Mechanics of Phagocytosis

Alexandra Zak[1,2],Sophie Dupré-Crochet[2],Elodie Hudik[2]
,Avin Babataheri[1],Oliver Nüsse[2],Julien Husson[1]
[1]Laboratoire d'Hydrodynamique de l'X (LadHyX), CNRS UMR7646, Ecole polytechnique, Palaiseau, France
[2]Laboratoire de Chimie Physique (LCP), CNRS UMR8000, Université Paris Sud, Orsay, France

The biological process of phagocytosis is one of the first steps of an immune response against microbial infection. This target-specific mechanism involves specialized cells, called phagocytes, among which are **neutrophils**. These foot-soldiers are able to internalize pathogens or dead cells into a dedicated compartment, the phagosome, and to digest them afterwards. During the creation of the phagosome, the cell surrounds the phagocytic target with a **phagocytic cup**. During this step, the neutrophil exerts some **forces** and **increases its tension** [1].

To investigate both cellular forces and stiffness, we use a **micropipette force probe** [2, 3] (Figure 1). This device allows handling a single neutrophil and bringing it in contact with a single target, here an opsonized polystyrene bead. We control the contact time between the neutrophil and its target, and we image the progression of the phagocytosis sideways under a high-magnification light microscope. The cell pushes or pulls on the opsonized bead, as witnessed by the bending of a flexible micropipette holding the bead. We can also impose this flexible pipette to indent the neutrophil thus measuring both **cellular tension and viscosity** according to time.

We observe that 12-μm diameter opsonized beads are not totally phagocyted. We investigate whether this is due to the target geometry or to limited membrane reservoirs. To quantify how the cell is able to actively mobilize these reservoirs, we indent the neutrophil while it is phagocyting a target. We measure both the **tension and the viscosity of the neutrophil** according to the phagocytic cup progression. This study will allow us to better understand the mechanical factors that regulate phagocytosis.

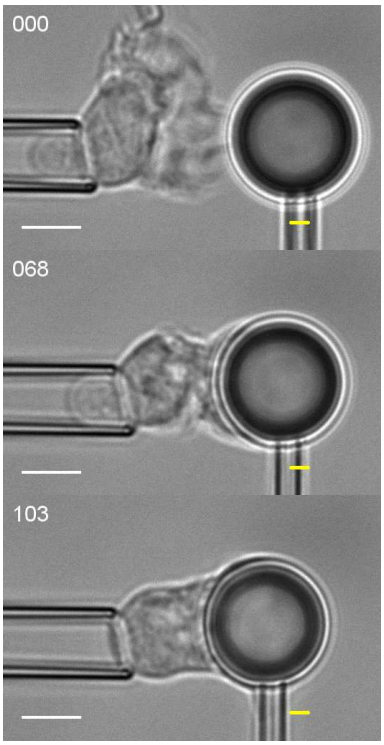

Figure 1: Chronology of events of a neutrophil forming a phagocytic cup on a 12-μm opsonized polystyrene bead. The yellow bar indicates the initial position of the flexible pipette. Aspiration pressure = 20 Pa. Time in seconds is upper left; scale bar = 5 μm.

References

[1] Marc Herant, Volkmar Heinrich, and Micah Dembo. Mechanics of neutrophil phagocytosis: behavior of the cortical tension. *Journal of cell science*, 118(Pt 9):1789–1797, 2005.

[2] Roshni Basu, Benjamin M Whitlock, Julien Husson, Judy Lieberman, Lance C Kam, Morgan Huse, Audrey Le, Weiyang Jin, and Alon Oyler-yaniv. Cytotoxic T Cells Use Mechanical Force to Potentiate Target Cell Killing Cytotoxic T Cells Use Mechanical Force to Potentiate Target Cell Killing. *Cell*, pages 1–11, 2016.

[3] L Guillou, A Babataheri, P Puech, A I Barakat, and J Husson. Dynamic monitoring of cell mechanical properties using profile microindentation. *Nature Publishing Group*, pages 1–13, 2016.