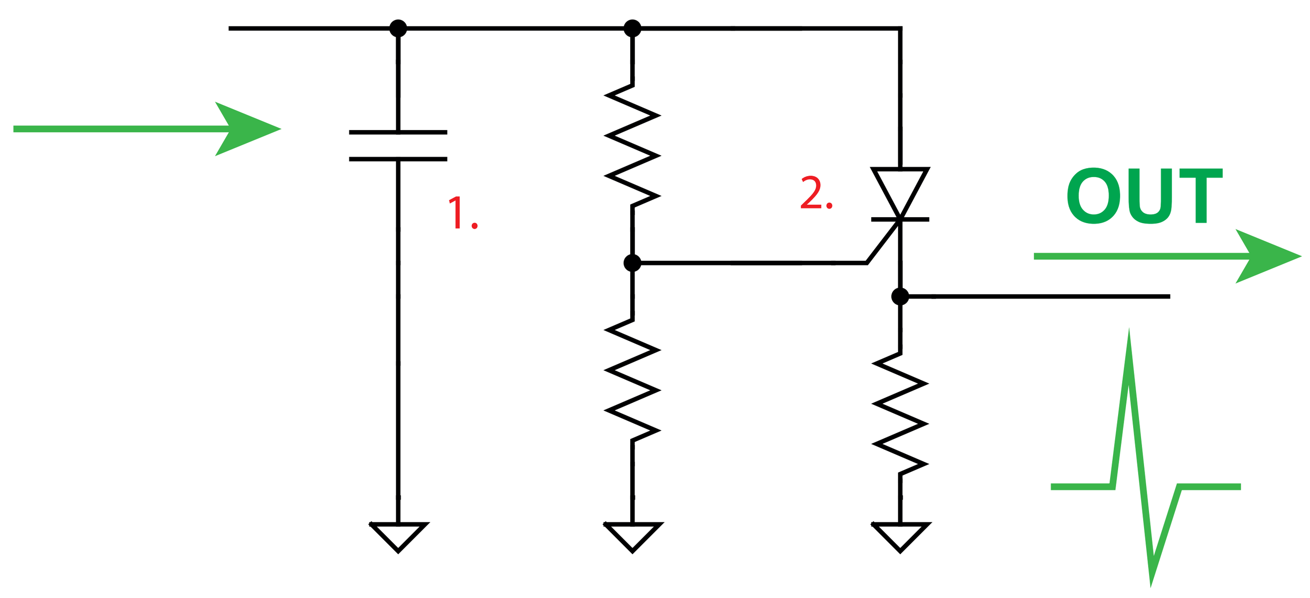
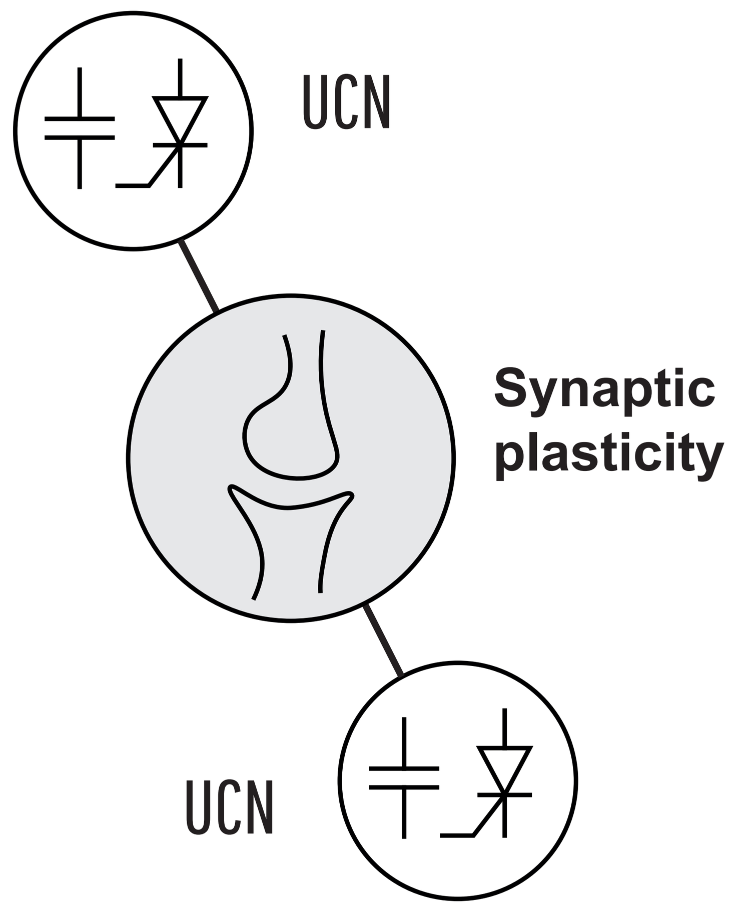
Domaine de Recherche et d'Innovation Majeur

