PhD project :

Nano-Ratchet : Active transport at the nanoscale

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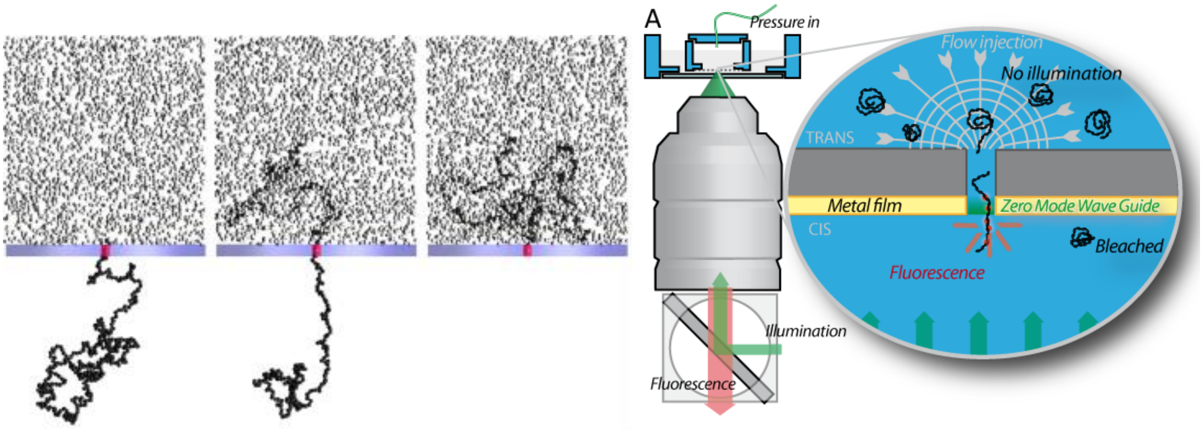
Summary: Flows of molecules at the nanometer scale play an important role in many biological, chemical and physical systems and have important applications. Nanoscale channels offer the possibility to explore new phenomena appearing for confined molecules or flows. New transport behavior and functionalities can be developed by taking benefit of the specific couplings occurring at these scales.

For example, the idea to select random fluctuations in order to force a particle in one direction has led to the paradox of the Brownian ratchet as introduced by Feynman. Translocation mechanisms that can be described as Brownian ratchets have been observed in various biological processes where proteins are translocated through a biological membrane. In this case a protein moves in and out through a nanopore by thermal fluctuations (Fig. 1a). On the in-side of the pore, smaller ratcheting particles may bind to the proteins and bound sites along the polymer are forbidden to move back through the pore.

In this project, we propose to use single molecule methods to create and control the active transport of biomolecules in an artificial nano-system. In a first part we will use a gradient of agents with high affinity for the cargos molecules to bias the diffusive motion of the molecules. We will benefit from a new near field optics technique developed in the lab (Fig 1b) to measure directly at the single molecule and single channel scale the force-velocity relation of this selective nano-pump. In a second part we will use optical trapping to force the transport of DNA molecules. We will characterize directly the energetics of this transport using out of equilibrium modeling.



a) Zero-Mode Waveguide for nanopores.Using a near field effect single molecule translocations can be observed in real time. b) Translocation ratchet simulation. Snapshots from simulations of BiP driven transl.cation. Langevin dynamics in a one to one configuration. (from left to right) The polymer is pulled from the lower chamber to the upper chamber because of the binding of the ratcheting agents.

Bibliography : Zero-mode waveguide detection of flow-driven DNA translocation through nanopores. Auger T, Mathé J, Viasnoff V, Charron G, Di Meglio JM, Auvray L, Montel F. **Phys Rev Lett**. 2014 Jul 11;113(2):028302.