BP 25: Oscillatory Systems

Time: Thursday 14:30–17:00 Location: H44

Invited Talk BP 25.1 Thu 14:30 H44

Mechanical amplification by sensory hair cells from the vertebrate ear — •Pascal Martin — Institut Curie recherche\CNRS - Laboratoire PCC (UMR168), 26 rue d'Ulm 75005 Paris, France

The dazzling sensitivity and frequency selectivity of the vertebrate ear rely on mechanical amplification of small sounds by hair cells, the sensory receptors of the inner ear that transduce mechanical stimuli into electrical signals that will then be received by the brain. As revealed by spontaneous oscillations and forms of mechanical excitability in response to force steps, the hair bundle that adorns each hair cell is both a mechano-sensory antenna and a force generator. To study active hair-bundle motility, we use flexible glass micro-fibers to stimulate mechanically in vitro a single hair bundle from the bullfrog's sacculus. We find that an oscillatory hair bundle amplifies its response to small stimuli at frequencies near that of the spontaneous oscillation. By combining measurements of force-displacement relations with Ca2+ iontophoresis, we show that the location of a bundle's operating point within its nonlinear force-displacement relation controls the type of movements observed. We have developed a simple theoretical description that can account for the various incarnations of active hair-bundle motility. There, mechanical activity stems solely from myosin-based adaptation, the process by which molecular motors (myosins) in the hair bundle set the open probability of mechano-sensitive ion channels at steady state. By taking intrinsic hair-bundle fluctuations into account, we could reach quantitative agreement between calculated and experimentally measured response functions.

BP 25.2 Thu 15:00 H44

Biophysics of Drosophila Audition — •Björn Nadrowski, Jörg Thaddäus Albert, and Martin Cornelius Göpfert — Zoologisches Institut, Universität Köln, Weyertal 119, 50923 Köln

In Drosophila, hearing is mediated by the antenna. Stimulus forces acting on the antennal receiver are coupled to dedicated neurons that comprise the molecular machinery for mechanosensory transduction, adaptation and amplification. Because the action of this machinery is reflected in the receiver's mechanics, the latter can be used to probe the molecular mechanisms that bring about hearing in an intact ear . These mechanisms are now shown to closely resemble those that are at work in hair cells in vertebrate ears. Based on the gating-spring model of transduction in vertebrate hair cells, we have developed an extended, symmetric gating-spring model that takes the fly's anatomy into account. This model explains the ear's performance, including the receiver's mechanics and the electrical response of the afferent nerve. These findings suggest that while the auditory anatomies are vastly different, the mechanisms that promote fly and vertebrate hearing are functionally equivalent and, possibly, evolutionarily conserved.

BP 25.3 Thu 15:15 H44

Mobility of Min-proteins in Escherichia coli by fluorescence correlation spectroscopy — Giovanni Meacci[1], Jonas Ries[2], •Elisabeth Fischer-Friedrich[1], Nicoletta Kahya[2], Petra Schwille[2], and Karsten Kruse[1] — [1]Max-Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]TU-Dresden, Biotec, Am Tatzberg 47-51, 01307 Dresden, Germany

In the bacterium Escherichia coli, positioning of the division site involves pole-to-pole oscillations of Min-proteins.

Different oscillation mechanisms based on cooperative effects between Min-proteins and the exchange of Min-proteins between the cytoplasm and the cytoplasmic membrane have been proposed.

However, the parameters characterising the dynamics of the Min-proteins in vivo are not known. Therefore, it has been difficult to compare the models quantitatively with experiments.

We have now performed in vivo measurements of the mobility of Min-proteins using fluorescence correlation spectroscopy.

Two distinct time-scales are visible in the correlation curves. While the faster time-scale can be attributed to cytoplasmic diffusion, the slower time-scale could result from diffusion of membrane-bound proteins or from protein exchange between the cytoplasm and the membrane.

We discuss implications of the measured values for the oscillation mechanism.

BP 25.4 Thu 15:30 H44

Nuclear oscillations during sexual reproduction in yeast — Sven Vogel and •Iva Tolic-Norrelykke — Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany

When two cells of the fission yeast *Schizosaccharomyces pombe* mate, the cell nucleus oscillates from one end of the cell to the other with a period of about 5 minutes and a total duration of a few hours. The biological significance of the nuclear oscillation seems to be in facilitating the spatial alignment of homologous chromosomes.

We set out to determine which forces drive the nuclear oscillation and how the force generation is spatially and temporally regulated. The nuclear oscillation is dependent on astral microtubules (MTs) radiating from the spindle pole body and on cytoplasmic dynein, a minus end directed MT motor. By cutting single MTs using laser nanosurgery, we can distinguish between different models of force generation and identify a subset of MTs that are responsible for nuclear oscillation. Our data provide direct evidence that the main forces contributing to the nuclear oscillation are pulling forces, which are typically generated at the cell ends, and that the event of force generation is driven by the interaction of forward-extending MTs with the cell end cortex.

