# Internship/PhD
# Swimming in stratified environments

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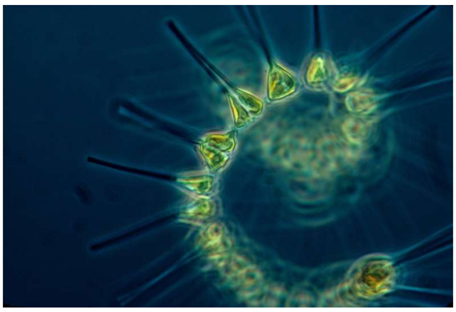
Natural bodies of water, such as the ocean, typically feature gradients in density and viscosity due to variations of temperature or salinity. These fluid inhomogeneities markedly affect the dynamics of large-scale fluid flows such as ocean currents and climate recirculation that govern weather. In addition, the local dynamics of small particles, both living organisms and synthetic particles, suspended in the fluid are also significantly altered by the presence of inhomogeneities in the mechanical properties of the fluid. For instance, recent work has shown that gradients in fluid viscosity [1] and density [2] can lead to the reorientation and taxis of swimming organisms, however these studies were limited to isolated very small organisms that do not substantially mix the fluid. Experimental evidence for larger organisms such as euphausiids, shows that gradients in fluid temperature or salinity tends to hinder their regular diel vertical migration. Moreover, in recent decades, density stratification of the ocean has increased substantially due to the effects of global warming and this could have dramatic effects on the dynamics of organisms and marine ecology. Currently there is a limited understanding of the dynamics of both living and synthetic particles suspended in stratified fluids.

We propose here to develop a theoretical framework to accurately model the effects of spatial variations in density and viscosity on the individual and collective dynamics of organisms in stratified fluids including the mixing of the fluids generated by the organism at finite Péclet number [3]. The goal of the internship will be to analyse the effect of the transport of temperature or salinity fields on the dynamics through their impact on viscosity and density distributions . This analysis will further provide critical information on the impact of the swimming motion on the vertical mixing in the ocean.

Depending on the motivation and forward progress of the student, the project can be continued into a PhD (funding already secured). In this second step, the effect of the mechanical inhomogeneity on the hydrodynamic signature of the swimmer will be considered in order to understand the resulting hydrodynamic interactions and collective behaviour of microorganisms in such stratified environments.

The PhD project will be hosted at LadHyX, Ecole Polytechnique – Institut Polytechnique de Paris, in joint supervision with the University of British Columbia in Canada.



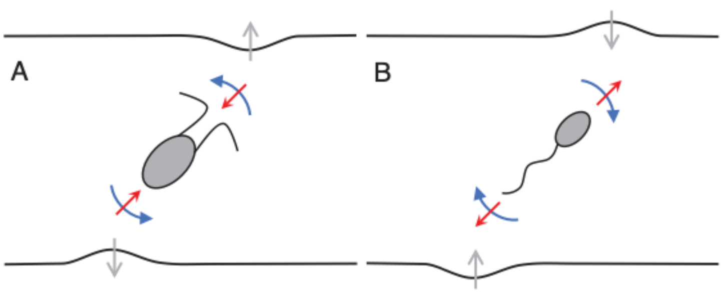



FIGURE 1 – (Left) Plankton perform vertical migration seeking food and mixing fluid layers. (Right) Model microswimmers and their effect on isopycnal profiles. [2] (see also here)

Interested applicants should contact Profs. Michelin & Elfring with (i) a CV, (ii) a brief description of previous research experience and coursework and (iii) the name of two academic references.

## References

[1] C. Datt & G. J. Elfring, Active particles in viscosity gradients, *Phys. Rev. Lett.*, **123** (2019) 158006

[2] V. A. Shaik & G. J. Elfring, Densitaxis : Active particle motion in density gradients, *PNAS*, **121** (2024) e2405466121

[3] S. Michelin & E. Lauga, Phoretic self-propulsion at finite Péclet numbers, *J. Fluid Mech.*, **747** (2014) 572–604