that governs numerous essential processes like wound healing, cancer metastasis, and embryonic development. Here, we present for the first time an experimental setup to separately address the dependencies of the chemotactic motion on the average background concentration and on the gradient steepness. In particular, this setup allows us to investigate the role of spatial versus temporal sensing. Our method relies on a computer controlled motorized microscope stage to compensate chemotactic cell movement in response to different stimuli. We use the controlled photolysis of caged compounds in a microfluidic chamber to address single cells with well-controlled concentration signals in space and time (flow photolysis). We show results from experiments with the social amoeba Dictyostelium discoideum to exemplify the role of spatial versus temporal gradient sensing in this widely used model organism of eukaryotic chemotaxis.

BP 24.15 Wed 17:30 Poster C

Amoeboid motion based on membrane folds that are driven by self organized actin waves. — •Matthias Gerhardt, Michael Walz, and Carsten Beta — Institut für Physik und Astronomie, Karl-Liebknecht-Strasse 24/25, 14476 Potsdam, Germany

We observed the movement of small particles enclosed in between the bottom membrane of a large electrofused Dicyostelium cell and the substrate surface. Self-organized waves generated by the actin network inside the cell were reliably pushing the particles forward, indicating that actin waves are generating forces against the cell membrane to push the cell forward. A vertical scan through the self-organized waves revealed that under certain conditions, waves can locally lift the cell membrane to form a small cavity in between the membrane and the substrate surface. These observations led us to propose a novel mechanism for amoeboid motion based on the wave-driven motion of membrane folds across the bottom surface of the cell. We have implemented a simple computer model that consists of a virtual membrane driven by the waves of an excitable FitzHugh-Nagumo system. Depending on the choice of parameters and initial conditions, the virtual membrane was found to move in the direction of wave propagation along either linear or curved trajectories.

BP 24.16 Wed 17:30 Poster C

Dynamics of membrane tubes filled with an active gel — •Dominic Jourdain and Karsten Kruse — Theoretische Physik, Universität des Saarlandes, Postfach 151150, 66041 Saarbrücken, Germany

Cellular systems display a multitude of tubular protrusions, e.g., filopodia, axons or stereocilia. These structures are essentially cylinders delimited by a lipid membrane and filled with cytoskeletal filaments. The intrinsic activity of such protrusions can induce mechanical instabilities. For example, peristaltic shape undulations of axons have been observed subsequent to osmotic perturbations [1]. To further understand possible mechanical instabilities of tubular protrusions, we study the dynamics of active gels inside tubular membranes. Cytoskeletal dynamics are described on a continuum level and on macroscopic length and time scales using a two-fluid hydrodynamic theory. We find that sufficiently large active stresses in the gel induce peristaltic instabilities.

[1] Pullarkat et al., *Phys. Rev. Lett.* **96**, 048104 (2006)

BP 24.17 Wed 17:30 Poster C

Using Scanning-Ion-Conductance-Microscopy to probe the axon initial segment of hippocampal neurons — •Ulrich Fromme[1], Christopher Dilip[2,3], Andreas Neef[2,3], and Christoph Schmidt[1] — [1]Drittes Physikalisches Institut, Fakultät für Physik, Georg-August-Universität, Göttingen — [2]Bernstein Center for Computational Neuroscience, Göttingen — [3]Max Planck Institute for Dynamics and Self-Organization, Göttingen

Scanning-Ion-Conductance-Microscopy (SICM) is a scanning-probe-microscopy which allows topographic imaging of living cells with resolutions superior to most optical methods. Its probe consists of an electrolyte-filled glass pipette as used in patch-clamp recordings, so that it can also be used for electrophysiological experiments. By combining SICM with fluorescence microscopy, specific stained structures can be indentified and imaged with SICM. In this work we used fluorescently labeled antibodies against Neurofascin, which is predominantly expressed at the Axon-Initial-Segment (AIS). This allows the identification of the AIS in live, cultured hippocampal neurons so that the surface structure can be imaged with lateral resolutions around 50 nm, and axial resolutions better than 10 nm. Electrophysiological measurements can then be done with the same piezo-driven pipette resulting in the same high precision. This way it is possible to combine structural information with electrophysiological information with high resolution. The shapes of extracellular action potentials can thus be recorded at various positions along the cell, which gives more information on ion current densities and kinetics than standard whole cell recordings.

