AKB 3 Cell Motility I

Time: Monday 11:30–13:15 Room: ZEU 255

Invited Talk

AKB 3.1 Mon 11:30 ZEU 255

Symmetry Breaking and Elastic Deformations drive Actin-Based Movement — •Ewa Paluch[1,2], Jasper van der Gucht[1], Jean-François Joanny[1], and Cécile Sykes[1] — [1]Institut Curie/CNRS, UMR 168, 26 rue d'Ulm, 75005 Paris, France — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Pfotenhauerstr. 108, 01307 Dresden, Germany

Cells move and change shape by means of the cytoskeleton, an active gel made of polar filaments such as actin. The filaments themselves are highly dynamic and continuously polymerize and depolymerize using chemical energy. Bacterial pathogens such as Listeria monocytogenes have been shown to hijack the actin polymerization machinery inside cells in order to propel themselves forward. This mechanism is often studied using beads, which polymerize on their surface an actin gel that spontaneously polarizes and gives rise to an actin comet that propels the bead forward.

We use a simple assay composed of purified commercial proteins to study the symmetry breaking event that precedes movement. We show that gel breakage results from a release of elastic energy and propose a model based on the theory of fracture in polymer gels. Moreover we provide direct evidence that the actin gel in the comet continues to deform even after symmetry breaking. We propose a model that accounts for these deformations, where the comet is considered as an elastic fluid.

AKB 3.2 Mon 12:00 ZEU 255

Dynamics of Cilia and Flagella — •Andreas Hilfinger[1], Ingmar Riedel[2], Amit Chattopadhyay[3], Karsten Kruse[1], Jonathon Howard[2], and Frank Jülicher[1] — [1]Max-Planck-Institute for the Physics of Complex Systems, Dresden — [2]Max-Planck-Institute of Molecular Cell Biology and Genetics, Dresden — [3]Mathematics Institute, University of Warwick, UK

Directed motion on the level of single cells is in many cases achieved through the beating of whip like appendages (cilia or flagella). These organelles contain a highly conserved structure called the axoneme, whose characteristic architecture is based on a cylindrical arrangement of elastic filaments (microtubules). In the presence of ATP, molecular motors (dynein) exert shear forces between neighbouring microtubules, leading to a bending of the axoneme through structural constraints.

We present a theoretical description of such an elastic cylinder, driven by internally generated stresses and show that self-organised bending waves emerge from a non-oscillatory state via a dynamic instability. The corresponding beat patterns are solutions to a non-linear wave equation with appropriate boundary conditions. We discuss three-dimensional beat patterns that resemble the vortical motion of nodal cilia, which play an important role in establishing the left-right axis of embryos in many vertebrate species.

AKB 3.3 Mon 12:15 ZEU 255

Biomimetic flagella and cilia — •Holger Stark and Erik Gauger — Universität Konstanz, Fachbereich Physik, D-78457 Konstanz

In biological systems, small organisms move in a Newtonian fluid and fluid itself is transported with the help of beating filaments (cilia) or rotating flagella. The motion is governed by small Reynolds numbers, i.e., by a regime where inertial effects can be neglected. Thus directed motion can only occur in systems where time-reversal symmetry is broken.

Recently, Dreyfus *et al.* realized a one-armed swimmer [1] that fulfills these requirements. It is based on an elastic filament formed by superparamagnetic particles that are hold together by chemical linkers. Whereas real flagella or cilia are driven by internal machinery, the artificial filament is actuated by an external field. We simulate the filament using a discretized elastic-rod model where the particles also interact via dipolar and hydrodynamic interactions. We discuss two characteristic quantities, i.e., the swimming velocity and its efficiency. Furthermore, we demonstrate how the biomimetic cilium when attached to a bounding surface can be used to transport fluid.

[1] R. Dreyfus, J. Baudry, M. L. Roper, M. Fermigier, H. A. Stone, and J. Bibette, Nature **437**, 862 (2005).

AKB 3.4 Mon 12:30 ZEU 255

Hydrodynamic flow patterns and synchronization of beating cilia — •Andrej Vilfan[1] and Frank Jülicher[2] — [1]J. Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia — [2]MPIPKS, Nöthnitzer Str. 38, 01187 Dresden, Germany

We study the dynamics of hydrodynamically interacting cilia by means of a minimal physical model, representing cilia as particles on tilted elliptical trajectories. We first calculate the hydrodynamic flow field generated far from a cilium which is attached to a surface and beats periodically. In the case of two beating cilia, we show that hydrodynamic interactions can lead to synchronization of the cilia. We present a state diagram where synchronized states occur as a function of distance of cilia and the relative orientation of their beat. Synchronized states occur with different relative phases. In addition, asynchronous solutions exist. Our model provides a basis for the explanation of metachronal waves in microorganisms and ciliated tissues.

AKB 3.5 Mon 12:45 ZEU 255

A self-organized simple swimmer driven by molecular motors — •Stefan Guenther and Karsten Kruse — Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany

Microorganisms often use flagella or cilia to move in an aqueous environment. In eukaryotes these hair-like appendages are internally driven by molecular motors. Spontaneous oscillations of the motors lead to two- or three-dimensional beating patterns of the appendage, which propels the organism. Due to the complicated structure of cilia and flagella our understanding of the swimming mechanism is still far from complete.

Here, we study a simple self-organized swimmer, that is based on elements thought to be important for the beating of flagella. The swimmer consists of three spheres arranged in a line. Two adjacent spheres are coupled by an active joint containing molecular motors. These joints are similar to sarcomeres, the elementary contractile units of muscle, and can oscillate spontaneously. Taking the hydrodynamic interactions between the spheres into account, the system moves directionally along its long axis. We calculate the swimming speed as a function of the fluid's viscosity and find a critical value above which there is no net motion. For parameters appropriate for sarcomeres, swimming speeds are in the order of μm/min and should be experimentally observable.

AKB 3.6 Mon 13:00 ZEU 255

Collective effects in ciliar arrays — •Andrey Ryskin and Peter Lenz — Fachbereich Physik, Philipps-Universität Marburg, D-35032 Marburg

Collective effects in ciliar arrays are studied analytically and numerically. A new phase oscillator description for ciliar motion is introduced which depends only on a single parameter. It allows to systematically study hydrodynamic interactions between cilia exhibiting arbitrary beating patterns. It is shown that under suitable conditions hydrodynamic interactions lead to synchronization of ciliar beating and formation of metachronal waves. The stability of these dynamical states is discussed.