Ottoline Leyser: The beauty of plant genetics

Leyser studies how plant hormones shape body plan in *Arabidopsis*.

A plant spends its life rooted in place. It may therefore seem that a plant is utterly at the mercy of its environment. But the truth is that plants are extremely adaptable in ways that animals aren’t. Plants can alter their entire body plan on the fly to adapt to ambient conditions.

As Director of Cambridge’s Sainsbury Laboratory, Ottoline Leyser is intent on uprooting the mysterious mechanisms of plant developmental biology. This passion, which she’s nurtured since she was an undergraduate, has spurred her efforts to advance our understanding of the molecular mechanisms of signaling by the plant hormone auxin. Now she’s testing how mechanisms of signaling by the plant hormone auxin shape hormone auxin.

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IN FLUX

So you started working on the plant hormone auxin…

In Mark’s lab I was working to identify the basis for auxin resistance in a mutant. We were expecting that our mutant gene would encode some sort of conventional signaling molecule: a kinase or transcription factor, for example. But the first gene that we identified was most closely related to the amino-terminal half of a ubiquitin-activating enzyme. We had no idea what that meant. It threw us into a total spin.

Ultimately, we discovered that this protein is involved in regulating the stability of a large family of auxin-responsive transcriptional repressors through a ubiquitin-mediated degradation pathway. The second gene that I cloned—by that time in my own lab at the University of York—is a member of this family of transcriptional repressors. Today, however, my lab is mostly interested in how auxin controls the interactions between shoots and how this affects the plant’s body plan. Should the plant be a single stem or a ramified bush? How many growing shoot tips should there be?

"As soon as I learned about Mendel’s segregating peas, that was it for me."

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We’d like to understand mechanistically how PIN is up-regulated along the path from source to sink. We feel the best hypothesis is that there’s a strong positive feedback between auxin flux and both the up-regulation and polarization of these PIN transporters in the direction of the flux. There’s no known mechanism for cells to sense auxin flux directly, but we suspect that they could instead be counting something proportional to flux.

If the initiation of leaves requires auxin efflux into the stem as part of the leaf patterning process, then we would expect that, if a bud can’t export auxin, it can’t grow. That’s a hypothesis we’re very interested in testing.

So plant body plan depends on auxin transport?

Young expanding leaves are the major source of auxin. From there it is transported down the plant from shoot to root, in a process that depends in large part on a family of transporters called PIN proteins. This transport system has an extraordinary self-organizing property where, if you have a strong source of auxin and a sink for that auxin, then a transport pathway emerges as basally localized auxin transporters of the PIN family become highly expressed along the narrow files of cells that connect the source to the sink. We think that it’s the creation of this connection—a process we call canalization—that controls bud growth.

CULTIVATING NEW IDEAS

How does canalization affect growth?

Each leaf contains an axillary meristem in its base, which can remain dormant as a small bud or can activate to form a branch. Each bud is potentially a very strong auxin source. But if another bud above it has already established a canalized connection through the stem to the root, then high stem auxin will make it very difficult for the axillary meristem to reconfigure PIN localization to export its own auxin. And because auxin synthesis is under feedback inhibition, a bud will stop making auxin if it can’t be exported.

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Are there other hormones involved?

The model I’ve just described is quite controversial, whereas the alternative explanations for auxin’s mode of action are much more straightforward. They suggest, for example, that the amount of auxin in the stem is read out into the amount of something else, which then goes into the bud and directly inhibits its growth. But one of the main reasons why I think the canalization idea is a runner-up is because of the manner of action of strigolactone. This is a second hormone that is made throughout the plant, but most highly in the root, that moves up the plant into the buds and can inhibit their growth. It could be that strigolactone inhibits bud growth by directly affecting transcription, but there’s very little evidence that it affects transcription in this way, whereas there is good evidence that it triggers rapid PIN removal from the plasma membrane via endocytosis. Now, if one considers that auxin flux drives the further accumulation of PIN proteins on the membrane, then a bud with already established canalization and strong auxin efflux will be able to counter the action of strigolactone. However, a new or inactive bud will find it much harder to canalize in the presence of strigolactone.

We’d very much like to understand how strigolactone regulates the removal of PIN protein from the plasma membrane, and that is something we’re working on right now. We’re also trying to understand strategies for deploying this regulatory system in different environmental conditions and using computational modeling to link these two projects. This computational approach is a big part of what the Sainsbury Laboratory in Cambridge is trying to do; we’re committed to the concept that, to understand the kind of dynamic systems that drive plant development, it’s necessary to incorporate computational modeling right from the beginning.

Do you have advice for young scientists?

I always tell people it’s absolutely possible to have both a career in science and children. But there isn’t much else one can fit in. Although I wouldn’t say I’m completely hobby free, my children have only just left for university, and for the last 20 years I’ve been doing science and being a mum but not much else. I thought when they left home I would have more time to do other things, but now I’m directing the Laboratory. [Laughs] Fortunately for me, I absolutely love my job.