BP 24.18 Wed 17:30 Poster C

High-speed video microrheology in syncytial Drosophila embryos — •Alok D. Wessel[1], Mahesh.G. Reddy[2], Jörg Grosshans[2], and Christoph F. Schmidt[1] — [1]Drittes Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Zentrum für Biochemie und Molekulare Zellbiologie, Georg August-Universität Göttingen, Germany

In early development, Drosophila melanogaster embryos are in a syncytial stage, i.e. multiplying nuclei are not yet separated by membranes, but are interconnected by cytoskeletal polymer networks consisting of actin and microtubules. Between division stages 9 and 13, nuclei and the cytoskeletal network form a well-ordered 2D cortical layer.

To understand the underlying mechanical properties and dynamics of this self-organizing "pre-tissue", we measure shear moduli of the interior of the embryo and its cortical layer by high-speed video microrheology. We record position fluctuations of injected micron-sized fluorescent beads with a high-speed camera at kHz sampling frequencies.

The interior of syncytial embryos shows a homogeneous, viscously dominated behavior, whereas in the actin-rich outer parts, near the nuclear layer, we see a viscoelastic response. Furthermore we are able to resolve temporal variations of the shear modulus inside the layer during the coordinated nuclear division cycle, e.g. viscosity becomes about three times higher than during interphase.

BP 24.19 Wed 17:30 Poster C

Bestimmung der Wärmeleitfähigkeit von Pflanzengewebe mit Thermomikrokapillaren — •Waldemar Wedel[1], Miriam Giesguth[2], Haleh Ebrahimian[1], Katharina König[2], Karl-Josef Dietz[2], Günter Reiss[1] und Simone Herth[1] — [1]Dünne Schichten & Physik der Nanostrukturen, Universität Bielefeld, Deutschland — [2]Biochemie und Physiologie der Pflanzen, Universität Bielefeld, Deutschland

Die Bestimmung der Körpertemperatur ist eine seit Jahrhunderten bekannte Methode. Neu hingegen ist die Messung der Temperatur in einzelnen Zellen. Mittels zwei verschiedener metallbeschichteten Glaskapillaren ist es nun möglich, sowohl lokal Wärme zu erzeugen als auch diese zeitgleich zu messen. **** Diese Thermomikrokapillaren (engl. Thermomicrocapillary, TMC) basieren auf dem Seebeck-Effekt (Messen) bzw. dem Joule-Effekt (Heizen). Die nanometerdicken Metallschichten Ni und NiCr (Typ K) bzw. Ta sind gegenüberliegend als schmale Linien auf der Kapillare aufgedampft. Die TMC macht aufgrund ihrer Spitze das reproduzierbare Einstechen in einzelnen Zellen möglich. In diesem Beitrag wird die Kombination der beiden TMCs zur Bestimmung der Wärmeleitfähigkeit von Pflanzengeweben demonstriert. Dazu wurde eine Heiz- sowie eine Messkapillare in das entsprechende Gewebe eingestochen und eine Spannung an die Heizkapillare angelegt, die zu einer Temperaturerhöhung von 20 °C führte. Der Temperaturverlauf wurde in mehreren definierten Abständen von

der Wärmequelle parallel mit der Messkapillare aufgezeichnet und mit mathematischen Methoden ausgewertet.

