BP 30: Tissue

Time: Thursday 15:00–17:30 Location: H43

Invited Talk BP 30.1 Thu 15:00 H43

Inversion and perversion in biomechanics: from microscopic anisotropy to macroscopic chirality. — •Alain Goriely — Mathematical Institute, University of Oxford

One of the fundamental problems of bio-physics is to understand the relationship between a microscopic structure and its overall macroscopic response. A paradigm for this problem is chirality. How does a right-handed structure behaves under loads? A simple example motivated by the study of DNA is the extension of a right-handed spring under pure axial load. Would it rotate clockwise or counter-clockwise? Similarly, many plant structures are fibre-reinforced and the problem is to connect the chirality of the fibre with the chirality of the rotation induced by change in pressure. Motivated by different biological experiments on active gels, DNA, plant cell walls, and fungi, I will show that biological systems, through a combination of internal stresses and nonlinear responses offer many puzzling and often counter-intuitive chiral behaviour leading to the interesting possibility of perversion, an inversion in chirality under load or remodeling.

BP 30.2 Thu 15:30 H43

Interplay of tissue extension and pattern formation during vertebrate segmentation — •David J. Jörg[1], Luis G. Morelli[2], Andrew C. Oates[3], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Departamento de Física, FCEyN UBA and IFIBA, Conicet; Pabellón 1, Ciudad Universitaria, 1428 Buenos Aires, Argentina — [3]Max Planck Institute of Molecular Cell Biology and Genetics, Pfotenhauerstr. 108, 01307 Dresden, Germany

During embryonic development of vertebrates, the elongating body axis is segmented into somites, precursors of the vertebrae, which appear sequentially. This process is coordinated by a tissue level patterning system based on cell-autonomous genetic oscillators, the segmentation clock. We develop a continuum theory of coupled phase oscillators that takes into account position-dependent tissue extension. This tissue extension corresponds to a cell flow field that enters the description of the phase dynamics through a convective term. We show that our theory can account for the key features of dynamic gene expression patterns observed in experiments.

BP 30.3 Thu 15:45 H43

Mechanically driven interface propagation between cellular populations — •maryam aliee[1], Jonas Ranft[2], Jacques Prost[3], Jean-François Joanny[2], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]Institut Curie, 26 rue d'Ulm, 75248 Paris cedex 05, France — [3]ESPCI ParisTech, 10 rue Vauquelin, 75231 Paris cedex 05, France

Many biological tissues consist of different cell types. The interface between two cell populations can evolve in time due to the interplay of cell dynamics and tissue mechanics. Here we introduce a continuum description of tissues with two cell types. The balance of cell numbers and the conservation of momentum include source terms, which account for the effects of cell division and apoptosis. We study the case where two cell populations with different homeostatic pressure are separated by an interface. The difference in the homeostatic pressures of two cell types drives the propagation of the interface, corresponding to the invasion of one cell type into the other. The dynamics of the system is described by a generalized version of the Fisher wave equation, which takes into account the coupling between cell number balance and tissue mechanics. We calculate the profile of the moving interface and its velocity as a function of relevant parameters. By linearizing the equations near the unstable front, we can compare our numerical results to analytical solutions. We show that both pulled and pushed front solutions occur, depending on parameter values.

BP 30.4 Thu 16:00 H43

***Physarum polycephalum* Percolation as a Paradigm for Topological Phase Transitions in Transportation Networks** — •Adrian Fessel[1,2], Christina Oettmeier[1,2], Erik Bernitt[1,2], Nils Gauthier[2], and Hans-Günther Döbereiner[1,2] — [1]Institut für Biophysik, Universität Bremen — [2]Mechanobiology Institute, National University of Singapore

As a foraging strategy, the slime mold *Physarum polycephalum* spans an extended vein network. If grown from disconnected pieces, evenly distributed in size, a giant component develops. Using tools from graph theory, this process can be understood as a percolation transition, driven by the distribution of node degrees (Fessel, PRL 109, 2012).

We present two analytical solutions for this topological transition, a two-dim. phase diagram representing the transition as a function of two node degree ratios and a one-dim. solution suitable for our system. Neither biological nor other constraints are taken into account, making the solutions universal for transportation networks, given local connectivity is low.

An experimental indication for universality can be found in vasculogenesis. Various malignant tissues mimic embryos which derive their blood vessels by fusing blood islands, i.e., aggregates of newly differentiated angioblast cells. This process can be studied in vitro by observing the behavior of plated endothelial cells. Reanalyzing such an experiment (Serini, EMBO 22, 2003) we find the same transition.

Due to the universal character of this process we conclude that percolation might serve as a gauge in anti-angiogenic theraphies.

