# BP 37: Active Matter (joint session BP/CPP/DY)

Time: Friday 9:30–12:00 Location: H 1058

BP 37.1 Fri 9:30 H 1058

**Collective cell behavior - a phase field active polar gel model** — •Axel Voigt, Simon Praetorius, and Dennis Wenzel — TU Dresden, Institut für Wissenschaftliches Rechnen

We consider a continuum model for collective cell movement. Each cell is modeled by a phase field active polar gel model and the cells interact via steric interactions. We provide a finite element implementation with a parallel efficiency in the number of cells. This is achieved by considering each cell on a different processor and various improvements to reduce the communication overhead to deal with the cell-cell interactions. We demonstrate results for up to 1.000 cells.

BP 37.2 Fri 9:45 H 1058

**Statistical physics and hydrodynamics of passive/active mixtures** — •Raphaël Jeanneret[1], Arnold Mathijssen[2], and Marco Polin[3] — [1]IMEDEA-UIB, Esporles, Spain — [2]Stanford University, Stanford, US — [3]Warwick University, Coventry, UK

In this talk I will present a series of experimental and theoretical results regarding the dynamics of passive particles in liquid bath of active ones. The active particles act here, via the flows they generate, as localized and erratic sources of momentum for the passive beads leading to non-trivial dynamics. Beyond their exciting features for the physicist, active/passive systems are worth studying quantitatively for applications as diverse as the transport of passive entities in cells, biogenic mixing (i.e. mixing of the ocean by living creatures), virus infection, cargo transport (e.g. drug delivery) or self-assembly (e.g. via motility-induced phase separation). The model system I consider is composed of the motile micro-alga Chlamydomonas reinhardtii, a model organism at numerous levels, and polystyrene beads. I will first show that the effective diffusion of micron-sized beads embedded in homogeneous suspensions of algae is greatly enhanced compared to their thermal counterpart. I will then demonstrate how this coarse-grained dynamics can be understood from the near-field hydrodynamics of the swimming organisms via hydrodynamical entrainment events. Finally I will talk about recent results regarding systems of weakly Brownian colloids in spatially heterogeneous suspensions of algae and show how our findings can be used to induce the spontaneous demixing of the two kinds of particles.

BP 37.3 Fri 10:00 H 1058

**Got worms? Collective feeding in C. elegans** — •Robert Endres, Linus Schumacher, Serena Ding, and Andre Brown — Imperial College, London, United Kingdom

Collective behaviour, a hallmark of complex living systems, is often studied in groups of large animals or small cells, but less at the mesoscopic scale. Here, we investigate the collective feeding of the nematode C. elegans, known for its easy genetic manipulation and stereotypic worm postures. In this system, small genetic perturbations can lead to strikingly different population-level behaviors. First, we quantified behavioral differences between the 'solitary' lab strain and a 'social' aggregating mutant strain, using fluorescence imaging and many-worm tracking to probe the dynamics inside aggregates. Second, to understand the mechanism of aggregation, we drew on concepts from motility-induced phase transitions and developed a minimal model. Finally, using this model, we investigated the potential benefits of collective feeding to explain the predominance of aggregating strains in the wild.

BP 37.4 Fri 10:15 H 1058

**A continuum model to study coordination of tissue growth** — •Maryam Aliee, Damir Vurnek, Sara Kaliman, and Ana-Sunčana Smith — Cluster of Excellence: Engineering of Advanced Materials, Friedrich-Alexander-University of Erlangen-Nürnberg

Living organisms represent fascinating and precise structures. It is still a big challenge to understand the mechanisms though which cells interact with each other and the environment to form reproducible patterns. We analyze how tissue growth is controlled by cell properties putting together a theoretical model and quantitative analysis of experiments. We measure carefully growth properties of a single-layered epithelium, cultured MDCK cells. In these experiments a group of several cells grows to a bigger colony. We observe the density of cells increases and a bulk region with a high constant density is established in the center, surrounded by the edge where cell density decreases. Our results demonstrate a gradual transition from an early exponential growth to a non-linear regime when growth speed increases with colony size.

