



PRESS RELEASE - PARIS - 16 AUGUST 2021

An artificial ionic neuron for tomorrow's electronic memories

- Artificial intelligence surpasses the human brain only at the cost of consuming tens of thousands of times more energy.
- A major difference between the brain and electronic systems is that neurons use ions, not electrons, to carry information.
- French scientists have designed theoretical artificial neurons with ions to carry the information.

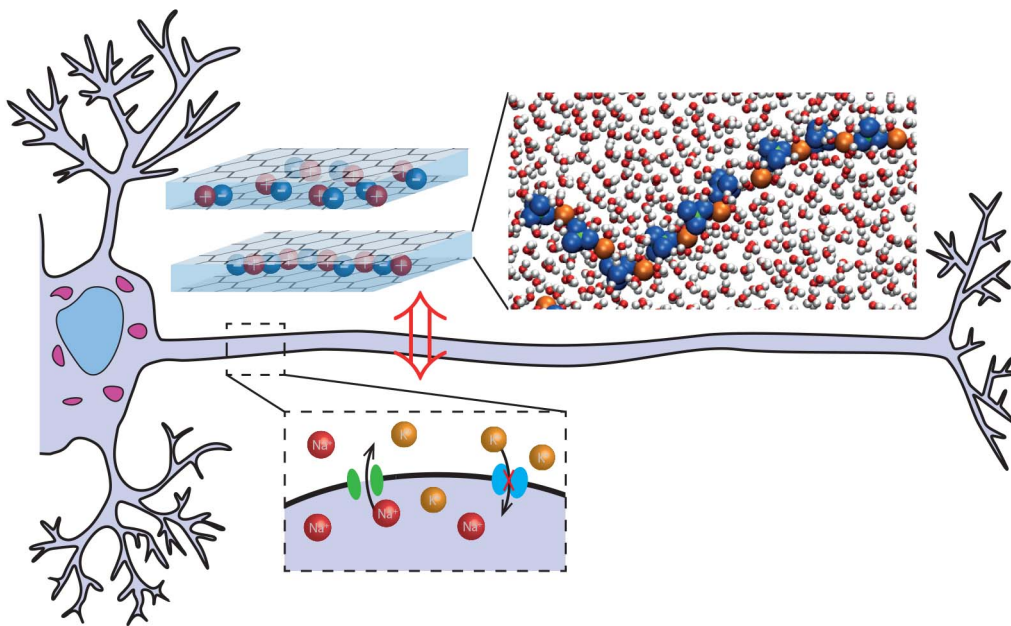
Brain-inspired electronics are the subject of intense research. Scientists from CNRS and the Ecole Normale Supérieure – PSL have theorized how to develop artificial neurons using, as nerve cells, ions to carry the information. Their work, published in *Science* on 6 August 2021, reports that devices made of a single layer of water transporting ions within graphene nanoslits have the same transmission capacity as a neuron.

With an energy consumption equivalent to two bananas per day, the human brain can perform many complex tasks. Its high energy efficiency depends in particular on its base unit, the neuron, which has a membrane with nanometric pores called ion channels, which open and close according to the stimuli received. The resulting ion flows create an electric current responsible for the emission of action potentials, signals that allow neurons to communicate with each other.

Artificial intelligence can do all of these tasks but only at the cost of energy consumption tens of thousands of times that of the human brain. So the entire research challenge today is to design electronic systems that are as energy efficient as the human brain, for example, by using ions, not electrons, to carry the information. For this, nanofluidics, the study of how fluids behave in channels less than 100 nanometers wide, offer many perspectives. In a new study, a team from the ENS Laboratoire de Physique (CNRS/ENS-PSL/Sorbonne Université/Université de Paris) shows how to construct a prototype of an artificial neuron formed of extremely thin graphene slits containing a single layer of water molecules¹. The scientists have shown that, under the effect of an electric field, the ions from this layer of water assemble into elongated clusters and develop a property known as the memristor effect: these clusters retain some of the stimuli that have been received in the past. To repeat the comparison with the brain, the graphene slits reproduce the ion channels, clusters and ion flows. And, using theoretical and digital tools, scientists have shown how to assemble these clusters to reproduce the physical mechanism of emission of action potentials, and thus the transmission of information.

This theoretical work continues experimentally within the French team, in collaboration with scientists from the University of Manchester (UK). The goal now is to prove experimentally that such systems can implement simple learning algorithms that can serve as the basis for tomorrow's electronic memories.





Artificial neuron prototype: nanofluidic slits can play the role of ion channels and allow neurons to communicate. Ion clusters achieve the ion transport that causes this communication.
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Note

¹ Recently invented in Manchester by the group of André Geim (Nobel Prize in Physics 2010)

Bibliography

Modeling of emergent memory and voltage spiking in ionic transport through angstrom-scale slits.
 Paul Robin, Nikita Kavokine and Lyderic Bocquet. *Science*, 6 August 2021. DOI: 10.1126/science.abf7923

Contacts

CNRS researcher | Lydéric Bocquet | lyderic.bocquet@ens.fr
ENS-PSL PhD Student | Paul Robin | paul.robin@ens.fr
CNRS Press Officer | Alexiane Agullo | T +33 1 44 96 43 90 | alexiane.agullo@cnrs.fr