BP 15: Tissue Mechanics II

Time: Wednesday 10:30–12:15 Location: BAR Schö

BP 15.1 Wed 10:30 BAR Schö

Hydrostatic pressure and lateral actomyosin tension control stretch and tension of the basement membrane in epithelia — •Karla Yanin Guerra Santillan[1,3], Elisabeth Fischer-Friedrich[1,2], and Christian Karla Yanín[1,3] — [1]Cluster of Excellence Physics of Life, Technische Universität Dresden, Dresden, Germany. — [2]Biotechnology Center, TU Dresden, Tatzberg, 01307 Dresden, Germany — [3]School of Science, Technische Universität Dresden, Dresden, Germany

The shaping of epithelial tissues into functional organs often depends on asymmetries in mechanical tension present at the apical and basal sides of cells. Contraction of an actomyosin meshwork underlying the apical side of cells is known to generate apical tension. The basal side of cells is also associated with an actomyosin meshwork, but it is, in addition, connected to a specialized extracellular matrix, the basement membrane. However, how basal tension is generated, and the role of the basement membrane in this process, are often disregarded and not well understood. Here, using atomic force microscopy, we measure mechanical tension in the basal surface of the wing disc epithelium of Drosophila. We find that basal tension depends crucially on the basement membrane with additional contributions of the actomyosin cytoskeleton. Further, performing localized optogenetic activation of actomyosin contractility and osmotic shocks, we deduce that elastic basement membrane stretch is generated by intracellular hydrostatic pressure and lateral actomyosin contractility.

BP 15.2 Wed 10:45 BAR Schö

Noisy growth and buckling in soft tissues — •Rahul G. Ramachandran[1], Ricard Alert[1,2], and Pierre A. Haas[1,2,3] — [1]Max Planck Institute for the Physics of Complex System, 01187 Dresden, Germany — [2]Center for Systems Biology Dresden, 01307 Dresden, Germany — [3]Max Planck Institute of Molecular Cell Biology and Genetics, 01307 Dresden, Germany

The generation of curved tissue shapes such as the villi of the gut or the gyrations of the brain has been associated with buckling instabilities that release elastic stresses accumulated by constrained growth. However, most mechanical theories for these morphogenetic processes assume homogeneous growth and mechanical properties, while these parameters often exhibit strong fluctuations in biological systems. Here, we therefore study a minimal mechanical model of these fluctuations: We analyze the buckling of a growing, neo-Hookean rod through nonlinear finite-element simulations. Fluctuations are introduced as spatial inhomogeneities of the growth tensor and the material parameters. Our results show that stronger growth fluctuations promote buckling by decreasing the buckling threshold. We interpret these results using strain energy distribution from homogenous, patterned and random growth simulations and validate them using analytical calculations.

BP 15.3 Wed 11:00 BAR Schö

Viscoelastic measurements in glioblastoma-infiltrated cerebral organoids — •Michael Frischmann[1], Elijah Shelton[1], Sofia Kalpazidou[2], Jovica Ninkovic[2,3], and Friedhelm Serwane[1,3] — [1]Faculty of Physics and Center for NanoScience, LMU Munich, Germany — [2]Biomedical Center, LMU Munich, Germany — [3]Munich Cluster for Systems Neurology, Munich, Germany

The glioblastoma is a malignant neuroepithelial brain tumor with median survival rates of a few months without treatment. One reason is the rapid infiltrative growth with active destruction of brain tissue and the resulting necrotic debris. Glioblastomas are well described from a molecular biology perspective. However, little is known about their mechanical properties which directly affect the tumor's ability to spread into adjacent tissues. I will present measurements of mechancial properties of glioblastoma and its surrounding tissue. To study tumor biophysics in an accessible in vitro system, we use cerebral organoids grown from induced pluripotent stem cells (iPSCs) with implantet glioblastoma cells. To determine the mechancial properties of the tumor and its microenvironment, we use magnetic microdroplets that we inject into the tissue via microneedles. Actuated by a homogeneous magnetic field, the droplet deforms and its deformation is recorded via a confocal microscope. The dynamic deformation is used to infer the viscoelastic properties of physiological and pathological tissue, as well as boundary regions. The recorded data allows us to establish a viscoelastic model of glioblastoma and to develop a mechanical understanding how brain tumors infiltrate their environment.

