BP 11: Cytoskeleton

Time: Tuesday 9:30–11:30 Location: H44

Invited Talk BP 11.1 Tue 9:30 H44

Network connectivity determines the mechanisms responsible for cytoskeletal elasticity — •Martin Lenz — Université Paris-Saclay, CNRS, LPTMS, 91405, Orsay, France — PMMH, CNRS, ESPCI Paris, PSL University, Sorbonne Université, Université Paris-Cité, F-75005, Paris, France

Much of the cell's mechanics is dictated by the properties of its cytoskeleton, a dynamic collection of semiflexible filaments. Here we review both old and new results on the emergence of its large-scale elasticity from the filaments' individual mechanical properties. We emphasize the role of the network's connectivity in determining the underlying physical mechanism. At high connectivity or under high stress, the tensile strength of the filaments dominate. Moderately coordinated networks, on the other hand, are governed by the filaments' bending elasticity. Finally, we discuss the very low coordination of branched actin networks, and argue that it implies that interfilament contacts play a major role in its response. This makes the mechanics of these networks analogous to that of a ball of unspun sheep's wool under compression.

BP 11.2 Tue 10:00 H44

Buckling action of molecular motors damages microtubules beyond self-repair — •Shweta Nandakumar[1], Jonas Bosche[1], Morgan Gazzola[2], Mirko Wieczorek[1], Mona Grünewald[1], Manuel Thery[2], Reza Shaebani M[1], Ludger Santen[1], Stefan Diez[3], and Laura Schaedel[1] — [1]Center for Biophysics, Saarland University, Germany — [2]IPGG, Paris, France — [3]B-CUBE,TUD Dresden. Germany

Microtubules (MTs) are rigid, hollow biopolymers that constitute a key component of the cytoskeleton, essential for cellular processes such as mitosis, intracellular transport, and migration. Despite their large bending rigidity, MTs often adopt highly curved conformations, indicating that they are exposed to significant mechanical forces in cells. These forces typically arise from molecular motor proteins like kinesin.

In this study, we investigated microtubule damage and subsequent self-repair as a result of both bending as well as dynamic buckling using kinesin motor proteins in vitro. We reveal that motor-induced buckling imposes massive damage on MTs, occasionally leading to the renewal of majority of the MT lattice visualised by the incorporation of new tubulin subunits into the damaged regions. We find that at high motor densities, MT damage exceeds self-repair and leads to frequent MT breakage.

Our results highlight the impact of mechanical forces, which significantly speed up MT damage and self-repair, on MT integrity. Our findings provide a framework for understanding how cells maintain MT function under repeated mechanical stress.

BP 11.3 Tue 10:15 H44

Active self-organization of focal adhesions driving cell shape changes — •waleed ahmad mirza, matt govendir, alejandro torres-sánchez, and maria bernabeu — European Molecular Biology Laboratory, Barcelona

Focal adhesions (FAs) are dynamic protein complexes that mediate the interplay between the actin cytoskeleton and the extracellular matrix (ECM), enabling cells to sense and respond to mechanical and biochemical cues. These complexes drive essential processes such as cytoskeletal reorganization, cell shape modulation, and migration. To investigate these processes, we developed an active gel mathematical model that couples the dynamics of FAs, actin cytoskeleton, and cellular shape changes, capturing the three-way interplay between these components. Numerical solutions of the model successfully recapitulated experimental observations, demonstrating its ability to predict how cells adapt to mechanical and topographical cues. Specifically, the model reproduced key phenomena such as the influence of substrate stiffness on FA dynamics, with stiffer substrates promoting larger, more stable FAs, aligned stress fibers, and enhanced cell motility. It also captured how anisotropic ECM features, such as aligned collagen fibers or patterned topography, direct cytoskeletal organization and cell alignment. Additionally, the model demonstrated how curvature and shear flow provide critical mechanical cues that shape cellular morphology and behavior. This work provides a novel framework for understanding the mechanistic feedback loops underlying cell-ECM interactions and highlights the central role of FAs in regulating cellular behavior.