BP 24.20 Wed 17:30 Poster C

Persistent motion in the crowd - The role of superdiffusivity in cell colony dynamics — •Patrick Krauss, Janina Lange, Claus Metzner, and Ben Fabry — Department of Physics, Biophysics Group, Friedrich-Alexander University, Erlangen, Germany

We study the 3D growth dynamics of circular tumor colonies on planar substrates. By tracking the motion of single cells within dense colonies, cell trajectories were found to have a surprisingly high degree of directional persistence, with a mean squared displacement (MSD) increasing as a fractional power of lagtime. The fractional exponent of the MSD, as well as the distribution of migration directions, depend systematically on the radial position within the colony. This is a qualitative difference to liquid spreading models of tumor growth, were the particles search for a global low energy configuration by non-directional diffusion. Using a generalized Molecular Dynamics method, we study the relation between directional persistence, cell-cell- and cell-surface-interactions, cell proliferation, and the resulting 3D morphology of the colony. Results are compared to experimental data from different cell lines.

BP 24.21 Wed 17:30 Poster C

Plectin contributes to the mechanical stability of keratinocytes and myoblasts — •Navid Bonakdar[1], Achim Schilling[1], Pablo Lennert[1], Michael Kuhn[1], Astrid Mainka[1], Wolfgang Goldmann[1], Gerhard Wiche[2], and Ben Fabry[1] — [1]Biophysics, University of Erlangen-Nuremberg, Germany — [2]Biochemistry and Cell Biology, University of Vienna, Austria

Plectin and its isoforms are promiscuous crosslinkers of actin filaments, microtubules and intermediate filaments (IF) in a wide variety of cell types. In epithelial cells and keratinocytes, it is also found in hemidesmosomes that link the laminin receptor a6b4 with the keratin IFs. Mutations in the plectin gene cause a skin blistering disorder (epidermolysis bullosa) that is also associated with a late-onset of muscular dystrophy. In both disorders, mechanical alterations of the keratinocytes and the myoblasts, respectively, are thought to be ultimately responsible for the pathological manifestation. To test this hypothesis, we measured the mechanical properties of plectin knockout and plectin-expressing mouse keratinocytes and myoblasts with a high force magnetic tweezer device. We found that in plectin-deficient myoblasts, stiffness, tractions, and adhesive strength were about 2-fold reduced, indicating that plectin is important for the mechanical stability of these cells. In contrast, plectin-deficient keratinocytes assessed under similar conditions were found to show other effects. Our results demonstrate that human diseases associated with plectin mutations have a cell mechanical origin, and that plectin affects the cytoskeleton in different cell types in distinct ways.

BP 24.22 Wed 17:30 Poster C

Non-Equilibrium Cell Mechanics Studied with a Dual Optical Trap — •Florian Schlosser, Florian Rehfeldt, and Christoph F. Schmidt — Drittes Physikalisches Institut - Biophysik, Georg-August-Universität Göttingen

It is accepted knowledge that cells sense the mechanical properties of their surroundings, and that many internal cellular processes not only respond to biochemical, but also to mechanical stimuli. Cells generate contractile forces themselves to probe and to adapt to the mechanical properties of their micro-environment. Key players in the generation of contractile forces are acto-myosin structures, such as stress fibers. We aim at elucidating the contributions of acto-myosin fibers to the total force produced by suspending a cell in an idealized geometry between two optical traps. In our setup we attach fibronectin-coated beads to opposite sides of a suspended 3T3 fibroblast cell. We analyze the correlated motion of the two beads at high bandwidth and with pN-resolution by laser interferometry. Using a combination of active and passive microrheology, we can dissect the non-equilibrium fluctuations and simultaneously probe the viscoelastic properties of the cell. Here we present data on contractile forces and elastic properties of the cell. The amount of force fluctuations transmitted to the outside depends on trap stiffness. Biochemical perturbation experiments interfering with the acto-myosin cytoskeleton or microtubules demonstrate the key role of myosin motors for contractile force generation. We used different bead sizes to determine the effect of cell-bead attachment and also tested the cellular response at different temperatures.

