On artificial cilia and nuclear pores: a solid mechanician going bio.

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In this presentation I will discuss two recent research topics that are aimed at understanding and learning from nature's intriguing working principles.

In the first topic, we explore a new way to propel fluids through micro-channels of lab-on-a-chip devices by mimicking the fluid transport mechanisms of natural ciliates, such as Paramecia. Fluid propulsion of Paramecia takes place by means of hair-like motile appendages known as cilia that beat in an asymmetric manner. In addition, the individual cilia beat out-of-phase which results in a wave-like motion (metachronal waves). Here, we design magnetic artificial cilia that can be externally actuated to mimic these non-reciprocal deformations (see Fig. 1). The artificial cilia can be realized using thin films consisting of a polymer matrix filled with magnetic nano-particles, allowing actuation by means of an external magnetic field. We use a coupled magneto-mechanical solid-fluid model to explore the conditions at which a magnetic film will mimic the asymmetric motion of natural cilia. The response of the artificial cilia is studied in terms of the dimensionless parameters that govern their physical behavior and identify the parameter space in which the cilia can generate maximal flow.

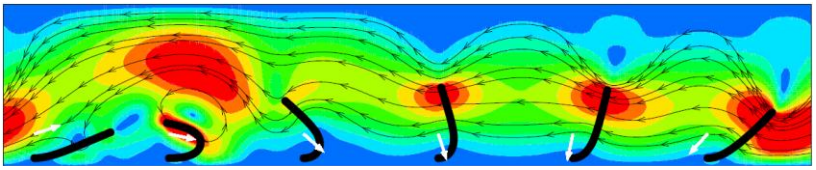

Fig. 1. Artifical cilia propelling fluid through antiplectic metachronal waves.

In the second topic, we explore the transport properties of the nuclear pore complex (NPC), a giant molecular complex that provides directional, fast and yet selective transport of proteins across the nuclear envelope. Natively disordered proteins (FG-nups) that line the central channel of the NPC play a key role in regulating the nuclear transport. The exact transport mechanism, however, is still not clear. To obtain insight in this process we propose a coarse grained model to study the collective behavior of FG-Nups inside the transfer channel via molecular dynamics simulations (see Fig. 2). The obtained density plots reveal a unique distribution of charged and hydrophobic residues inside the NPC. In addition, we show that these distributions are encoded in the specific amino-acid sequence of the FG-Nups.

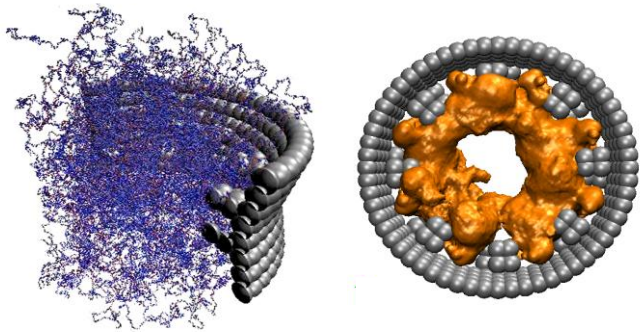

Fig. 2. The NPC-scaffold filled with coarse-grained one-bead-per-amino-acid FG-nups (left). Amino-acid density distribution (right).