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Viscous and solid-like friction in biological systems

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The aim of this presentation is to review the role of friction in cell and tissue mechanics at various scales: at the molecular scale of the proteins, at the cellular scale and at the more macroscopic scale of a tissue.

Keywords : cell mechanics, morphogenesis, protein friction

In a cell when two objects are linked by proteins, the friction force between them is much larger that the classical viscous drag. The linking proteins bind and unbind at a constant rate and the relative motion between the objects stretches the bound proteins. The friction is due to the dissipation of the associated elastic energy upon unbinding of the proteins. This mechanism has been proposed by K. Sekimoto and is called protein friction. It is very similar to the Lake and Thomas mechanism that explains the friction of rubbers on a solid substrate or to the principles of colloidal glues for polymeric materials proposed by L. Leibler.
Protein friction plays for example major role in the motion of molecular motors walking on a filament.

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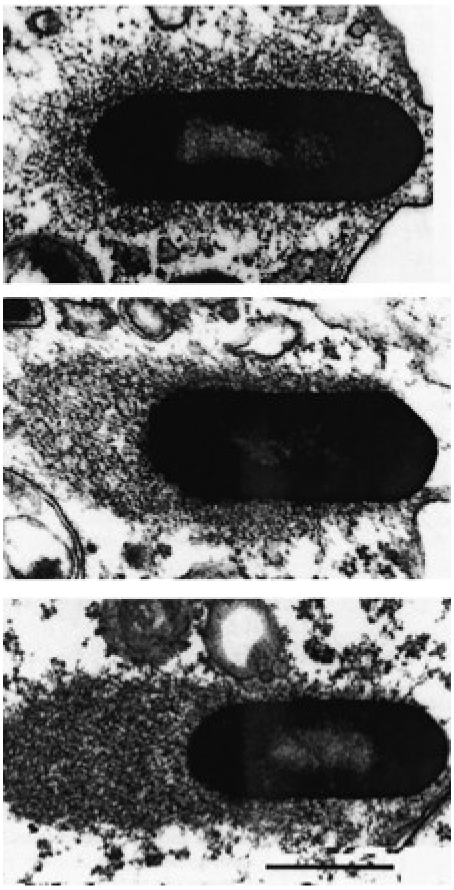

Figure 1: Growing comet that propels the bacterium *Listeria Monocytogenes*.

A different type of friction due to proteins is found in hair cells that detect sound in the ear. The friction force is in part due in this case to the fluctuations of opening and closing of ion channels.

At the level of cells, friction and adhesion play an important role in cell motility. We show two examples: cells crawling on a solid substrate and the swimming of the bacterium *Listeria Monocytogenes.* The adhesion of a crawling cell on a substrate is due to protein complexes called focal adhesions. The focal adhesions have the unusual property that they strengthen when the force applied on the cells increases.
Listeria swims in water by growing a comet which is a gel of actin filaments. The growth of the comet is shown on Figure 1. The friction between the actin comet and the body of the bacterium can vary in a non-monotonic way with the velocity. This is at the origin of a periodic saltatory motion of the bacterium very similar to stick slip.

The collective properties of cells in a tissue or a cell aggregate are very different than their individual properties. A monolayer of cells plated on a solid substrate spreads because of cell motion and cell motility. The friction of the cells on the substrate opposes this motion. The active nature of the friction force that can drive a collective global motion of the cells.