Modeling the thermal sensitivity of *Paramecium*, the "swimming neuron"

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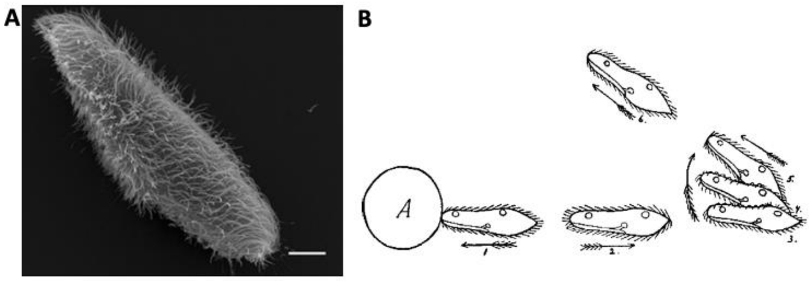
More details: http://romainbrette.fr/neuroscience-of-a-swimming-neuron/

Paramecium is a unicellular organism that swims in fresh water by beating thousands of cilia. When it is stimulated (mechanically, chemically, optically, thermally…), it often swims backward then turns and swims forward again. This "avoiding reaction" is triggered by a calcium-based action potential. For this reason, some authors have called *Paramecium* a "swimming neuron" (Brette, 2021). This project belongs to a broader project aiming at developing integrative models of *Paramecium*, bridging physiology and behavior. This is a collaborative effort between the laboratories of Romain Brette (Neuroscience, Vision Institute), Alexis Prevost and Léa-Laetitia Pontani (Physics, Laboratoire Jean Perrin) and Eric Meyer (Genetics, École Normale Supérieure) in Paris. The team has already developed experimental techniques (behavior and electrophysiology), including a device to immobilize *Paramecium* for electrophysiology experiments (Kulkarni et al., 2020), and a basic biophysical model of the action potential and electromotor coupling (Elices et al., 2022).



A – Scanning electron microscopy image of Paramecium tetraurelia (scale bar: 10 µm) (Valentine et al., 2012).
B – Avoiding reaction against an obstacle, as illustrated by Jennings (Jennings, 1906).

This project aims at developing a model of thermal sensitivity in *Paramecium*. When placed in a thermal gradient, *Paramecium* tends to gather around a preferred temperature, thanks to temperature-triggered avoiding reactions (Nakaoka and Oosawa, 1977). This behavior is mediated by membrane potential changes (Tominaga and Naitoh, 1992) produced by cold- and heat-sensitive thermoreceptors (Kuriu et al., 1998, 1996; Tominaga and Naitoh, 1994). In addition, the preferred temperature shifts when *Paramecium* is left at the same temperature.

A basic experimental device has been built in Laboratoire Jean Perrin to observe paramecia in controlled thermal gradients. The first part of the project is to refine this device and to film trajectories with normal paramecia, and with mutants that do not produce action potentials. The second part is to use the trajectories extracted with tracking software to build a model of thermosensitivity. Within a trajectory, the time-varying temperature is mapped to a sequence of action potentials and we want to infer the mapping. This is formally equivalent to the problem of inferring a neuron model based on its input and output, for which the lab has developed computational techniques (Teska et al., 2020). The model will then be simulated to see if it accounts for the thermosensitive behavior. Theoretical analysis is also possible using biased diffusion models.

Depending on time and interest, the student will have the opportunity to either investigate the electrophysiological basis of the inferred input-output mapping (by measuring electrical responses to thermal changes), or its molecular basis (by inactivating receptors either pharmacologically or genetically with RNA interference).

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