BP 24.23 Wed 17:30 Poster C

Integrin dependent mechanical properties of fibroblasts under shear stress — •Fenneke KleinJan[1], Yoojin Lee[1], Reinhard Fässler[2], and Kay Gottschalk[1] — [1]Ulm University, Institute of Experimental Physics, Ulm, Germany — [2]Max-Planck Institute of Biochemistry, Department of Molecular Medicine, Martinsried, Germany

Physical forces are increasingly recognized as an important biological signal. The protein family of integrins are a key element in force sensing, functioning as a bidirectional force signalling protein. They link the cytoskeleton and the extracellular matrix, giving the cells the opportunity to respond to force by adapting the cytoskeletal filaments. However, how the different integrins cooperatively modulate the force response of the cytoskeleton is not understood.

To study the crosstalk between integrin avb3 and a5b1 we use mouse fibroblasts that express only the single integrin or a combination of both. We focused on the local mechanical properties of isolated cytoskeletal filaments using microrheology, studying both fibroblasts under static conditions and under influence of shear stress. Preliminary results show that the avb3 integrin is responsible for reinforcing the network under shear stress. Without it (a5b1 fibroblasts) the network is less elastic with a decreased elastic modulus under stress.

BP 24.24 Wed 17:30 Poster C

Dynamics of Stem Cell Stress Fibers — •Carina Wollnik[1], Ina Schachtschneider[2], Carsten Gottschlich[2], Stephan Huckemann[2], and Florian Rehfeldt[1] — [1]Third Institute of Physics - Biophysics, Georg-August-University, Göttingen, Germany — [2]Institute for Mathematical Stochastics, Georg-August-University, Göttingen, Germany

Mechanical cues can be as important to cell behaviour as biochemical ones. Engler et al. demonstrated that varying the substrate stiffness could guide human mesenchymal stem cells (hMSCs) towards different lineages in the absence of additional biochemical cues. The complex differentiation process takes several days up to weeks, but primary characteristic changes of the cytoskeleton can be detected within the first 48 hours. Here the key players are cytoskeletal structures like stress fibers, composed of actin filaments, actin binding- and crosslinking-proteins, and non-muscle myosin motor-proteins. Stress fibers generate and transmit forces within the cell and to the extracellular matrix.

During the initial adhesion and spreading process the cell area changes as well as the cells' aspect ratio and stress fiber structure. We study the dynamics of these processes to gain a deeper understanding of the differentiation initiation steps. In our experiments we use live-cell imaging of RFP-Lifeact transfected hMSCs and trace the acto-myosin stress fibers with novel sophisticated filament tracking algorithms, which enable us to investigate the dynamics of stress fiber formation that leads to a non-monotonic dependence of stress fiber polarization on the Young's modulus of the underlying substrate.

BP 24.25 Wed 17:30 Poster C

Estimation of Local Cellular Tension with Active Cable Models — Philip Guthardt Torres[1], •Jérôme Soiné[1], Christoph Brand[1], Jonathan Stricker[2], Venkat Maruthamuthu[2], Patrick Oakes[2], Margaret Gardel[2], and Ulrich S. Schwarz[1] — [1]Bioquant and Institute for Theoretical Physics, Heidelberg University, Germany — [2]Institute for Biophysical Dynamics, University of Chicago, USA

The ability to generate intracellular tension is essential for adhesion-dependent tissue cells, allowing them to actively probe and adapt to their mechanical environment. Traction force microscopy on planar elastic substrates has been successfully implemented to reconstruct the cellular traction field, but the correlation with intracellular tension states is largely unexplored. We have developed a procedure to estimate intracellular tension from elastic substrate data by minimizing the difference to the predictions of a theoretical model based on active cable networks. This model has been successfully used before to predict cell shape on micropatterned substrates. We now have extended it to describe not only contractile networks, but also various types of contractile bundles commonly observed in adherent cells. Contractile models are generated from images of adherent cells by segmenting cell shape and actin structures. Subsequent computer simulation of network contraction and parameter optimization allows us to estimate the most likely distribution of tension over the various contractile structures. In the future, our predictions might be compared to experimen-

tal results from laser cutting or force-sensitive fluorescent probes.