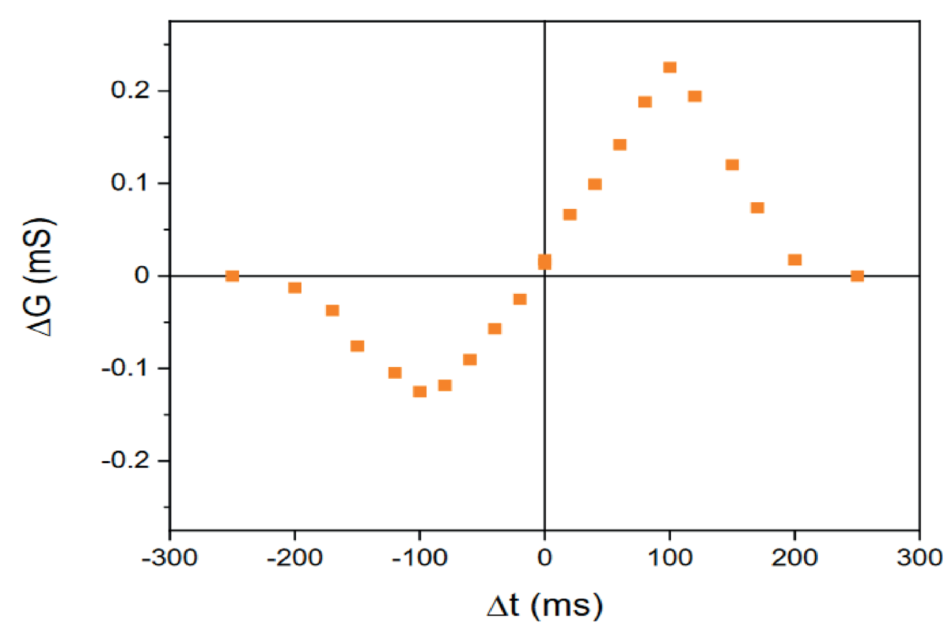
Unsupervised learning in an electronic spiking neural network for brain-machine interfaces