BP 11.4 Tue 10:30 H44

Interactions between single actin and vimentin filaments — •Pallavi Kumari and Sarah Köster — Institute for X-Ray Physics, University of Göttingen, Germany

The cytoskeleton plays a crucial role in maintaining cellular structure, mechanics, and function. Recent advances suggest that the diverse tasks of the eukaryotic cytoskeleton depend on the interactions between its filamentous components - microtubules, actin filaments, and intermediate filaments. Despite a growing number of studies to better understand these interactions, it remains unclear whether actin and intermediate filaments interact directly without an auxiliary protein. Previous in vitro studies on reconstituted mixed filament networks have reported contradictory results. To clearly resolve this contradiction, it is essential to further simplify the system down to the single filament level. Here, we present a study on the direct interactions between actin filaments and vimentin intermediate filaments at the single filament level, examining the effects of different ions at varying concentrations on the interaction force. We employ quadruple optical tweezers combined with confocal microscopy and microfluidics to precisely control the conditions for the interaction of the two reconstituted protein filaments, visualize the interactions, and measure the forces involved. Our research provides direct indications of interactions between actin and vimentin filaments. Our findings will provide important insight that will help to unravel the interplay of cytoskeletal filaments at the network level.

BP 11.5 Tue 10:45 H44

Active Gel Theory for Cell Migration With Two Myosin Species — •Nils Winkler, Oliver M Drozdowski, Falko Ziebert, and Ulrich S Schwarz — Institut für theoretische Physik und Bioquant, 69120 Heidelberg

Motility of animal cells is essential for a wide range of biological phenomena, from the development of embryos to the spread of cancer. It is mainly driven by flow of the actin cytoskeleton, which in turn is generated by both actin polymerization and actomyosin contractility. Non-muscle myosin II is present in three different isoforms, but it is unclear what their respective roles are. Starting from phenomenological binding kinetics that include the competition of the myosin motors for binding sites through excluded volume interactions, we derive an active gel model for cell migration that includes a fast and a slow variant, corresponding to the non-muscle myosin II isoforms A and B, respectively. We find non-linear diffusion laws and predict species gradients that agree with experimental observations. Through numerical continuation and simulations, we identify a pull-and-push mechanism that can produce different system states, including steady migration as well as cell oscillations in length and velocity.

BP 11.6 Tue 11:00 H44

Keratin networks in epithelial cells under strain — •Ruben Haag, Ruth Meyer, and Sarah Köster — Institute for X-Ray Physics, University of Göttingen, Germany

The cytoskeleton is mainly made up of microtubules, actin and intermediate filaments (IFs). The composition of the IF-network is cell-type specific and influences the viscoelastic properties of cells. In epithelial cells, the keratin IF network connects to desmomes in the cell membrane, while in the cell center keratin IFs can bind to the nuclear lamina via plectin proteins. The keratin IF network thus forms a mechanical link from the nucleus to the cell membrane. In in-vitro experiments, it was previously observed that IFs, unlike actin filaments, resist being stretched to high strains. We now ask whether this force-extension behavior of IFs is also relevant in whole cells and, more specifically, if mechanical signals from outside the cell are transmitted to the nucleus via the keratin IF network. To answer this question, we stretch cells both uniaxially to linear strains of 80 % and equibiaxially to area strains of 87 %. During stretching, we image the nuclei, deconvolve the images to recover their 3D shape, segment the nuclei and track each nucleus during stretching. This procedure allows us to investigate their deformation at increasing strain. We compare wild type epithelial cells to keratin knockout cells to study the influence of the keratin IF network on the nuclei. We find that the deformation orthogonal to the

stretching direction of the nuclei matches the deformation of the cell better in the keratin wild type cells. Our results suggest, that the keratin network helps to adapt the nucleus to mechanical perturbation.

BP 11.7 Tue 11:15 H44

Investigating the interaction between two single heart cells through TNTs using ROCS and Fluorescence microscopy — •Arash Felekary and Alexander Rohrbach — Lab for Bio and Nano Photonics, IMTEK, Freiburg, Germany

Cell-cell communication is vital for biological processes, particularly in the heart. Tunneling nanotubes (TNTs), dynamic and thin protrusions, facilitate cellular interactions by transferring organelles, including mitochondria. To investigate TNT composition and their roles in cardiac fibroblast (FB) communication, we employed Rotating Coherent Scattering (ROCS) microscopy, a label-free super-resolution technique, in addition to Fluorescence microscopy. ROCS enables up to 100 Hz recordings of lamellipodia dynamics along TNTs, and 3D imaging across different z-planes up to 6μm in depth, which is critical for visualizing TNTs. We observed a linear correlation between TNT density and lamellipodia motion velocity. Lamellipodia, driven by actin polymerization and branching via Arp2/3 activation, play a key role in FB migration and interaction. Collagen staining demonstrated that TNTs and lamellipodia interact with collagen fibers, a major component of the extracellular matrix (ECM). This interaction not only influences ECM remodeling, but also activates actin branching signals that enhance FB migration and protrusion dynamics. In this presentation, we investigate the coordinated roles of TNTs, lamellipodia, and collagen in regulating FB interaction and migration, offering new insights into heart tissue repair.