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Biologische Neuronen auf elektrischen Leiterbahnen — •Olga Simon[3], Stefan Niehörster[1], Markus Schäfers[1], Marius Schirmer[1], Matthias Schürmann[2], Barbara Kaltschmidt[2], Christian Kaltschmidt[2] und Andy Thomas[1,3] — [1]Universität Bielefeld, Physik, Universitätsstrasse 25, 33615 Bielefeld — [2]Universität Bielefeld, Biologie, Universitätsstrasse 25, 33615 Bielefeld — [3]Universität Hamburg, Angewandte Physik, Jungiusstrasse 11, 20355 Hamburg

Die Synapse ist ein wichtiger Bestandteil in neuronalen Netzwerken, jedoch fehlte bisher ein einfaches, elektrisches Bauteil, welches dieselbe Funktion in einer Schaltung übernehmen kann. Dies erschwert die Entwicklung von Hardware, die die Architektur des biologischen Nervensystems imitiert. Nun haben die Fortschritte auf dem Gebiet der Memristoren das Interesse in künstlichen neuronalen Netzen zusätzlich aufleben lassen. Der Widerstand eines Memristors hängt von seinen bisher eingenommenen Zuständen ab, genau dies kann ausgenutzt werden, um die synaptische Verbindung zwischen zwei Neuronen zu imitieren. Eine Wunschvorstellung wäre die Signalübertragung von einem biologischen Neuron in einen elektronischen Schaltkreis. In diesem Beitrag präsentieren wir erste Ergebnisse zum Wachsen von Nervenzellen auf elektrischen Leiterbahnen. Dabei wird versucht die Biokompatibilität der Unterlage durch geschickte Materialwahl zu beeinflussen. Darüber hinaus wird versucht sicherzustellen, dass nur einzelne Nervenzellen auf die Leiterbahnen aufgebracht werden, um geplant Spike-Detektion den Neuronen zuordnen zu können.

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Fluctuations and differential contraction during regeneration of Hydra vulgaris tissue toroids — •Claus Fütterer[1,2], Michael Krahe[1], Iris Wenzel[1], Kao-Nung Lin[1], Julia Fischer[1], Joseph Goldmann[3], and Markus Kästner[3] — [1]Institut für Experimentelle Physik I, Universität Leipzig, 04103 Leipzig, Germany — [2]Translationszentrum für Regenerative Medizin (TRM), Universität Leipzig — [3]Institut für Festkörpermechanik, Technische Universität Dresden, 01062 Dresden, Germany

While much is known about the physics of single cells, the mechanics of self-organization and regeneration of cells in tissues and cell assemblies is largely unexplored. We studied regenerating tissue toroids from Hydra vulgaris and relate our macroscopic observations to the dynamics of force-generating mesoscopic cytoskeletal structures. Tissue fragments undergo a specific toroid-spheroid folding process leading to complete regeneration towards a new organism. The time scale of folding is too fast for biochemical signalling or morphogenetic gradients which forced us to assume purely mechanical self-organization. The initial pattern selection dynamics was studied by embedding toroids into hydro-gels allowing us to observe the deformation modes over longer periods of time. We found increasing mechanical fluctuations leading to an instability due to a supra-cellular actin ring destabilizing the toroidal symmetry. We discuss the evolution of their power spectra for various gel stiffnesses. Our observations are related to single cell studies which explain the mechanical feasibility of the folding process. In addition, we observed switching of cells from a tissue bound to a migrating state.