15 min. break

BP 15.4 Wed 11:30 BAR Schö

Density-dependent active flow transition of biological tissues — •Mathieu Dedenon[1,2], Carles Blanch-Mercader[3], and Karsten Kruse[1,2] — [1]Department of Biochemistry, University of Geneva, 1211 Geneva, Switzerland — [2]Department of Theoretical Physics, University of Geneva, 1211 Geneva, Switzerland — [3]Laboratoire Physico-Chimie Curie, Institut Curie, Université PSL, Sorbonne Université, CNRS UMR168, Paris, France

Biological tissues of elongated cells can spontaneously flow thanks to active stresses, as predicted by 2D generalized hydrodynamics. This effect has been recently confirmed experimentally with confined C2C12 myoblasts.

Under circular confinement, those cells are observed to undergo tissue rotation at confluence. Cells have maximal orientational order at the disc periphery, forming a spiral +1 topological defect. However at a later stage, cell density increases and the tissue ceases rotational motion. This transition is accompanied by a reorientation of cells along the radial direction, transforming the +1 defect into a static aster.

To understand density-dependent spiral-aster transitions, we generalize the previously used 2D polar active fluid description to incorporate a generic passive coupling between cell density and polarity fields. Using symmetry arguments, several energy terms are allowed and we explore systematically how such couplings affect the spontaneous flow transition, under which conditions they promote a spiral-aster transition. This work shows that collective motion is not only driven by tissue active stress but is also sensitive to cell density.

BP 15.5 Wed 11:45 BAR Schö

Capturing the mechanosensitivity of cell proliferation in models of epithelium — •Maxime Hubert[1], Kevin Höllring[1], Lovro Nuić[2], Luka Rogić[2], Sara Kaliman[1], Simone Gehrer[1], Florian Rehfeldt[3,4], and Ana-Sunčana Smith[1,2] — [1]FAU Erlangen-Nürnberg, Erlangen, Germany — [2]Ruđer Bošković Institute, Zagreb, Croatia — [3]University of Göttingen, Göttingen, Germany — [4]University of Bayreuth, Bayreuth, Germany

The proliferation of epithelial cells, the process of cell growth and cell division, is affected by the mechanical properties of the surrounding environment. While an extensive literature covers single cell mechanoresponse, information about tissue-wide mechanoresponse are scarce. It is only known that high cell density restricts proliferation and eventually leads to homeostasis. In this presentation, we aim at completing the existing literature by addressing the role of both cell density and extracellular stiffness in the proliferation of cells in epithalial monolayer. Using MDCK-II epithelial tissues stained with EdU we are able to measure the fraction of dividing cells at a given cell density and quantify mechanoresponse. We build a cell-level theory of proliferation based on a two-population description which is compared successfully to the experiments and implemented into simulations. Using experiments and simulations, we also address the role of proliferation in the large scale growth of tissues. A tissue-scale theory of epithelial growth based on the cell-level findings is finally presented. This work provides a first step towards a complete description of proliferation at the tissue scale and its influence on its compartmentalization.

BP 15.6 Wed 12:00 BAR Schö

Quantitative 3D live-imaging of self-organisation in embryonic organoids — •Valentin Dunsing, Sham Tlili, Claire Chardès, Léo Guignard, and Pierre-François Lenne — IBDM & CENTURI, Aix-Marseille University/ CNRS, Marseille, France

The emergence of asymmetries within a mass of equivalent cells is the starting event in the development of embryos, resulting in the formation of the main body axes. Despite its fundamental role, the mechanisms that induce symmetry breaking remain largely unknown because they are difficult to probe in vivo, particularly in mammalian embryos. A promising in vitro model to study such mechanisms are embryonic organoids, which undergo gastrulation-like movements similar to those observed in embryos. We aim to use live imaging to disentangle the

interplay between signaling, cell differentiation and mechanics underlying self-organized symmetry breaking. Currently available imaging platforms are limited to low-throughput 3D or high-throughput 2D imaging. To overcome this limitation, we establish multi-view single-objective lightsheet microscopy, allowing us to image tens of organoids over hours to days with cellular resolution and sufficient temporal sampling to track cells in 3D. We present ongoing efforts using deep learning based segmentation and quantitative image analysis to correlate cellular dynamics and rearrangements with the expression of key differentiation markers during polarization of aggregates. We thereby analyze how spatially localized expression domains and collective cell movements establish symmetry breaking. Finally, we analyze the variability of spatiotemporal patterns across multiple specimen.