BP 29: Posters - Multi-Cellular Systems

Time: Tuesday 14:00–16:00 Location: P2-EG

BP 29.1 Tue 14:00 P2-EG

Stress-Strain Relation in Reconstituted Tissue — •Simone Gehrer[1], Damir Vurnek[1], Sara Kaliman[1], Maryam Aliee[1], Diana Dudziak[2], Bernd Hoffmann[3], Rudolf Merkel[3], and Ana-Sunčana Smith[1,4] — [1]Puls Group, Institute for theoretical Physics, FAU Erlangen — [2]University Clinic Erlangen — [3]ICS-7:Biomechanics, Forschunszentrum Jülich — [4]Division of Physical Chemistry, IRB Zagreb

Epithelial cells form active two-dimensional sheets that are involved in variety of functions like morphogenesis, embryogenesis, wound healing and organ development. Mechanical stress stimulates i.e. processes like growth, proliferation and remodeling of the surfaces.

To study the stress-strain relation in model tissues Madin-Darby canine kidney II cells were seeded on fibronectin coated polydimethylsiloxane elastomer chambers in a droplet wise manner. The resulting surface was uniaxially stretched with amplitudes of 0, 10, 20 and 30%. Subsequently the reaction and growth of clusters was imaged in phase contrast on timescales from minutes to days.

We present a comprehensive study of tissue growth after stretching. The change in cell size, elongation and orientation as well as connectivity and relaxation was investigated.

BP 29.2 Tue 14:00 P2-EG

Predicting cell colony growth from single cell proliferation and migration behavior — •Nico Wunderling, Julian Übelacker, Janina Lange, Ben Fabry, and Claus Metzner — Biophysics, University of Erlangen, Germany

The macroscopic growth of cell colonies on planar substrates is driven by the division and migration of individual cells. Experiments show that many qualitative features of the colony growth dynamics, such as a linear growth of the colony radius with time, are universal among many diff erent cell types, thus pointing to a generic mechanism behind this collective phenomenon. Here, we describe colony growth by a celldensity-dependent proliferation and diffusion. Using cells seeded at different confluencies (30-100%), we measure how the proliferation rate and the diffusion constant vary with cell density for three differently metastatic tumor cell lines (HT1080 fibrosarcoma, MDA-MB-231 epithelial breast carcinoma, and MCF-7 epithelial breast carcinoma). We find that cell proliferation saturates at high cell densities in HT1080 and MDA-MB231 cells, but shows a maximum at intermediate cell densities for MCF-7 cells. Cell diffusion is independent of cell density in MDA-MB-231 and MCF-7 cells, but linearly increases with cell density in HT1080 cells. With these experimentally obtained density-dependent proliferation and diffusion profiles, we numerically predict the cell colony growth over several days. In each case, we find a linear growth of the colony radius versus time with a growth speed that closely matches the experimental data, thus demonstrating that colony growth can be predicted from single cell behavior.

BP 29.3 Tue 14:00 P2-EG

Theoretical Model for Absorption Profiles in Xylem Networks — •Felix Meigel and Karen Alim — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Plant leaves receive their supply of nutrients from the soil through sap flow traveling up the plant stem and then being spread out within the leaf through the leaf's vascular network. Within sap flow nutrients are transported by advection and diffusion while they are readily absorbed into the leaf's cells. Assuming that all leaf cells require the same amount of nutrients one would expect the ideal case to be homogeneous absorption of nutrients throughout the entire leaf. Yet, the entire leaf only has one inflow of sap through the single vein connecting it to the plant stem. How must the leaf vascular network be set up such that a single inflow can give rise to homogeneous absorption of nutrients throughout a leaf? We present a model for the sap flow and the resulting absorption pattern in a leaf vascular network. We find that the sap influx rate is the dominating factor. There exists an optimal influx rate that corresponds to the most homogeneous absorption profile. We simplify the flow dynamics in an extended vascular network to a simple leaky pipeline. This toy model allows us to determine a simple scaling law for the optimal influx rate.

BP 29.4 Tue 14:00 P2-EG

Coalescence of bacterial microcolonies reveals liquid-like dynamics — •Tom Cronenberg, Enno R. Oldewurtel, Nadzeya Kouzel, and Berenike Maier — Department of Physics, University of Cologne, 50539 Cologne, Germany

Many bacteria are able to form communities called microcolonies. Within these structured communities they benefit from various advantages including facilitated gene transfer and increased antibiotic resistance. The human pathogen *Neisseria gonorrhoeae* is able to aggregate into spherical microcolonies due to active retraction of its type 4 pili, which is the first step of biofilm formation. Once two microcolonies are within a minimal range, an actively driven fusion process is initiated. To test if the fusion of microcolonies shows liquid-like dynamics, we acquired time lapsed microscopy data of newly formed microcolonies in liquid environment. The contour of fusing colonies was extracted and fitted by an ellipse to calculate the ratio between minor and major axis. According to a model developed by Young, the deformation of a liquid droplet from an ellipse to a sphere is driven by surface tension σ and resisted by viscosity η. Therefore, we used Young's model to characterize the spatio-temporal dynamics of colony fusions quantitatively by calculating the ratio σ/η.

