An example of active liquids :
Hydrodynamic and chemical interactions of phoretic swimmers

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Bacteria and other microorganisms are tiny, and their individual impact on their fluid environment is invisible at our scale. But their collective organization and dynamics can profoundly affect the macroscopic characteristics of the flow (e.g. so-called bacterial turbulence, modification of the effective flow viscosity).

An important engineering challenge lies in the conception of artificial active fluids, that can be used either to perform dedicated tasks such as mixing or targeted drug delivery, or to tailor macroscopic fluid properties from an actuation at the microscopic scale.

Phoretic or fuel-based swimmers are a promising example of such active particles : through chemical and/or thermodynamic interactions with their environment, they are able to force a fluid flow at their surface in response to local gradients of temperature or solute concentration they themselves generate through catalytic reactions or solute/heat release.

To obtain accurate description of the suspension, a first step is a good understanding and modeling of the individual properties and behavior of such active systems. This is the main goal of the present Master thesis that can easily lead to a PhD depending on the student's interests. Possible questions that we would focus on are :

— How do particles interact (hydrodynamically and chemically) ? What are the characteristics of the macroscopic flow generated through their collective motion ?
— Response to a chemical signal : how do such particles respond to an outer chemical forcing ? what are the characteristics of their response ?
— How do particles react to the presence of an outer boundary (solid wall or free surface) ?

The approach of this project combines analytical calculations and modeling with numerical simulations. Collaborations with experimental groups on self-propelled systems are also planned.

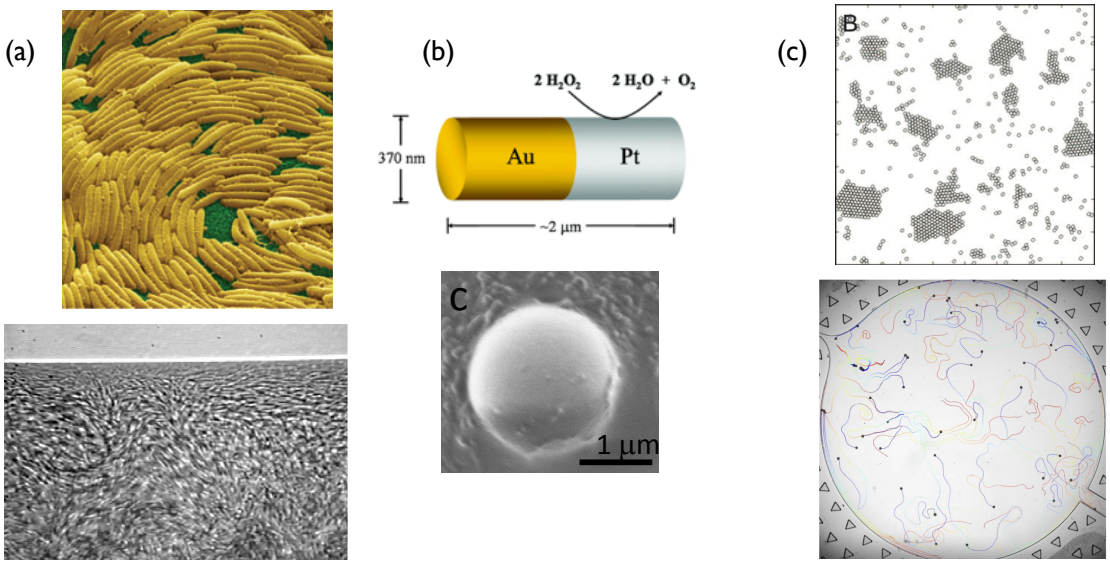

FIGURE 1 – (a) Bacterial "turbulence" and swarming are examples of collective self-organization that creates a net flow at scales much larger than the organism's size. (b) Examples of phoretic swimmers : bi-metallic "Janus" rods and spherical colloids. (c) Collective organization of active particles.