Master's internship 2011: Spatiotemporal vesicle dynamics in microfluidics and blood rheology

Keywords: Experiments, biomembrane, fluid-structure, complex fluids, shape instability
Internship's supervisor: Marc Leonetti (leonetti@irphe.univ-mrs.fr, 04.96.13.97.43)
Research's team: Julien Deschamps (04.96.13.97.83) and Marc Georgelin (04.96.13.97.54)
Laboratory: IRPHE, UMR CNRS 6594, Technopôle de Château-Gombert, Marseilles, France
https://www.irphe.fr/-Auto-organisation-dans-les-
Continuation in Ph.D: yes (Ecole Doctorale 353)

Blood is a complex fluid with various components from suspending cells (red blood cells and leucocytes) to proteins. Its properties depend also on the space ratio, cell size over capillary diameter. Several ways are relevant to understand this rising and all-embracing problem of fluid dynamics, rheology of a large number of very soft objects in a liquid. Soft means here that thermal fluctuations can play a role. Experimentally, the current challenge is to link the deformations of model systems imitating some cell properties in a flow to the macroscopic properties of such a suspension. Indeed, biological membranes are lipids self-organized in a bilayer of thickness 4 nm which has the characteristics of a bidimensional incompressible liquid. Thus, Contrary to drops, membrane's area is fixed. Moreover, interfacial mechanics is dominated by the curvature energy (evanescent surface tension) and there is no fusion between two cells. Note that at a fundamental point of view, this system is very original with strong geometric constraints.

A bottom-up approach is to consider system models such as vesicles (closed lipid bilayer) which fulfill the previous characteristics. At thermodynamical equilibrium, their properties are known. The present project is to study experimentally their out of equilibrium behaviors when a flow is constrained. The tools developped in microfluidics associated to microscopy and micro-PIV allow to investigate several configurations: role of membrane rigidity in the spatiotemporal dynamics of a vesicle in a shear flow, dynamics in an hyperbolic flow, generation of a lipidic tube and pearls, interactions between two and more vesicles in a flow.

Following the inclination of the candidate, another relevant way to solve the initial questioning on blood rheology is to investigate other objects such as capsules which have not a liquid membrane but a solid one dominated by extensional and shear elasticity. One advantage is the possibility to have a monodisperse suspension of large capsules (~100 µm) and the capacity to study their rheology in a rheometer equipped for visualizations at large (the suspension) and small (one vesicle up to a few ones) scale.

In all the cases, our method is to work on shape deformations and their associated instabilities to reach a better understanding of suspension of very soft materials such as blood.

Figure: Several experiments on vesicles under an hydrodynamic flow in our team: left-shear flow and right-hyperbolic flow (vesicle size ~ 20 µm).

Références:
[1] J. Deschamps, V. Kanstler and V. Steinberg, Phys.Rev.Lett. 102, 118105 (2009); Phase diagram of single vesicle dynamical states in shear flow
[2] J. Deschamps, V. Kanstler and V. Steinberg, PNAS 106, 11444 (2009); Dynamics of a vesicle in general flow