BP 29.5 Tue 14:00 P2-EG

A Computational model of nuclei ordering in early Drosophila embryos — •Franz Kaiser[1], Zhiyi Lv[2], Jörg Grosshans[2], and Karen Alim[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Biochemistry and Molecular Cell Biology, University of Göttingen, Göttingen, Germany

During interphase, nuclei in early *Drosophila melanogaster* syncytial embryos actively arrange in an ordered fashion. Interaction between nuclei in this syncytial embryo through F-actin and microtubule networks is assumed to play an important role for the establishment of nuclei order. However, the observed patterns still lack a physical explanation. Here we develop a theoretical model including passive interactions mediated by the extracellular matrix and active elements arising from microtubule dynamics to explain the observed ordering. We perform computer simulations and quantify the observed degree of orientational order. Results are compared to experimental recordings of tracked nuclei to identify mechanical model parameters. We observe how mechanical properties and nuclei order change between subsequent interphases.

BP 29.6 Tue 14:00 P2-EG

Controllability of discrete pattern formation by local inputs — •Stephan Kremser[1], Tiago Ramalho[1], Hao Wu[2], and Ulrich Gerland[1] — [1]Physics of Complex Biosystems, Physics Department, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany — [2]LOEWE Zentrum für Synthetische Mikrobiologie, Philipps-University-Marburg, Hans-Meerwein-Str. 6, 35043 Marburg, Germany

Controllability is a fruitful concept to explore the extent to which a dynamical system can be steered by external inputs or internal feedback signals. Although it has been applied to a diverse range of problems in science and engineering, the controllability of a large class of dynamical systems, those that describe pattern formation processes, is not well understood, despite the fundamental role of controled pattern formation in biology and technology. Here, we propose a minimal system for studying the control of discrete patterning, based on a one-dimensional cellular automaton model, which has only a finite set of possible update rules that specify its dynamics. The control signals are given by individual cells that are located either within the system or at its boundary. We consider two different control schemes and determine the extent to which the pattern formation process is controllable under a given control scheme.

BP 29.7 Tue 14:00 P2-EG

Direct measurements reveal significant improvement in retinal light transmission due to photoreceptor nuclear inversion — •Kaushikaram Subramanian[1], Martin Weigert[1], Irina Solovei[2], and Moritz Kreysing[1] — [1]Max Plank Institute of Molecular Cell Biology & Genetics, Dresden, Germany — [2]Department of Biology, Ludwig Maximilian University, Munich, Germany

The vertebrate retina bears the odd evolutionary heritage of being inverted, necessitating photons to travel through hundreds of microns of living neuronal tissue before detection by photoreceptor cell (PRC) outer-segments. The large number of PRCs results in densely packed nuclei in the tissue which can potentially scatter light. Postnatal retinal PRC nuclei in nocturnal mammals undergo a hallmark process of inversion in their chromatin architecture [1]. Interferometric measurements and simulations, suggested that this chromatin rearrangement could lead to reduced light scattering and that each nuclei possess optical quality of lenses [2]. Using the concept of modulation transfer, we show that optical transmission of wild type (WT) mouse adult retina is significantly better than a WT retina in its postnatal development stages. Also, WT retina has a significantly higher strehl ratio than retina of a transgenic mouse where this inversion does not take place. We also complement these results with simulations to develop a mechanistic understanding of the light propagation in these tissues and visual behavioral studies. References [1] Solovei et al, Cell, 137(2) (2009) [2] Błaszczak et al, Opt Express, 22(9) (2014)

BP 29.8 Tue 14:00 P2-EG

Cell Jamming: Connecting the Shape and Density Dependences — •Steffen Grosser, Linda Oswald, Jürgen Lippoldt, Paul Heine, and Josef A. Käs — Universität Leipzig, Germany

Cellular dynamics has been shown to display characteristics of jamming transitions which originally had been observed as a function of cell number density (Angelini et al., PNAS 2011). Recently, the Self-Propelled Voronoi (SPV) model has predicted a density-independent transition as a result of the counterplay of adhesion and contractile forces (Bi et al., Nat. Phys. 2015), visible in the dimensionless shape parameter.

We present experimental data for MCF-10A and MDA-MB-231 showing that shape and number density actually evolve in close concert; shape parameters decrease under increasing cell density. This feature, not predicted by the SPV model, happens in both the epithelial and mesenchymal cell lines, albeit with different consequences. Mesenchymal cells strongly delay their jamming transition even under high densities.