BP 25.5 Thu 15:45 H44

Waves of gene expression in vertebrate segmentation — •Luis G. Morelli[1], Saul Ares[1], Leah Herrgen[2], Christian Schröter[2], Andrew Oates[2], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Max Planck Institute of Molecular Cell Biology and Genetics

During vertebrate development, the body axis segments sequentially from the head to the tail of the embryo. This process is driven by genetic oscillators together with a moving determination front that slows down and arrests the oscillators. As a result, waves of gene expression propagate along the body axis. We propose a theoretical description based on coupled phase oscillators that describes the patterns of gene expression observed in experiments, both in wild type and mutants. Based on experimental evidence our description introduces a frequency profile, together with a moving boundary that describes axis elongation. To account for the time it takes for signaling molecules to be produced and exported to the cell membrane we include a time delay in the coupling. We derive analytical expressions for the wavelength of the patterns and the period of oscillations.

BP 25.6 Thu 16:00 H44

A bidomain threshold model of intracellular calcium release — •Rüdiger Thul[1], Stephen Coombes[1], and Greg D. Smith[2] — [1]School of Mathematical Sciences, University of Nottingham, Nottingham, NG7 2RD, UK — [2]Department of Applied Sciences, The College of William and Mary, Williamsburg, Virginia, 23187, USA

We introduce a bidomain threshold model of intracellular calcium release. By the explicit construction of travelling wave solutions we are able to probe the dependence of wave speed on physiologically important parameters, including the rate of calcium pumping between the endoplasmic reticulum and the cytosol. Importantly we develop a linear stability analysis that predicts the onset of front instabilities, leading to the emergence of waves that propagate in a back-and-forth manner. Direct numerical simulations are used to confirm our travelling wave predictions.

BP 25.7 Thu 16:15 H44

Spontaneous shape oscillations in non-adherent fibroblasts — •Pramod Pullarkat — University of Bayreuth, Bayreuth-95440, Germany

Fibroblast cells which are maintained in suspension exhibit a dynamic shape instability resulting in sustained, periodic oscillations. This instability is due to the active, contractile nature of the cortical actin layer in these cells. We will discuss experiments aimed at understanding this dynamic instability. We will show how myosin motor activity and signaling via extracellular calcium plays a role in this process. We will also reveal some remarkable similarities between the oscillatory dynamics and the commonly observed blebbing dynamics in cells. Finally a 'working model' will be proposed for the observed phenomena.

BP 25.8 Thu 16:30 H44

Velocity oscillations in polymerizing actin networks — •Azam Gholami[1], Martin Falcke[1], and Erwin Frey[2] — [1]Hahn-Meitner-Institut, Abteilung Theorie, Glienicker Str. 100, D-14109 Berlin, Germany — [2]Arnold-Sommerfeld-Center for Theoretical Physics and Center for NanoScience, Department of Physics, Ludwig-Maximilians-Universität München, Theresienstrasse 37, D-80333 München, Germany

Force generation by semiflexible polymers is versatilely used for cell motility. The leading edge of lamellipodia of crawling cell is pushed forward by a polymerizing actin network and bacteria move inside cells by riding on a comet tail of growing actin filaments. In vivo systems are complemented by in vitro assays using plastic beads and lipid vesicles that, when coated with appropriate proteins, move much the same way as the pathogens. We present a simple theoretical description for actin-based motility. We show that cooperative attachment and detachment of actin filaments to the obstacle, polymerization of the filaments free ends and cross-linking of the actin network lead to spontaneous oscillations of the obstacle velocity.

BP 25.9 Thu 16:45 H44

Dynamics of Phase Singularities in Cardiac Tissue — •Amgad Squires[1,2], Gisa Luther[2], Robert Jr. Gilmour[1], Eberhard Bodenschatz[2], and Stefan Luther[2] — [1]Department of Biomedical Sciences, Cornell University, NY — [2]Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany

Many spatially extended, nonlinear systems exhibit spatio-temporal chaos in terms of irregular wave fronts or turbulent spiral dynamics. Examples can be found in systems as diverse as Rayleigh-Bénard convection, liquid crystals and excitable media. An example of the latter is cardiac tissue. Here, spiral waves and subsequent wave breaks correspond to an electro-mechanical malfunction of the heart. Spiral wave cores and breakup correspond to phase singularities or defects. We investigate the dynamics of these objects using numerical simulations and arterially perfused canine wedge preparations.

We use an automated phase transformation method that can identify and track these objects from onset to termination of an arrhythmic episode. The system is robust to noise and can be used in vivo and in silico. It has been used to study various arrhythmias as well as a recently proposed far-field defibrillation protocol. Singularity detection and tracking allows us to analyze the interaction of singularities with each other and with external stimuli, in both space and time, and to characterize the complexity of spatiotemporal states. In light of these methods, we discuss current hypotheses of cardiac fibrillation.