We develop a continuum model to take into account cell mechanics and growth to study dynamics of tissues. We consider balance of cell number and forces for viscoelastic materials modified by active terms coming from cell division and apoptosis. We solve the equations with analytical and numerical methods. Our results show establishment of bulk and edge regions independent of many details. We study how the dynamics of the colony is controlled by cell characteristics and their interactions with surroundings. Remarkably, our model reproduces the nontrivial properties of MDCK growth in different experiments.

BP 37.5 Fri 10:30 H 1058

**Synthetic reconstitution of beating cilia** — •Isabella Guido, Smrithika Subramani, Christian Westendorf, and Eberhard Bodenschatz — Max Planck Institute for dynamics and self-organization, Göttingen, Germany

Cilia are microscopic hair-like structures that present a rhythmic waving or beating motion and are found on the surface of almost all mammalian cells and on the body of some protozoan organisms. They are used for fluid flow based transport (e.g. removal of pollutants in the trachea) or for the locomotion in viscous fluid environments.

In our work we aim to develop synthetic ciliated systems able to propel themselves or to move fluids across a fixed surface. For this purpose we employ a bottom-up approach for assembling a simple system made of few building blocks adapted from natural cilia, namely microtubules and motor proteins. Using Kinesin-1, a processive motor powered by ATP hydrolysis, we synthesized a system containing MT bundles that are free to move in all planes, deviating from the conventional gliding assay. By binding them to a surface using a suitable anchor system, we are able to observe the microtubules-motor protein system oscillations in a manner that closely mimics ciliary movement.

The issue that we are addressing in our experiments is: how simple is the simplest system that is able to beat?

BP 37.6 Fri 10:45 H 1058

**DNA in the cell nucleus is organized similar to an active microemulsion** — •Lennart Hilbert[1,2,3], Yuko Sato[4], Hiroshi Kimura[4], Frank Jülicher[1,3,5], Alf Honigmann[2], Vasily Zaburdaev[1,3], and Nadine Vastenhouw[2] — [1]Center for Systems Biology Dresden — [2]Max Planck Institute of Molecular Cell Biology and Genetics — [3]Max Planck Institute for the Physics of Complex Systems — [4]Tokyo Institute of Technology — [5]Center for Advancing Electronics Dresden

Inside cell nuclei, DNA is stored in the form of chromatin. Chromatin is three-dimensionally organized in response to transcription of DNA into RNA. Here, we studied the mechanisms by which transcription organizes chromatin, using experiments in zebrafish embryonic cells and theory. We show that transcription establishes an interspersed pattern of mutually exclusive chromatin-rich domains and RNA-rich domains. Ongoing transcriptional activity stabilizes the interspersed domain pattern by establishing contacts between the RNA and transcribed parts of chromatin. We explain our observations with an active microemulsion model based on two macromolecular mechanisms: (i) RNA/RNA-binding protein complexes and chromatin undergo phase separation, while (ii) transcription tethers RNA/RNA-binding proteins to chromatin and thereby forms amphiphile particles that intersperse the phases. Thus, three-dimensional DNA organization in the cell nucleus is an example of an unconventional, active microemulsion, stabilized by a catalytically active amphiphile that produces one of the emulsified phases.

BP 37.7 Fri 11:00 H 1058

**Size increases produce coordination trade-offs in a simple multicellular animal near criticality** — Mircea R. Davidescu[1], •Pawel Romanczuk[2,3], Thomas Gregor[4], Corina E. Tarnita[1], and Iain D. Couzin[5,6] — [1]Dept. of Ecology and Evol. Biology, Princeton University ,USA — [2]Institute for Theoretical Biology, Dept. of Biology, Humboldt Universität zu Berlin, Germany — [3]Bernstein Center for Computational Neuroscience, Berlin, Germany — [4]Joseph Henry Laboratories of Physics, Princeton University, USA — [5]Dept. of Collective Behavior, MPIORN, Konstanz, Germany — [6]Dept. of

Biology, University of Konstanz, Germany

Based on theoretical arguments from statistical physics, it has been suggested that collective systems in biology should operate close to criticality in order to maximize their susceptibility to external signals [Mora & Bialek, J Stat Phys, 144, 2 (2011)]. Recently, this hypothesis received increased attention in the context of collective behavior in biology. However, it is still rather controversial and up to know most support for it comes from idealized mathematical models and few experimental systems. Here, we will discuss some recent experimental observations of Placozoa (*Trichoplax Adhaerens*), a simple multicellular animal effectively corresponding to a quasi two-dimensional cellular sheet. By combining experimental data with simple mathematical model of Placozoa motion as a collective system, we find that the observed dynamics are indeed consistent with the criticality hypothesis, but as a consequence these simple animals without a central nervous system have to face a fundamental size-coordination trade-off.

