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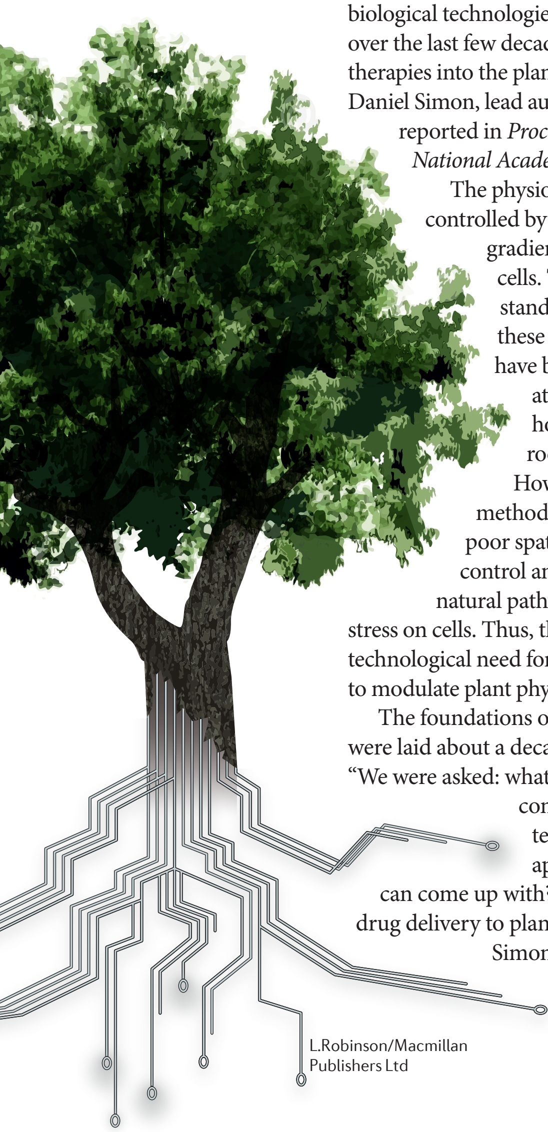
PLANT PHYSIOLOGY

Organic electronics take root

Research in organic electronics is typically within the context of light-emitting and photovoltaic devices, stretchable and wearable devices, and biomedical applications. However, researchers have now extended the technology of an organic electronic ion pump (OEIP) for a slightly less obvious purpose — to regulate plant physiology. "We see this study as a first step toward bridging the amazing biological technologies developed over the last few decades for human therapies into the plant kingdom," says Daniel Simon, lead author of the work reported in *Proceedings of the National Academy of Sciences.*

The physiology of plants is controlled by tight hormone gradients between cells. To better understand and modulate these processes, there have been several attempts to deliver hormones to the roots of plants. However, previous methods suffered from poor spatiotemporal control and disruption of natural pathways or induced stress on cells. Thus, there is an unmet technological need for a new method to modulate plant physiology.



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The foundations of this project were laid about a decade ago. "We were asked: what is the craziest combination of technologies and applications you can come up with? Our answer: drug delivery to plants!" explains Simon. His group later contacted Ove Nilsson, director of the Umeå Plant Science Centre, who pointed them towards colleague Markus Grebe (a co-author of the study). "Without the willingness of Ove and Markus — and the Wallenberg Foundation — to work with crazy engineers, none of this project would have been possible."

OEIPs are polymer-based electrophoretic devices that transport ions through a conductive channel under an applied voltage. They were developed for mammalian systems to allow the delivery of small quantities of chemicals with high spatiotemporal control (for example, for application as artificial nerves). However, a limitation of these 'ionotronic' devices is that they are based on linear polyelectrolytes, which can only transport atomic ions and small linear molecules. "Because linear polymers of this kind are amorphous, they are difficult to crosslink and do not maintain a consistent effective 'pore size'; in other words, we get some very tightly bound and some less-tightly bound regions," notes Simon. This precludes transport of larger molecules, such as plant hormones.

To overcome this limitation, the researchers developed a new type of ion-transport material based on dendrolytes' — hyperbranched or dendrolytic polyelectrolytes. This material forms uniform pores and is compatible with common patterning techniques, such as photolithography. When positioned next to the root of an *in vivo* plant model, the device successfully delivered the plant hormone auxin dynamically on a cellular scale, thereby affording control over plant growth. "With plant hormone-delivering OEIPs, we can control growth with the push of a button, by 'speaking' with the plant using the same chemical language that it naturally uses for internal communication (in this case, auxin gradients)," adds Simon.

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Following this proof of concept, the authors — unsurprisingly — are not short of ideas for subsequent research. "We have many experiments on the horizon!" exclaims Simon, who intends to determine whether it is possible to tailor cell development with customized hormone gradients, to counteract or supplant the role of gravity with hormone gradients, and whether other physiological aspects (for example, flowering or transpiration) can be controlled with this technology. The researchers are also currently incorporating the device with some of their previously reported bioelectronic systems: "We work with a variety of biosensing technologies and are investigating closed-loop plant systems, similar to our previous work with mammalian cells," says Simon. "And, of course, we are investigating the incorporation of OEIPs with our other focus in plant science: electronically functionalized living plants or 'e-plants'."

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ORIGINAL ARTICLE Poxson, D. J. *et al.* Regulating plant physiology with organic electronics. *Proc. Natl Acad. Sci. USA* http://dx.doi.org/10.1073/pnas.1617758114 (2017)
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