Invited Talk BP 30.5 Thu 16:15 H43

A noisy path to order: refinement of a developing tissue — •Buzz Baum — LMCB, UCL, London, WC1E 6BT, UK

The remarkable complexity we see in the macroscopic biosphere is generated during development. Even though cellular processes are inherently noisy, the complex order we see in multicellular organisms is generated by the actions of semi-autonomous cells working in constant dialogue with one another. Here, I will use two examples from our work in the fly notum that reveal ways in which noise at the cellular level can contribute to the refinement of patterning and cell packing at the tissue scale.

BP 30.6 Thu 16:45 H43

Morphogenesis and ageing of MDCK epithelial tissues depend on substrate elasticity — •Sara Kaliman[1], Christina Jayachandran[2], Damir Vurnek[1], Florian Rehfeldt[2], and Ana-Sunčana Smith[1] — [1]Institute for Theoretical Physics, University Erlangen-Nürnberg, Germany — [2]3^{rd} Institute of Physics-Biophysics, University ofGöttingen, Germany

Morphogenesis of epithelial tissues is the key to understanding tissue development and regeneration, or tumour growth. It is believed to be dominated by intercellular interactions, and hence, independent of substrate rigidity. However, here we show that different regimes of growth occure on soft and hard substrates. Substrates with a rigidity higher than 5 kPa promote radially growing clusters, which in early stages expand exponentially with a persistantly low density of cells. When the cluster radius exceeds 5 mm, its area increases linearly in time. During that period, a bulk tissue of higher density forms in the center of the cluster, whereas the edge remains at a constant low density, independently of the cluster size. On 1 kPa substrates the cells initially form small multilayered dropplets that, if sufficiently large, nucleate a very dense and well structured monolayer in its center. These clusters expand to macroscopic sizes by adopting irregular shapes, while mantaining the initial monolayer morphology. In both cases, tissues age, the signature of which are (i) an inhomogeneous density, and (ii) nuclei that deform strongly due to the substrate sensitive restructuring of the actin cortex. Furthermore, dome-like and tubule-like structures are found on hard substrates, while soft substrates promote anoikis.

BP 30.7 Thu 17:00 H43

Cell Shape and Dynamics on micropatterned Substrates — •Philipp J. Albert and Ulrich S. Schwarz — Institute of Theoretical Physics, University of Heidelberg

Micropatterned substrates have been used for cell normalization and to quantitatively study the relation between cell shape and function. In order to design micropatterns, models to predict shape and dynamics of cells are needed. To this end, we combine two previously introduced models. The tension elasticity model (TEM) [1] focuses on strongly contracted shapes which can be predicted correctly on dot pattern substrates. However, the TEM cannot predict dynamical changes, like the movement from one pattern to the next. A two-dimensional cellular Potts model (CPM) [2] combined with directional persistence is used

to account for the dynamics of cells on micropatterned substrates. In contrast to earlier applications of the CPM in the context of tissues, in our case the area of cells is not fixed as they can exchange material with the third dimension. We modify the energy function of previous formulations of the CPM to account for this feature as well as to include insights from the TEM and to represent the effect of the adhesive micropattern. We use our model to predict the dynamics of cell shape, spreading and division, and to identify promising patterns for experiments.

[1] I.B. Bischofs, F. Klein, D. Lehnert, M. Bastmeyer and U.S. Schwarz, Biophys. J. **95**, 3488 (2008).

[2] F. Graner and J.A. Glazier, Phys. Rev. Lett. **69**, 2013 (1992).

BP 30.8 Thu 17:15 H43

On the Relevance of Cellular Adhesion for Compartmentalization — •Steve Pawlizak, Anatol Fritsch, and Josef A. Käs — University of Leipzig, Institute for Experimental Physics I, Soft Matter Physics Division, Linnéstraße 5, 04103 Leipzig, Germany

Compartmentalization is a fundamental organization process of cells, which can be demonstrated *in vitro* by means of a simple model system: When two different populations of suspended cells are mixed, the mixture will eventually segregate into two phases, whereas mixtures of the same cell type will not. Nowadays, the concept of compartmentalization is coming more and more into focus of cancer research because it has been observed that even tumor cells are confined to their original compartment for a relatively long time in their development. For that reason, the understanding of the mechanical principles underlying this process is of great importance. The *differential adhesion hypothesis* by Malcolm S. Steinberg gives a first explanation by differences in surface tension and adhesiveness of the interacting cells. We are investigating whether cellular adhesion is in fact a necessary or even sufficient factor to characterize compartmentalization and tumor spreading. For our studies, we use healthy and cancerous breast cell lines of different malignancy as well as primary cells from human cervical carcinoma. We apply a broad set of techniques to study their mechanical properties and interactions, including 3D segregation experiments in droplet cultures, *optical stretching* for whole cell rheology, and *AFM* to directly measure cell-cell-adhesion forces. The combination of these techniques will help to shed some new light on the role of cellular adhesion.