BP 3: Cell Adhesion and Migration, Multicellular Systems I

Time: Monday 9:30–13:00 Location: H 2013

BP 3.1 Mon 9:30 H 2013

Molecular motors govern liquid-like ordering and fusion dynamics of bacterial colonies — •Tom Cronenberg, Anton Welker, Robert Zöllner, Claudia Meel, Enno R. Oldewurtel, Katja Siewering, and Berenike Maier — Department of Physics, University of Cologne, Zülpicher Str. 77, 50539 Köln, Germany

Bacteria can adjust the structure of biofilms to enhance their survival rate under external stress. Here, we explore the link between bacterial interaction forces and colony structure. We show that the activity of extracellular pilus motors enhances local ordering and accelerates fusion dynamics of bacterial colonies. The radial distribution function of mature colonies shows local fluid-like order. The degree and dynamics of ordering are dependent on motor activity. At a larger scale, the fusion dynamics of two colonies shows liquid-like behavior whereby the ratio between surface tension and viscosity decreases with decreasing motor activity.

BP 3.2 Mon 9:45 H 2013

Organization of Fibronectin and NIH/3T3 Fibroblasts on Bulk Microgrooved TiO2 — •Astrid Weidt[1,2], Mareike Zink[1], and Stefan G. Mayr[2,3] — [1]Junior Research Group Biotechnology and Biomedicine, Peter-Debye-Institute for Soft Matter Physics, Leipzig University, Germany — [2]Leibniz Institute of Surface Engineering (IOM) e.V., Leipzig, Germany — [3]Division of Surface Physics, Leipzig University, Germany

The choice of suitable nano- and microstructures of biomaterials is crucial for successful implant integration within the body. In particular, surface characteristics affect the adsorption of various extra cellular matrix proteins. This work illustrates the interaction of protein adsorption and early cell adhesion on bulk microstructured titanium surfaces with parallel grooves of 27 to 35 micron widths and 15 to 19 micron depths, respectively. In contact with low concentrations of fibronectin solutions, distinct adsorption patterns are observed on the edges of the ridges. Moreover, NIH/3T3 fibroblasts cultured in serum-free medium for 1 h, 3 h and 1 d show enhanced early cell adhesion on fibronectin coated samples compared to uncoated ones. In fact, early adhesion and cell contacts occur mainly on the groove edges where fibronectin adsorption was preferentially detected. Such adsorption patterns also support cellular contact guidance on short time scales which is hardly seen for uncoated samples. Thus, surface structures can promote directed adsorption of low concentrated fibronectin which facilitates early cell adhesion. These results may give rise to new developments in surface engineering of biomedical implants for improved osseointegration.

BP 3.3 Mon 10:00 H 2013

Mechanics and Dynamics of Dictyostelium discoideum Adhesion — •Nadine Kamprad[1,2], Christian Westendorf[1], Albert Bae[1], Lyova Mamoyan[2], and Marco Tarantola[1] — [1]Max-Planck-Institut for Dynamic and Self-Organization, Göttingen, Germany — [2]University of Göttingen, Germany

Motile cells exert traction on the substratum in order to extend anterior pseudopodia and retract the rear. While the cytoskeleton generates protrusive and contractile forces, interaction of the ventral cell surface with the underlying support is necessary for force transmission. Here we focus on substrate adhesion of Dictyostelium discoideum (D.d), an integrin-free cellular model system. The amoeba adheres to substrates using actin foci; the latter are actin-rich areas, believed to be involved in non-specific adhesion processes. We perform co-localization studies of actin and known adhesion mediators like Talin, SCAR, Arp2/3 and the D.d. specific transmembrane adhesion protein Sad A. Coincidence is assessed using Total Internal Reflection Fluorescence Microscopy of single cells in an early developmental stage with considerably reduced motility. Current opposing hypotheses view actin foci as byproducts of endocytosis and not as adhesive areas. Thus, we examine colocalization of a protein coating endocytotic vesicles, Clathrin, to discern endocytosis from adhesion. In addition, we study cell lines with impaired adhesion based on knock out approaches for the aforementioned proteins and assess their influence on contact area morphology and adhesion forces.

BP 3.4 Mon 10:15 H 2013

Confinement and topography control 3D motility of crawling cells — •Benjamin Winkler[1], Igor S. Aranson[2,3], and Falko Ziebert[1,4] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany — [2]Department of Biomedical Engineering, Pennsylvania State University, University Park, USA — [3]Materials Science Division, Argonne National Laboratory, USA — [4]Institute for Theoretical Physics, Ruprecht-Karls-University Heidelberg, Germany

The natural environment of motile cells are heterogeneously-shaped, three-dimensional geometries, often inducing also strong confinement effects. In turn, it is of great importance to model the role substrate topography and confinement play in cellular movement. We have developed a three-dimensional computational model, based on the so-called phase field approach, to study lamellipodium-driven crawling cells in arbitrarily shaped surroundings. We then studied several well-defined scenarios, such as a systematic variation of substrate curvature (from cells on thin fibers to the movement inside a capillary), vertical confinement between two plates, as well as topographically structured substrates. The derived, purely physical, guiding principles for motile cells should help discerning effects from truly specific biochemical cues and/or regulatory activity from the cell itself.

