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FLEXIBLE ELECTRONICS

A Venus-flytrap-based actuator

Conformable electrodes can be used to manipulate the electrical properties of a Venus flytrap, creating actuators that can be wirelessly controlled.

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Molecular electronics and electrical circuits play an important role in the plant kingdom. Plants, seeds, flowers and fruits use a variety of electronic components including resistors and capacitors[1], and rely on a variety of electronic devices including d.c.-to-d.c. converters, rechargeable batteries, light sensors, pressure sensors, amplifiers and electrical generators[2]. In order to evaluate these electrical circuits, electrostimulation with rigid electrodes is often employed. The approach allows intracellular and intercellular communication via electrical signals to be observed. It can, in particular, be used to monitor the electrical signalling in higher plants, allowing electrical communication during environmental changes to be studied. Writing in *Nature Electronics*, Xiaodong Chen and colleagues now report a flexible, lightweight electrode that can be used to analyse — and manipulate — the electrical properties of a Venus flytrap[3].

Bioelectrochemical excitation is a fast way to transmit a signal over long distances between plant tissues and organs. It allows plants to respond quickly to changes in, for example, light intensity, osmotic pressure, temperature and water availability. It also allows them to respond to chemical compounds (such as herbicides and plant growth stimulants), wounding and mechanical stimulation. And it is such excitation that makes the Venus flytrap capable of very fast movements to catch insects. Specifically, touching trigger hairs that protrude from the upper leaf epidermis of a Venus flytrap activates mechanosensitive ion channels and generates receptor potentials, which can be amplified by voltage-gated ion channels to action potentials.

To access and control the electrophysiological properties of a Venus flytrap, Chen and colleagues — who are based at the Nanyang Technological University in Singapore — developed non-invasive, lightweight electrodes that can conform to the surface of plants. The electrodes consist of an adhesive hydrogel to provide contact with the plant, and a gold-nanomesh and polydimethylsiloxane layer that acts as the transducer. The set-up can simultaneously deliver electrical signals to the plant and detect electrical signals from it.

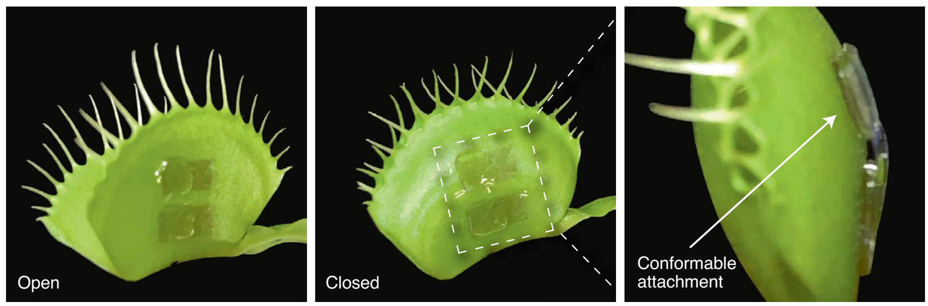

Fig. 1 | **Electrostimulation of a Venus flytrap.** The open state of the trap contains high elastic energy accumulated due to the hydrostatic pressure difference between the hydraulic layers of the lobe. The electrical trigger signal from the conformable electrodes induces the opening of water pores between these layers and the fluid transfers from the upper to the lower layer. The leaf relaxes to its equilibrium state, corresponding to the closed configuration. Figure reproduced with permission from ref. [3], Springer Nature Ltd.

The researchers used the electrodes to electrostimulate the voltage-gated ion channels of the Venus flytrap. A voltage of only 1.5 V (and at power consumption of only 10^{-5} W) was found to be sufficient to instantaneously close the trap (Fig. 1). With such low voltages, it was also possible to use a WiFi module to send an electrical output to the electrodes and activate closing. The Venus-flytrap-based actuators can thus also be controlled wirelessly, and Chen and colleagues demonstrate control via a smartphone. Notably, this illustrates that the actuator is compatible with complementary metal–oxide–semiconductor (CMOS)-based electronics. Furthermore, the researchers show that the plant-based actuator (or phytoactuator) can be isolated from the plant stem and integrated on a finger and a robotic hand, and is capable of grasping thin wires.

The approach of Chen and colleagues creates new opportunities for exploring the fundamental processes involved in the electrical signal generation, transduction and communication that occurs within plants, and also between them (a system that has been termed the plant wide web[4]). Recent research has also seen the development of a number of plant-based robots[3,5–8], memristors[9] and sensors[2,4], and the work of Chen and colleagues provides a valuable addition in the push to create such novel devices and systems. Plant-based systems could, in particular, be of use in the development of sensors for environmental monitoring (such as the detection of pollutants, pesticides and defoliants), providing detection systems with greater sensitivity and specificity than their synthetic counterparts. ❐

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Published online: 10 February 2021
https://doi.org/10.1038/s41928-021-00544-6

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Competing interests

The author declares no competing interests.