BP 37.8 Fri 11:15 H 1058

**Harnessing emergence in bacterial populations: From biological mixing to active mechanics** — •Anupam Sengupta — Institute for Environmental Engineering, ETH Zurich, Switzerland — Physics and Materials Science Research Unit, University of Luxembourg

At the scale of a single cell, interactions between a bacterium and its micro-environment represent a complex biophysical interface between phenotypic states (free-living planktonic or surface-attached sessile state) and external cues. In this talk I will discuss two recent works where we use experiments and modeling to elucidate how bacterial phenotype cross-talks with immediate micro-environment, and harnesses the emergent physics for biological functions. In the first case, we will see how Chromatium okenii, a 10 $\mu$m long purple sulphur bacterium, is capable of mixing over a meter thick layer of water in the Swiss Alpine lake, Lago di Cadagno. By changing the local fluid density, C. okenii is able to trigger convection rolls, creating a sustained well-mixed nutrient layer within an otherwise stratified lake. In the second instance, we will examine emergent geometrical and mechanical properties of a bacterial colony growing on a soft substrate. We show that such an expanding colony self-organizes into a "mosaic" of micro-domains consisting of highly aligned cells, before emerging into an active nematodynamic system. Interestingly, phenotypic traits - motility in the first and growth-induced stresses in the latter - couple with local hydrodynamics, to elicit important ecological functions at scales that can be orders of magnitude higher than single cells.

BP 37.9 Fri 11:30 H 1058

**Hydrodynamic theory of aster positioning by motor proteins** — •Andrej Vilfan — J. Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia

In fertilized egg cells of certain species the male pronucleus is transported to the center of the cell by growing an asymmetric microtubule aster, which then serves as a track for motor proteins carrying vesicles towards the center. Because these vesicles experience a viscous drag in the surrounding cytoplasm, the motors exert the opposite force on the microtubules. The asymmetry of the aster then leads to a net pulling force towards the cell center. Yet hydrodynamic interactions make the understanding of the process difficult.

Here we discuss a coarse-grained approach where we describe the aster as a porous medium and the moving vesicles as sources of an active pressure gradient. In parallel, we use computational models to determine the parameters of the continuum model. For realistic parameters, we show that a significant proportion (10-20%) of the motor force is converted to a pressure gradient and contributes to aster centering. We conclude that vesicle transport in a viscous environment is a surprisingly efficient way of force generation.

BP 37.10 Fri 11:45 H 1058

**Active polymer models for the 3D organization of chromosomes** — •Johannes Nuebler[1], Geoffrey Fudenberg[2], Maxim Imakaev[1], Nezar Abdennur[1], and Leonid Mirny[1] — [1]Institute for Medical Engineering and Science, Massachusetts Institute of Technology, Cambridge, MA 02139, USA — [2]University of California, San Francisco, Gladstone Institutes, San Francisco, CA 94158, USA

Eukaryotic chromatin is far from being a randomly arranged polymer in the cell nucleus. Rather, a high degree of spatial organization on various length scales is revealed by Hi-C and imaging techniques. We show that the organization on intermediate scales emerges from the interplay of two mechanisms, one active and one passive: first, on the scale of one million basepairs and below, active formation of growing chromatin loops emerges as a general organizational principle throughout the cell cycle. Second, a block-copolymer based phase separation explains chromatin compartmentalization on larger scales. Interestingly, these processes interact: only the interplay of loop extrusion and spatial segregation explains a large number of experimental perturbations, namely removal of the loop extruder cohesin, removal of the cohesin boundary element CTCF and removal of the cohesin unloader Wapl, and it makes specific predictions for variations in the compartmental interaction and topological constraints (bioRxiv: https://doi.org/10.1101/196261).