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Stochastic dynamics of gliding motility — •Thorsten Erdmann[1,2] and Ulrich S. Schwarz[1,2] — [1]Institute for Theoretical Physics, Heidelberg University, Heidelberg, Germany — [2]BioQuant, Heidelberg University, Heidelberg, Germany

After being injected into the skin tissue of a vertebrate during a mosquito bite, the sporozoite form of the malaria parasite glides through the tissue in order to reach blood vessels. Experimental trajectories reveal strong fluctuations of the speed of the gliding motility. On the sub-second time scale, sporozoites seem to move in a stick-slip fashion. On longer time scales, gliding is arrested by occasional stationary attachments of the rear of the sporozoite. In order to investigate the stochastic dynamics of gliding motility, we derive a model for the propulsion mechanism, in which specialized adhesion molecules bind to the substrate and are displaced relative to the sporozoite body by small groups of non-processive molecular motors. We study the different regimes of movement in dependence on the binding characteristics of the adhesion molecules, which are described as slip bonds as well as catch bonds, and in dependence on the effective processivity and force-velocity relation characterizing the molecular motors. In order to assess the role of elasticity, we also study the motion of stiff segments of the basic model which are elastically coupled to each other.

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Bacterial force spectroscopy: the influence of cell wall proteins on the adhesion process of Staphylococci — •Nicolas Thewes, Peter Loskill, and Karin Jacobs — Saarland University, Experimental Physics D-66123 Saarbrücken

Bacterial adhesion to surfaces is a complex process that depends on many factors such as the type of bacterium, the type of surface [1] and the surrounding medium, as well as the composition of the material [2] and the time of contact.

In this study we show the important role of bacterial surface proteins during the adhesion process to an artificial surface.

Using AFM-force spectroscopy, we studied the differences in the adhesion process of two bacterial strains of the Staphylococcus genus, S. aureus and S. carnosus. Measurements with increasing and decreasing surface delay times showed severe differences due to different cell wall protein compositions. To be more precise, pathogenic S. aureus showed a much higher adhesion capability than apathogenic S. carnosus.

In addition, we developed a new set-up to attach single bacteria to an AFM cantilever which now enables adhesion measurements on a single cell level.

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Automated Optical Stretching — •Roland Stange, Tobias Kiessling, Anatol Fritsch, Susanne Rönicke, and Josef Käs — Institut für Experimentalphysik 1, Leipzig, Deutschland

The mechanical behavior of single eukaryotic cells is known to play a defining role in cell migration, cell division, mechanotransduction, tissue formation and embryogenesis. Thus huge effort was made to develop methods able to test single cell mechanics (e.g.: Optical Stretcher, optical tweezer, atomic force microscope, micropipette aspiration, magnetic beat rheology). Despite the low throughput of these methods it got clear, that cells of the same cell type (e.g. from the same tissue or cell-line) are not mechanically equal, but show a broad, non-Gaussian, asymmetric distribution. To further investigate cell mechanics from a statistical perspective we increased the throughput of the Optical Stretcher technique to 300 cells per hour leading to cell counts of more than 1000 cells for a simple measurement. By measuring fully automated, human bias is drastically reduced and resulting distributions are smooth and reliable due to standard errors smaller than 5%.

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Novel elastic force sensors for live cell investigations — •Sören Björn Gutekunst, Julia Reverey, and Christine Selhuber-Unkel — Christian-Albrechts-University Kiel, Institute for Materials Science, Germany

Phagocytosis is an essential mechanism found in many cell types. It is of key importance for the functioning of biological systems and tissues and plays a significant role for the immune system. So far, the forces acting during the uptake of target cells and artificial particles are still not known. It can be suggested from electron microscopy that pathogenic amoebae such as Acanthamoebae exert comparably large forces during the phagocytosis of target cells. In order to elucidate the complexity of such force generation events during phagocytosis in different cellular systems and to gain further insight into the underlying processes, we fabricate elastic polyacrylamide beads (EPABs). To this end, we transfer the concept of traction force microscopy into the third dimension and synthesize fluorescent elastic polyacrylamide beads (EPABs) with incorporated fluorescent nanoparticles by means of inversed emulsion polymerization. The elasticity of the EPABs can be changed by varying the amounts of crosslinker and is characterized with AFM. Our goal is to finally be able to relate changes in particle shape to the forces exerted by cells in a bead deformation assay (BDA). We will in particular use this method to investigate target cell killing and uptake in Acanthamoebae.

