Plant Biology

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Guiding plant growth electronically

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In the not too distant future computers may be used to directly monitor and control the growth of plants. For a moment, consider the prevalence of sophisticated electronic medical technologies already in use today. Patients now regularly receive retinal and cochlear implants to restore vision and hearing. Meanwhile, those suffering from diabetes or heart disease mitigate their conditions using electronic devices that provide continuous real time feedback and regulation of insulin levels and heart rhythm.

The recent development of new organic electronic materials could make the difference in this promising and rapidly expanding field of biomedical technology. Based on special classes of polymers, organic electronic materials and devices have demonstrated their capacity for mediating precise interactions with both the electronic and chemical signals of living systems.

Soft and flexible biocompatible medical implants and wearable technologies can be made possible by incorporating such polymer-based electronics. Indeed, the development of organic bioelectronics has largely been driven by the vision of technology that integrates seamlessly, on and in our bodies, to digitally interface with the fundamental electrical and chemical signals of our cells, tissues, and organs. Might the capabilities of such materials and medical therapeutics have overlapping applications for plants?

The regulation of chemical signals within and between cells is not a unique feature of humans. Rather, chemical signaling is a ubiquitous and defining characteristic of life. Plants have evolved highly complex and sophisticated chemical signaling systems that allow them to coordinate their growth, monitor their surroundings, and react appropriately to dynamic environmental conditions. Thus, based on the capabilities of bioelectronics to interface chemically and electrically - in a distributed fashion and at the cellular scale - it seems likely that there will be a wide range of potentially important botanical, agricultural, and arboriculture applications for such technologies.

To begin exploring this possibility, in a collaborative and multidisciplinary effort, materials scientists and device engineers at the Laboratory of Organic Electronics at Linköping University teamed up with plant biologists at the Umeå Plant Science Center to adapt organic electronic devices suitable for plants. The combined expertise of these two leading Swedish research institutions led to the demonstration of the first organic electronic devices - and one of the first electronic devices of any kind - capable of interacting with the hormonal signaling networks within plants.

For organic electronic devices to fully speak in the signaling language of plants, the underlying materials must have the capability to transport and deliver plant hormone signaling compounds with great precision. To facilitate the delivery of such compounds, we first developed an entirely new material system based on branching tree-like polymers known as dendrites. Controlling the density and spacing of the dendrite network provides a means for enabling electronically mediated transport and release of plant hormones.

Utilizing organic electronic delivery devices based on this "dendrolyte" system, we then demonstrated targeted delivery of auxin, perhaps the most well-known and most important plant hormone, to the roots of living plants. Specifically, *Arabidopsis thaliana* seedlings genetically modified to fluoresce in the presence of increased auxin levels enabled us to confirm and monitor hormone delivery. Delivering auxin in this manner was also shown to induce rapid changes in physiology. Among other roles, it is known that specific concentrations of auxin in the root tips have a direct influence on growth and elongation. Thus, by precisely controlling the location and amount of auxin delivered, we demonstrated that this technology could influence a living plant's physiological function.

This study was only the first step in adapting organic electronic devices for plants. In the near term, we plan to improve our technology and to conduct more sophisticated experiments to better understand the underlying mechanisms of plant growth and development. However, we see these results as a precursor to more capable organic electronic technologies to manipulate a plant's signaling systems to govern important biologic processes such as flowering, growth, resistance, and overall physiology.

There is still much to be learned about how plants function and how to influence and interact with their chemical signaling systems. However, we anticipate a not-to-distant future where bioelectronic-based technologies control maturation in orchards and vineyards, tailor the shape and sizes of trees or monitor the health and stresses of entire forests. We even imagine more exotic scenarios, such as the unique challenges involved in non-terrestrial applications. For example, fine-tuned control of plant growth may provide a means to counteract the low gravity environment of space.