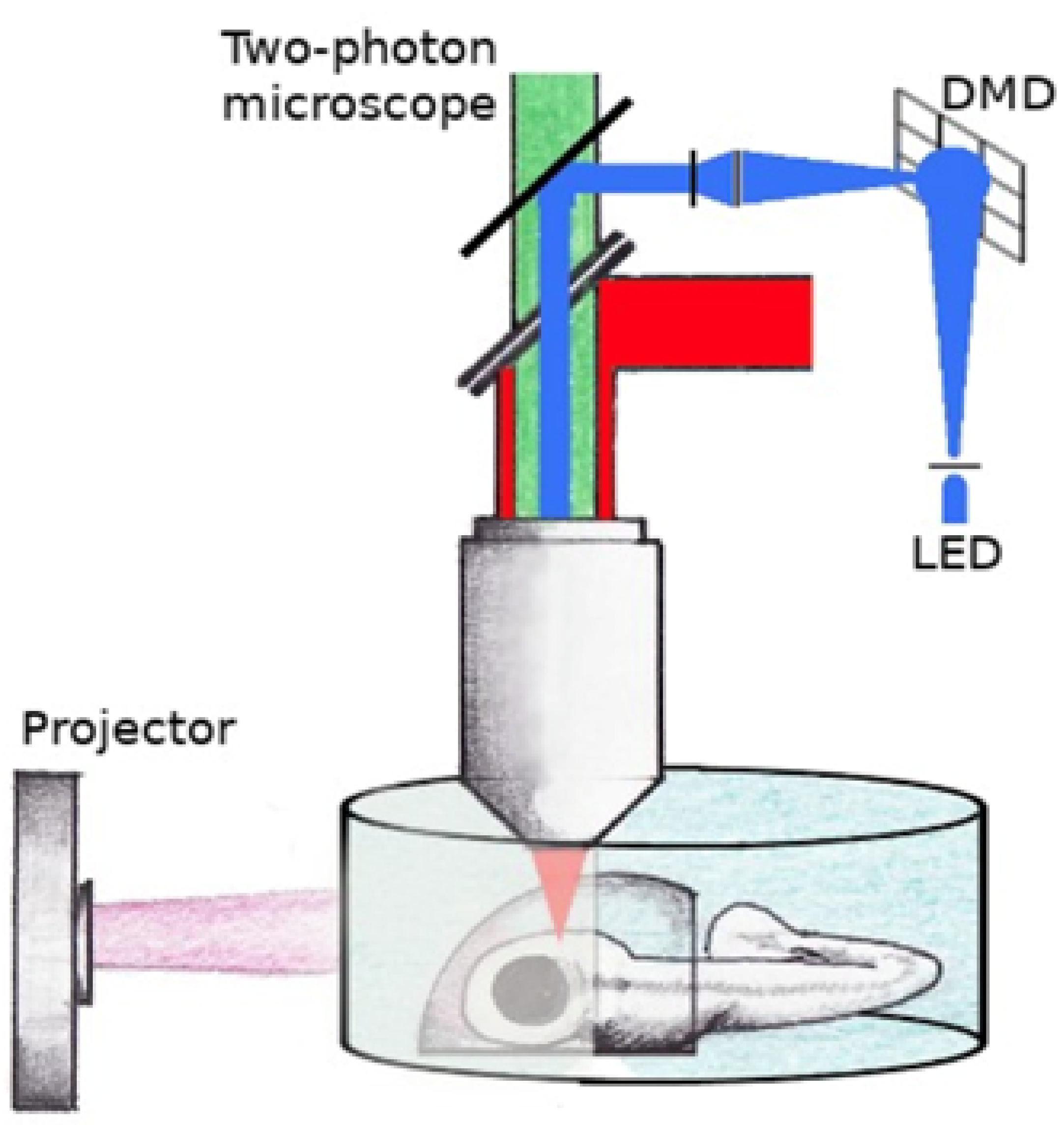


The **ultra compact neuron** (UCN) is an easy to manufacture spiking apparatus. Currents are integrated in real time through a capacitor **(1.)** until the voltage is high enough to open the gate of a thyristor **(2.)**. When the thyristor is open, the current quickly leaks from the capacitor which induce a sudden increase of the output pin voltage, similar to a biological **spike**.



