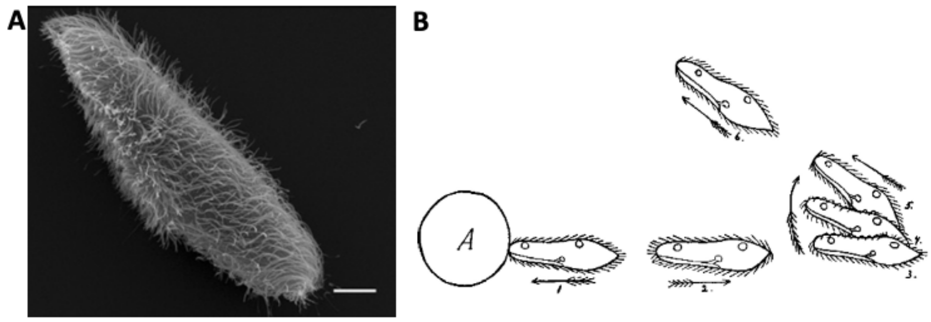
Mechanisms of *Paramecium* escape from a capillary

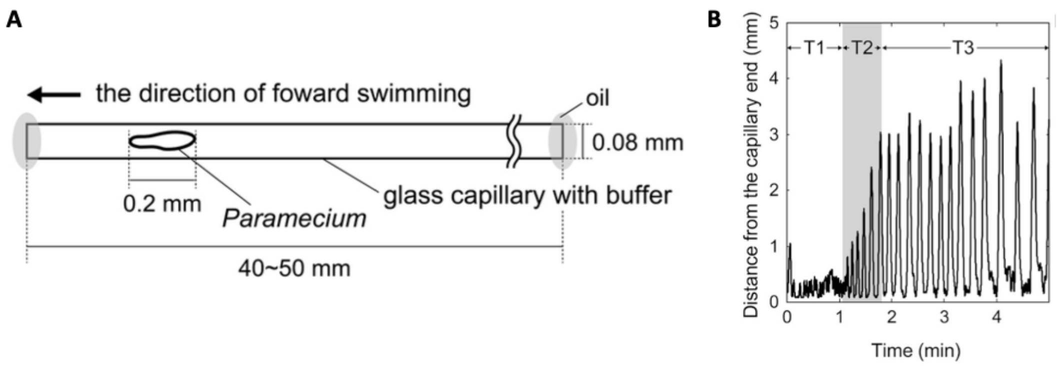
Contact: romain.brette@inserm.fr

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 labs of Romain Brette (neuroscience, Vision Institute), Alexis Prevost et Laetitia Pontani (physics, Laboratoire Jean Perrin) and Eric Meyer (genetics, Ecole 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.



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 understanding how *Paramecium* escapes from a dead end. When *Paramecium* swims in a narrow capillary that does not allow it to turn, it may be trapped into a dead end, where it will give the avoiding reaction repeatedly, alternatively moving backward and forward against the wall (Kunita et al., 2014). But after a minute, the avoiding reaction suddenly becomes much longer (several millimeters), potentially allowing the organism to escape.



A, Experimental setup of (Kunita et al., 2014). B, Trajectory of Paramecium in a 5 mm capillary, showing an increase in backward swimming after 1 min, corresponding to about 40 avoiding reactions.

The first step of the project is to reproduce this experiment. The next step will be to distinguish between two types of explanations:

1. *Paramecium* releases some substance in the extracellular medium (CO_2 or some protein), which builds up with time, and which influences its behavior.

2. Repeated avoiding reactions trigger a change in intrinsic properties, for example potentiation of the calcium channel, or inactivation of potassium channels.

To distinguish between (1) and (2), the experiment will be repeated with the same capillary and a different cell. If (2) is correct, the student will determine whether it is the excitation or the mechanical contact that triggers the change, for example by inserting a repelling substance at the capillary end. If (1) is correct, some indication of the molecule involved in the phenomenon will be obtained by measuring the diffusion time.

Next, the student will determine what kind of physiological change is responsible for the phenomenon, by measuring the action potential under the electrophysiology setup, and in case (2) is correct, by reproducing the phenomenon electrically.

Finally, depending on time and interest, the student will develop a model of the phenomenon, by building on the existing action potential.

The project can be adapted to the duration of the project and the profile of the student.

Brette R (2021) Integrative Neuroscience of Paramecium, a "Swimming Neuron." eNeuro 8:ENEURO.0018-21.2021.

Jennings HS (1906) Behavior of the lower organisms. New York, The Columbia university press, The Macmillan company, agents; [etc., etc.].

Kulkarni A, Elices I, Escoubet N, Pontani L-L, Prevost AM, Brette R (2020) A simple device to immobilize protists for electrophysiology and microinjection. Journal of Experimental Biology 223.

Kunita I, Kuroda S, Ohki K, Nakagaki T (2014) Attempts to retreat from a dead-ended long capillary by backward swimming in Paramecium. Front Microbiol 5.

Valentine MS, Rajendran A, Yano J, Weeraratne SD, Beisson J, Cohen J, Koll F, Van Houten J (2012) ParameciumBBS genes are key to presence of channels in Cilia. Cilia 1:16.