Indian Institute of Science
Centre for BioSystems Science and Engineering
BSSE Seminar

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Biological fluids: mucus swirling, white blood cells snaking, and red blood cells swinging

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About the speaker:

Annie Viallat is a senior scientist at the French National Centre for Scientific Research, France, she received her PhD in Physics working on polymer gels and NMR in Grenoble (France). After a postdoc on theory of conjugated polymers at the University of Santa Barbara (USA), she joined the Spectrométrie Physique lab (Grenoble) in 1989, studying polymer gels and heterogeneous polymer solutions. Her research moved to biological physics in 1999. She has developed a strong expertise on the dynamics in microflows of vesicles and blood cells and techniques of fast video-microscopy. From 2007 to 2014 she was the director of the CNRS French Consortium 'Physics from Cell to Tissue'. She heads the "Physics and Engineering for Living Systems" Department in Marseille. Since 2014, A. Viallat has been working in the field of active matter, microcirculation of red blood cells in disease and the physics of the mucociliary clearance.

Her current interests are

- Blood microcirculation. Role of the deformability of blood cells on their dynamics and associated medical applications. Active RBC effects under strong external stress.
- Mucociliary transport. Collective behaviour of active bronchial cilia

Abstract:

We first show how active mucus-cilia hydrodynamic coupling drives self-organisation of human bronchial epithelium and then present examples of the dynamics of blood cells in microflows and show how their mechanical properties are critical for a proper transport in the microvasculature.

The respiratory tract is protected by mucus, a complex fluid transported along the epithelial surface by the coordinated beating of millions of microscopic cilia. Its impairment is a strong marker of severe chronic respiratory diseases. The relationship between ciliary density and the spatial scale of mucus transport, as well as the mechanisms that drive ciliary-beat orientations

during ciliogenesis are much debated. We show on polarized human bronchial epithelia that mucus swirls and circular orientational order of the underlying ciliary beats emerge and grow during ciliogenesis, until a macroscopic mucus transport is achieved for physiological ciliary densities. We demonstrate that cilia/mucus hydrodynamic interactions govern the collective dynamics of ciliary-beat directions. We propose a two-dimensional model that predicts a phase diagram of mucus transport in accordance with the experiments.

Microcirculation of blood cells.

She will present one of the two cases described below:

Proper circulation of white blood cells (WBCs) in the pulmonary vascular bed is crucial for an effective immune response. In this branched vascular network, WBCs have to strongly deform to pass through the narrowest capillaries and bifurcations. We mimic the pulmonary capillary bed by a microfluidic network of narrow channels whose size and applied pressure have physiological values. We show that the dynamics of monocytes have an adaptive dynamic in the capillary network with a first non-stationary regime characterized by a slow movement with hops followed by a fast and smooth motion allowing efficient transport. We propose a simple mechanical model that shows that a very-finely tuned cortical tension combined with a high cell viscosity govern the fast transit through the network while preserving cell integrity. We finally highlight that the cortical tension controls the steady-state cell velocity.

Fitness test of red blood cells in the red pulp of the spleen. Red blood cells (RBCs) must be highly deformable to pass through blood capillaries. Their deformability is probed in the spleen, where RBCs squeeze through submicron inter-endothelial slits. We have developed a microfluidic device containing slits with submicron width replicating the physiological dimensions of splenic slits where the RBC dynamics can be observed through the slits and recorded by optical microscopy. We report their dynamics as a function of the relevant external parameters (slit dimensions, pressure drop) and cell morphologies. In particular, we show original modes of deformation with the formation of tips at the cell front. Conjointly, Zhangli Peng (University of Illinois at Chicago) developed numerical simulations that recover both RBC transit times and shape deformation. The comparison of experiments and simulations leads to a deep insight of the mechanisms of RBC transit through the slits