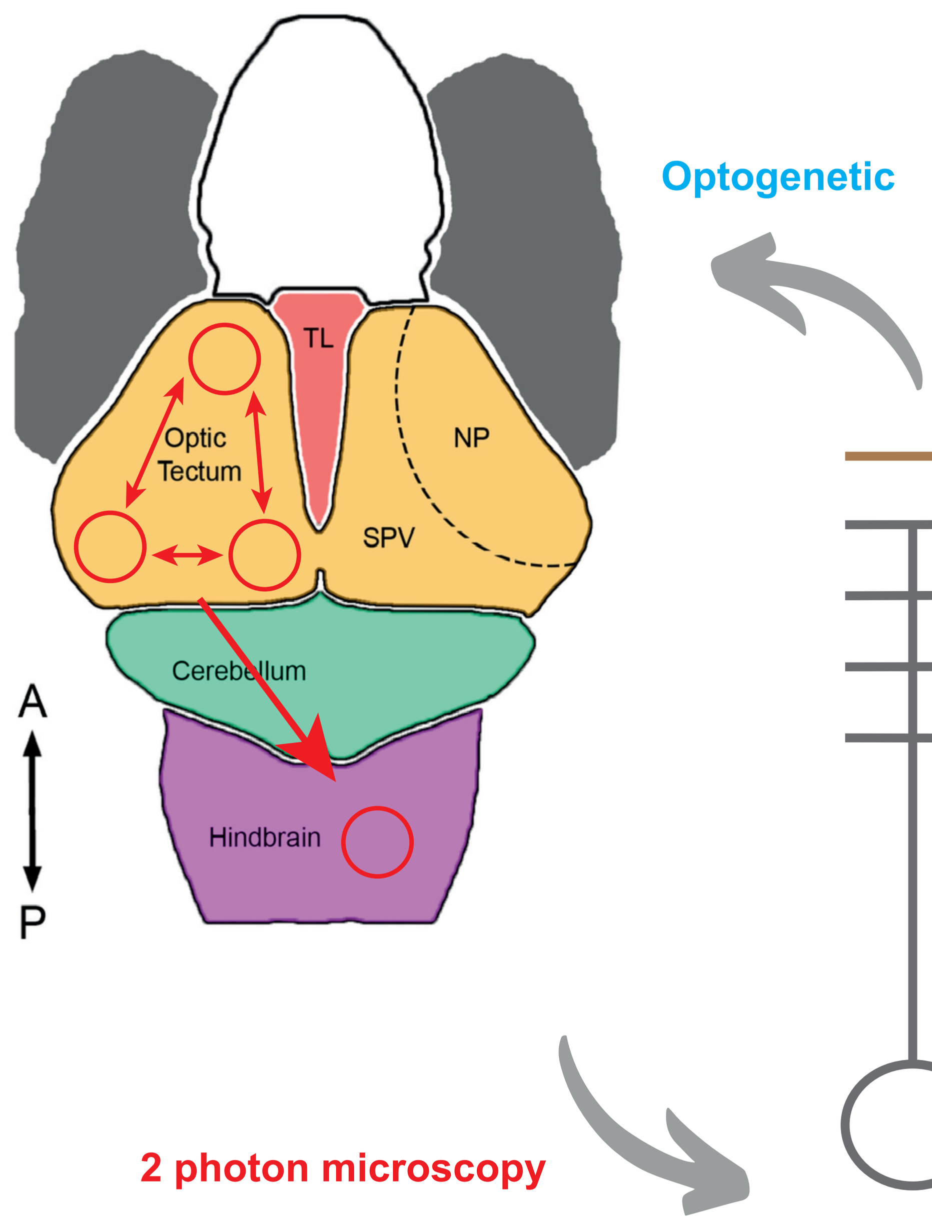
UCN's are building blocks that can be connected to build spiking neural networks. To enable **unsupervised training** in a network, rules of **synaptic plasticity** are implemented in Silico. Below is an example of plasticity rule called STDP, derived from experimental observations.