BP 29.9 Tue 14:00 P2-EG

Probing liquid-liquid phase transitions via fast and localized temperature stimuli — •Anatol Fritsch[1], Matthäus Mittasch[1], Andrés Diaz[1], Frank Jülicher[2], Anthony Hyman[1], and Moritz Kreysing[1] — [1]MPI of Molecular Cell Biology and Genetics, Dresden — [2]MPI for the Physics of Complex Systems, Dresden

Recent studies report membrane-less organelles (MLO) to show liquid-like behavior formed by phase transition of aqueous solutions. These organelles foster a dynamic, spatially separated platform for important biochemical reactions inside the cell. In *C. elegans* embryos MLOs called P granules segregate asymmetrically and play a key role in the specification of the germ cell fate. We want to shed light on the physical principles underlying this segregation process.

Since liquid-like organelles are formed by phase separation, they should respond to variations in their environment such as changes in pH, salt concentration or temperature. To study the kinetics of MLO phase transition we use temperature as a control parameter for defined changes between the mixed and demixed state. For fast and localized temperature control, we use a custom build IR-laser scanning microscopy setup combined with a Peltier controlled sample stage. Experiments on *in vivo* P granules and corresponding *in vitro* reconstituted systems show fast transition times and allow for the characterization of growth and melting kinetics of the phase separated domains. Furthermore, specific temperature patterns can be used to capture the thermodynamics of P granule segregation inside the embryo.

BP 29.10 Tue 14:00 P2-EG

Mode structure of morphogen transport — •Daniel Aguilar-Hidalgo[1,2], Maria Romanova-Michaelides[2], Marcos González-Gáitan[2], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]University of Geneva

Concentration profiles of specific signaling molecules, also called morphogens, have been identified that control patterning and growth of developing tissues. In this regard, the morphogen transport dynamics defines the shape of the morphogen profile, which has been highlighted as a key factor in a number of growth control mechanisms, hence the importance to understand how molecules are transported in tissues. We propose a general theoretical framework and a novel approach for the study of morphogen transport dynamics in cell monolayer tissues. In particular, we analyze the mode structure of a transport model, where we allow molecules to spread by free diffusion and transcytosis that is a trafficking process in which molecules travel long distances by subsequent rounds of internalization and externalization at different positions in cells. Our theory reveals different transport modes in the system. We discuss how seemingly contradictory interpretation of experiments that measure morphogen transport dynamics (FRAP, FCS) may capture different dynamical modes in the system. Our theoretical framework allows quantifying effective transport parameters as well as rates for elementary transport events, unifying measures from different experimental assays. As a particular case of study, we apply our theory to quantitatively describe the transport of the morphogen Dpp in the Drosophila wing disc.

BP 29.11 Tue 14:00 P2-EG

Scaling of peristaltic waves in slime moulds by a feedback between actin contractions and flow — •Jean-Daniel Julien, Natalie Andrew, and Karen Alim — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

The coordination of movements over macroscopic organisms laking in any neural circuit, such as slime moulds, fungi or plants, is a fascinating yet poorly understood phenomenon. Plasmodial slime moulds grow as networks of tubes whose extent can vary on several orders of magnitude. The coordinated contractions of the tubes lead to the transport of biomass and nutrients over the network. Recent studies of *P. polycephalum* have demonstrated that those waves of contraction scale with the size of the organism in order to optimise the transport. How such a giant cell can perform this scaling independently of its size is unclear. *F. Septica*, another slime mould, displays similar patterns of contractions, and also builds simple networks constituted of a single loop, thus making it ideal to theoretical analysis. By modelling the turnover of the actin cortex at the periphery of the tube and the flow generated by the contractions, we show that a positive feedback between the flow and the wavelength of the peristaltic wave can explain how the mechanical wave scales with the extent of the network.

BP 29.12 Tue 14:00 P2-EG

Protein-protein interactions in developmental cell-cell fusion quantified by fluorescence fluctuation spectroscopy — •Valentin Dunsing[1], Benjamin Podbilewicz[2], and Salvatore Chiantia[1] — [1]Cell Membrane Biophysics, Institut für Biochemie und Biologie, Universität Potsdam — [2]Department of Biology, Technion - Israel Institute of Technology, Haifa

Cell-cell fusion is a universal process in development which is involved in the formation of various organs and tissues. Failure of fusion leads to severe morphogenic disorders. The epithelial fusion failure protein EFF-1 was shown to be necessary and sufficient for fusion in the small nematode C.elegans and cell culture systems. However, its mechanism of action remains poorly understood.

Using fluorescence fluctuation microscopy approaches (Number&Brightness, Scanning FCS) we study the cis- and trans- interactions of EFF-1 and its dynamics in the plasma membrane. We observe a concentration dependent cis-trimerization of the protein in living cells and monitor cell-cell (i.e. protein-protein) trans-interactions by calculating cross-correlation of spectrally separated fluctuations.

Finally, we present an experimental setup to investigate EFF-1 interactions in vivo, i.e. epithelial cell-cell fusions in developing C.elegans embryos.