Bionic roses implanted with electronic circuits

Materials scientists nonplussed by wired-up plants with colour-changing leaves.

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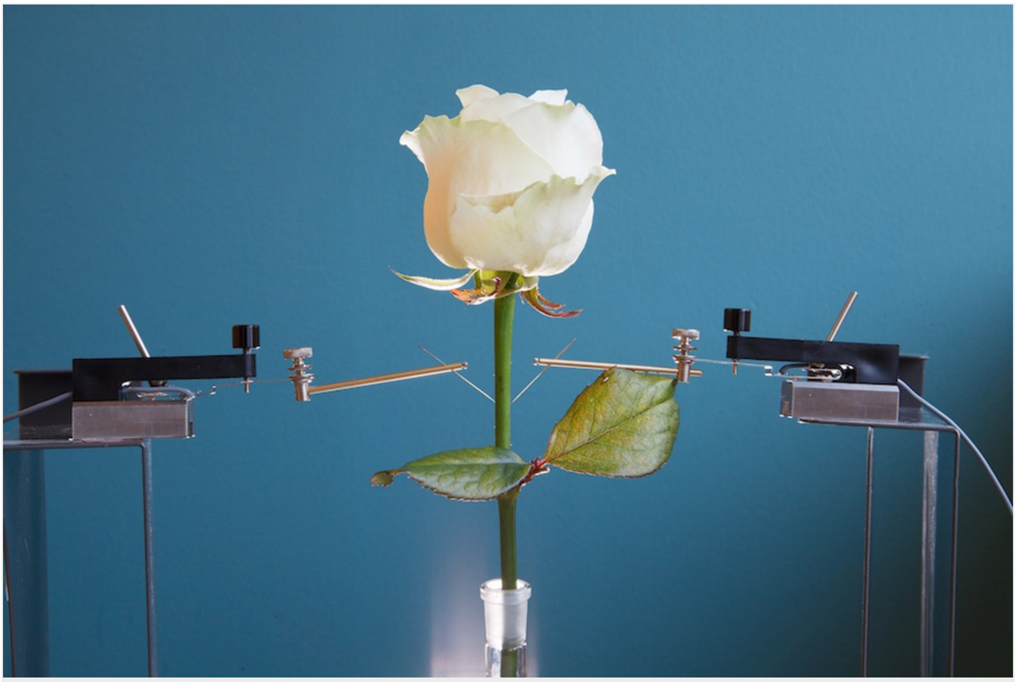

Eliot Gomez/Linköping University.

Roses have been infiltrated with conductive polymers in their leaves or stems.

Every rose has its thorn – but roses grown in a Swedish lab have transistors and electrodes too.

Researchers at Linköping University have created bionic roses by incorporating plant-compatible electronic materials into them. One of their modified roses has simple digital circuits running through its stem: another's leaf changes colour when a voltage is applied.

The scientists want to make tools for biologists to record or regulate plant physiology — the plant equivalent of medical implants such as pacemakers. Electronic components might also be a way to engineer plants instead of manipulating their DNA, adds Magnus Berggren, a materials scientist at Linköping University who led the research, published in *Science Advances*[1].

Materials scientists say that they like Berggren's creativity, but are not sure what to make of the experiments. "It seems cool, but I am not sure exactly what the implication is. But that is science and scientific curiosity, I guess," says Zhenan Bao, who works with organic electronics at Stanford University in California. Christopher Bettinger, a biomedical engineer at Carnegie Mellon University in Pittsburgh, Pennsylvania, who develops edible and biodegradable electronic materials, calls the work "cool, fun and thought-provoking".

Wired up

The idea of bionic plants is not new. Last year, Michael Strano, a chemical engineer at the Massachusetts Institute of Technology in Cambridge, showed that spinach chloroplasts take up carbon nanotubes, for instance[2]. He reported that this boosted the rate of plant photosynthesis because the nanotubes absorbed light at wavelengths that the chloroplasts do not.

But the Swedish team's work is the first time that researchers have incorporated all the components of an electronic circuit — including transistors (electronic switches) — into plants.

Berggren started by submerging the cut end of a rose stem into a solution of PEDOT, a conducting polymer that is commonly used in printable electronics and is soluble in water. Capillary action pulls the polymer up into the rose's vascular tissue or xylem. There, the polymer came out of solution and self-assembled into wires, some as long as 10 centimetres. By attaching gold probes coated with PEDOT to the wires, the researchers made individual transistors and demonstrated a simple digital circuit using the switches. The transistors' electrical performance is on a par with that of conventional printed PEDOT circuits, says Berggren.

Next, the researchers put rose leaves in a syringe full of a solution of PEDOT mixed with cellulose nanofibres. By applying a vacuum, they expelled air from the tissue, and then drew the PEDOT solution into the empty spaces left behind. When a voltage is applied, the bionic leaves subtly change colour between bluish greenish hues.

Flower power

Bettinger speculates that it might be possible to manipulate a plant — triggering a growth spurt, for example — via its embedded electronic circuits.

But Strano is sceptical: filling up a rose's water-transporting stem and gas-exchanging leaves with a conducting polymer might interfere with normal plant transpiration, he says.

Berggren says that although most of the initial studies were done using plant cuttings, the group also made the leaves of living plants change colour[1]. These plants are still alive months later, he says, and the leaves haven't fallen off. (The experiments with modified stems, however, were only conducted in plant cuttings).

The group is now collaborating with biologists to develop applications for monitoring plant physiology. Berggren is also investigating whether the PEDOT devices can be used in a system that would turn plants into living fuel cells, something that has been done with single-celled creatures but not with plants. Such a system would directly convert some of a plant's sugars into electricity. "We call it flower power," Berggren says.

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References

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2. Giraldo, J. P. *et al*. *Nature Materials* **13**, 400–408 (2014).