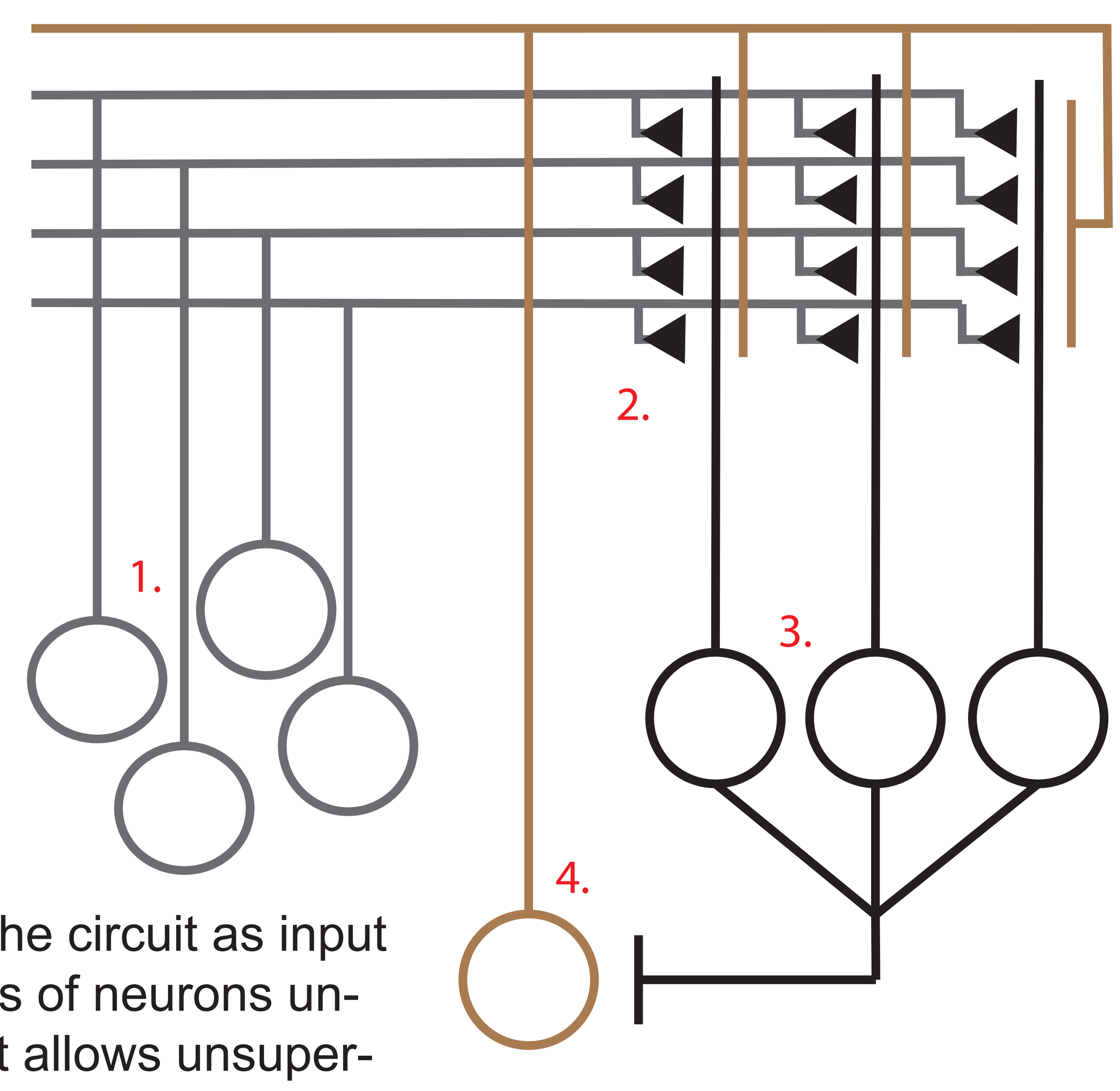




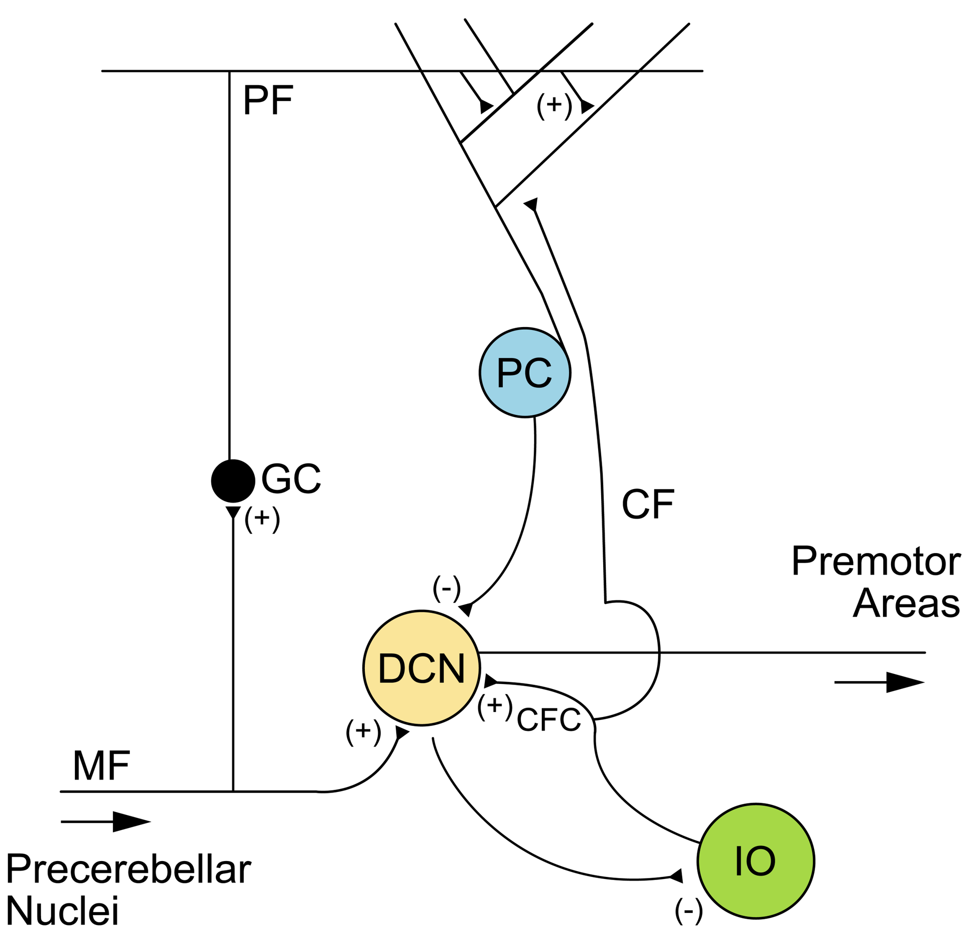
Zebra fishe's brain can be directly observed using two-photon microscopy. The transparency of its skull and its ability to be immobilized in an agarose gel, while keeping its tail mobile make it an ideal animal model for brain-machine interface applications. Transgenic lineages express genes that lead to the production of fluorescent or light-sensitive transmembrane proteins, allowing us to observe and manipulate nerve activity.

The circuit is interfaced in **real time** with the zebra fishe brain. The circuit uses sensory activity from the optic tectum to predict and influence, through optogenetics, the activity in the hind brain.





Activity from the **optic tectum** is fed in the circuit as input data **(1.)**. Synapses between populations of neurons undergo a special kind of plasticity **(2.)** that allows unsupervised learning. The teacher neuron **(4.)** modulates the plasticity of the learning population **(3.)**. The learning population inhibites the teacher neuron to modulate its own learning.



The circuit architecture is modeled after the structure of the **cerebellum**, which is believed to leverage present sensory context to **anticipate** future sensory and proprioceptive inputs. This form of learning is considered "**self-supervised**," as the signal from the inferior olive modulates the plasticity of Purkinje cells to learn essential sensory activity patterns. The circuit's inhibitory feedback loop, similar to the one presented above, contributes to the stability of the learning process.

Goals

This project aims to achieve several objectives. Firstly, it seeks to establish a model of an analogous circuit that can perform real-time and supervised associative learning without experiencing degradation in its stability or its learning due to noise. Once the circuit is developed, it will be trained to predict the activity of specific areas in the zebrafish nervous system based on the activity of other areas. For instance, motor activity can be inferred from sensory activity. Lastly, the study will investigate the interaction between real-time circuit learning and the behavioral and neurophysiological modalities of the fish during the learning of a given task.