BP 3.5 Mon 10:30 H 2013

Bacterial adhesion under flow condition — •Johannes Mischo[1], Friederike Nolle[1], Christian Spengler[1], Nicolas Thewes[1], Markus Bischoff[2], and Karin Jacobs[1] — [1]Department of Experimental Physics, Saarland University, Saarbruecken — [2]Institute for Medical Microbiology and Hygiene, Saarland University, Homburg/Saar

Bacterial biofilm formation reduces the effect of antibiotics, which is one of the main reasons for the mandatory removal of infected implants from the body. Therefore, the prevention of biofilm formation or material specifications that result in the death of adhering bacteria without harming somatic cells is considered key in medical implant development. Our flow chamber experiments, as a first step towards *in vivo* situations, aim at characterizing bacterial adhesion and viability of *S. aureus* on silicon surfaces. While surface chemistry and subsurface composition of the silicon surfaces are consistent, bacterial adhesion rate and viability on nano-rough silicon can be ascribed to geometry constraints, as changes in the adhesion strength due to a variation of the long-range van der Waals force can be neglected. Comparing adhesion rate and viability on hydrophobic and hydrophilic substrates of identical roughness reveals the influence of short-range, e.g. hydrophobic, forces. The data obtained from our flow chamber measurements can be compared to our single cell force spectroscopy data on the same surfaces.

BP 3.6 Mon 10:45 H 2013

Patterning of adhesion mediated by binders of multiple types — •Josip Vlajčević[1] and Ana-Sunčana Smith[1,2] — [1]Rudjer Bošković Institute, Division of Physical Chemistry, Zagreb — [2]PULS Group, Institut für Theoretische Physik, Univesität Erlangen-Nürnberg

Cellular adhesion is mediated by binding of multiple proteins of different lengths, flexibilities and binding affinities. However, in most modelling efforts so far, only one type of molecular binding has been considered. These studies showed that the membrane, which in the absence of specific molecular forces resides in a non-specific potential, deforms upon molecular complexation. This in turn introduces cooperative effects that promote further binding.

Building on a coarse grained Monte Carlo framework that quantitatively captures the dynamics of adhesion mediated by a single type of ligand-receptor pairs, we study a complete phase behaviour and the dynamics in the system containing two types of molecular binders which differ in molecular flexibilities, lengths, binding energies and densities.

By including ligand-receptor pairs and flexible polymers that can crosslink both adherent interfaces, we can capture the behaviour observed in experiments with artificially produced DNA-oligomers or the adhesion of T-lymphocyte cells induced by binding of TCR to pMHC and LFA-1 to ICAM-1 proteins during the formation of the immune synapse.

15 min. break

Invited Talk BP 3.7 Mon 11:15 H 2013

Morphology control by active fluid flows — •Karen Alim — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Fluid flows can induce long-ranged interactions and propagate information on large scales. Especially during the development of an organism, coordination on large scales in short time is essential. What are the principal mechanisms of how fluid flows induce, transmit and respond to biological signals and thus control morphology? The role of fluid flows in patterning and morphing is particularly prominent during the growth and adaptation of transport networks like vascular networks. Here, the network-forming slime mould *Physarum polycephalum* emerged as a model to study the complex dynamics of transport networks. Investigating the pivotal role of fluid flows in this live transport network we find that flows are patterned in a peristaltic wave across the network thereby optimising transport. In fact, flows are hijacked by signals to propagate throughout the network promoting their own transport by invoking a propagating front of increased flow. These simple non-linear dynamics are sufficient to explain surprisingly complex dynamics of the network-like organism as adapting into the shortest path through a maze.

BP 3.8 Mon 11:45 H 2013

Stochastic Dynamics of Cell Migration in Complex Environments — •David B. Brückner[1], Alexandra Fink[2], Christoph Schreiber[2], Peter J. F. Röttgermann[2], Joachim O. Rädler[2], and Chase P. Broedersz[1] — [1]Arnold-Sommerfeld-Center for Theoretical Physics and Center for NanoScience, Ludwig-Maximilians-Universität, München — [2]Faculty of Physics and Center for NanoScience, Ludwig-Maximilians-Universität, München

The migration of cells is crucial in a variety of biological processes, including development, homeostasis, and cancer. In all these cases, cells migrate in complex and confined environments. To elucidate the physics of such confined migration in a standardised manner, we study cancer cells (MDA-MB-231) migrating on dumbbell-shaped micropatterns consisting of two square adhesion sites connected by a thin guidance cue. We observe that these cells stochastically migrate back and forth between the adhesion sites. We reconstruct equations of motion directly from the experimentally determined short time-scale dynamics, allowing us to decompose the migration into deterministic and stochastic contributions. This equation of motion captures the full dynamics of the confined cell and accurately predicts the long time-scale transitions between the sites. Our findings unveil the non-linear dynamics that governs cell migration in such environments. This approach could provide a basis for the understanding of the microscopic processes driving cell migration as well as the collective dynamics of many cells.