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Blood platelets - a model system for understanding cellular mechanics — •Aishwarya Paknikar, Sarah Schwarz G. Henriques, Rabea Sandmann, and Sarah Köster — Institute for X-Ray Physics, Georg-August-Universität Göttingen, Germany

Platelets get activated during an injury, change their shape and rearrange their actin-myosin cytoskeleton to generate forces, resulting in contraction. The mechanical principles underlying this dynamic

process are poorly understood. The average total traction force of a single platelet on a soft polyacrylamide (PAA) substrate (elasticity ˜4 kPa), measured by traction force microscopy (TFM) is ˜34 nN. Immunostaining experiments also indicate that the platelet cytoskeletal reorganization is dependent on the substrate stiffness and myosin contributes majorly to the total force generation, leading to some open questions. Firstly, the mechanical response of platelets to different substrate stiffness is elusive. We are analyzing this influence of the substrate stiffness on the spreading of single platelets by varying the substrate elasticity within the physiological range (1-100 kPa). Secondly, the extent of contribution of other, myosin-independent forces to the total measured forces is unclear. Hence, we inhibit platelet myosin by blebbistatin, and simultaneously record the platelet force fields by TFM. We have designed an efficient microflow setup that allows for the defined application of blebbistatin to the platelets adhered to PAA substrates during an ongoing TFM recording. Our experimental findings aim at building a mechanical model for platelet activation.

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Quantification and Simulation of Depletion Induced Red Blood Cell-Cell Adhesion — •Elisabeth Eckle, Richards Grzibovskis, Patrick Steffen, and Christian Wagner — Saarland University, Saarbrücken, Germany

Interactions between cellular components of blood such as aggregation, agglutination or adhesion of cells are observed in a variety of normal and pathological conditions like, for example, rouleaux formation, platelet adhesion and aggregation in both thrombosis and haemostatic clot formation. The aggregation of erythrocytes can be seen if the red blood cells are re-suspended in electrolyte solutions containing neutral macromolecules like dextran. The aggregation of erythrocytes is completely reversible and the disaggregation of these rouleauxs is readily achieved by shearing the suspension. In this study, AFM based single cell force spectroscopy was used to investigate the interaction of single red blood cells in various dextran concentrations. To numerically simulate this interaction, a mathematical model based on free energy minimization was formulated. The equilibrium shape of red blood cell was obtained by means of the minimization of the surface bending energy functional and the interaction supports via the interaction potential. The calculated results have been compared with the experimental results.

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Mathematical Modelling of the Surface Change of Erythrocytes due to Mechanical Influences — •Elisabeth Eckle and Richards Grzibovskis — Saarland University, Saarbrücken, Germany

Interactions of erythrocytes with artificial surfaces (e.g. specially prepared glass or a mesh of microfibers) and between themselves attract a lot of attention from both experimental and modeling communities. Besides rapid changes in the shape of the cell, these phenomena feature forming of contact areas between the cell and the surface in question or another cell. In spite of the overwhelming biochemical complexity of an erythrocyte, simple bilayer membrane models are widely used to gain an insight into a variety of processes it is involved in. We consider the classical Helfrich model of bilayer membranes with additional contact energy terms as well as total volume and surface area constraints. The equilibrium shapes of the cell are obtained numerically through a proper FEM discretization of the weak formulation of the gradient flow for the resulting energy functional. Computations are performed in three space dimensions. We study properties of the model by exploring its results for different physical parameters, discretizations, and configurations of the artificial surfaces.