BP 3.9 Mon 12:00 H 2013

Time-Resolved Force Spectroscopy of Flagella-Surface Contacts — •Anni Röse, Christian Titus Kreis, and Oliver Bäumchen — Max Planck Institute for Dynamics and Self-Organization (MPIDS), Am Faßberg 17, D-37077 Göttingen, Germany

Cellular appendages such as cilia and flagella are important tools for microbes to sense their environment, to propel themselves and also for mediating cell adhesion to surfaces. Despite the fact that the flagella axoneme represents a universal building block in cell biology, the biological mechanisms and characteristics of flagella mediated adhesion remains elusive so far. Recently, we discovered that *Chlamydomonas*, a unicellular biflagellated microalga, can actively switch the flagella adhesiveness on and off by light [1]. This rapid adaptation to environmental conditions within seconds distinguishes the adhesion mechanism of microalgae (eukaryotes) from bacteria (prokaryotes). In order to obtain a quantitative understanding of the characteristics of microalgal adhesion, we study flagella-substrate interactions by means of time-resolved in vivo force spectroscopy. Our micropipette-based force measurements allow us to correlate adhesion forces with optical images of flagella configuration during the rupture of the adhesive contact. These experiments indicate that each flagellum forms multiple adhesive contacts with the substrate. We identify the spatial distribution of the contacts on the flagella and also measure the strength of the individual contacts. These characteristic signatures of microalgal adhesion represent a remarkable difference compared to bacterial adhesion.

[1] Kreis et al., Nature Physics, 2017.

BP 3.10 Mon 12:15 H 2013

Universal kinetics for the engagement of mechanosensing pathways in cell adhesion — •Samuel Bell and Eugene M. Terentjev — Cavendish Laboratory, 19 JJ Thomson Ave, Cambridge, CB3 0HE, United Kingdom

When plated onto a 2D substrate, cells will adhere and then spread, before becoming polarised. It is well known that cells plated onto surfaces with lower elastic moduli spread to a smaller final area than on stiffer surfaces. We studied the time of onset of spreading for two cell lines, endothelial cells (EA.hy927) and fibroblasts (NIH/3T3) onto a large range of substrates, and, remarkably, found that the dynamics of early spreading are the same over a wide range of stiffnesses (460Pa-30GPa). Instead, the dynamics were found to be greatly influenced by temperature. The long-time probability of onset displays an exponential activation, $P(t) \sim \exp(-kt)$ for both cell lines, with an Arrhenius-type rate constant $k \propto \exp(-G/k_BT)$. The energy barrier was found for both cell lines to be $G \approx 19$kcal/mol, and tallies with a recent study on the activation of focal adhesion kinase (FAK). Further to this, the short-time probability of having spread by time t follows a universal power law scaling, much as in nucleation theory, $Q(t) \propto t^5$. This is evidence for the onset of spreading being governed by the assembly of focal complexes with 5 major steps of building followed by FAK activation.

BP 3.11 Mon 12:30 H 2013

Flow rate of transport network controls uniform metabolite supply to tissue — •Felix J. Meigel and Karen Alim — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Functioning of higher organisms depends on the continuous supply of metabolites to tissue and organs. What are the requirements on the transport network pervading the tissue to provide a uniform supply of metabolites? We consider the transport dynamics of metabolites in a vascular network of connected tubes. On a single tube level, we describe metabolite spread by diffusion and advection as well as absorption at the tube wall. Applying our theoretical model of metabolite supply to the example of xylem vasculature in leaves, we find that on the network level, the flow rate is the key factor for uniform supply. While at low inflow rate metabolites are already exhausted near the flow inlet, too high inflow flushes metabolites through the network. We identify a scaling law, predicting the optimal inflow rate providing uniform metabolite supply. We identify how overall change in network topology compensates sub-optimal inflow rates in numerical simulations.

BP 3.12 Mon 12:45 H 2013

Collective cell migration in embryogenesis follows the laws of wetting — •Bernhard Wallmeyer[1], Sarah Trinschek[2], Sargon Yigit[1], Uwe Thiele[2], and Timo Betz[1] — [1]Institute of Cell Biology, ZMBE, Münster, Germany — [2]Institute for Theoretical Physics, Münster, Germany

Collective cell migration is a fundamental process during embryogenesis and its initial occurrence, called epiboly, is an excellent *in vivo* model to study the physical processes involved in collective cell movements that are key to understand organ formation, cancer invasion and wound healing. In zebrafish, epiboly starts with a cluster of cells at one pole of the spherical embryo. These cells are actively spreading in a continuous movement towards its other pole until they fully cover the yolk. Inspired by the physics of wetting we determine the contact angle between the cells and the yolk during epiboly. Similar to the case of a liquid drop on a surface one observes three interfaces that carry mechanical tension. Assuming that interfacial force balance holds during the quasi-static spreading process, we employ the physics of wetting to predict the temporal change of the contact angle. While the experimental values vary dramatically, the model allows us to rescale all measured contact angle dynamics onto a single master curve explaining the collective cell movement. Thus, we describe the fundamental and complex developmental mechanism at the onset of embryogenesis by only three main parameters: the offset tension strength α, the tension ratio δ and the rate of tension variation λ.