

EXPLORE THE ISSUE BEING INVESTIGATED

The Control of Patterning in Plant Root Development

Did you ever think of how a root grows? Down in the dark, with gravity its only cue, the very tip of the root elongates, periodically forming a node from which root branches will extend. How does the root determine the position of its branches, and the spacing between them? The serial organization of the root's branches is controlled by events that happen on a microscopic scale out at the very tip of the root, the so-called root apex. There, within a space of a millimeter or less, molecular events occur that orchestrate how the root will grow and what it will be like.

The problem of understanding how a plant's root apex controls the way a root develops is one example of a much larger issue, perhaps the most challenging research problem in modern botany: What mechanism mediates central pattern formation in the plant kingdom? Almost nothing was known of these mechanisms a decade ago, but intensive research is now rapidly painting in the blank canvas.

Much of the most exciting research on plant pattern formation is being performed on a small weedy relative of the mustard plant, the wall cress *Arabidopsis thaliana* (see photo above). With individual plants no taller than your thumb that grow quickly in laboratory test-tubes, *Arabidopsis* is an ideal model for studying plant development. Its genome, about the size of the fruit fly *Drosophila*, has been completely sequenced, greatly aiding research into the molecular events underlying pattern formation.

To gain some insight into the sort of research being done, we will focus on work being done by John Schiefelbein and colleagues at the University of Michigan. Schiefelbein has focused on one sharply defined aspect of plant root pattern formation in *Arabidopsis*, the formation of root hairs on the epidermis, the outer most layer of cells. These root hairs constitute the principal absorbing surface of the root, and their position is under tight central control.

In a nutshell, the problem of properly positioning root hairs is one of balancing cell production and cell differentiation. Cells in the growth zone beneath the surface of the root—a sheath called a meristem—are constantly dividing. The cells that are produced by the meristem go on to differentiate into two kinds of cells: trichoblasts which form hair-bearing epidermal cells, and atrichoblasts which form hairless epidermal cells. The positioning of trichoblasts among atrichoblasts determines the pattern of root hairs on the developing root.

When researchers looked very carefully at the dividing root meristem, they found that the initial cells that produce



Arabidopsis thaliana. An important plant for studying root development because it offers a simple pattern of cellular organization in the root.

trichoblasts and atrichoblasts alternate with one another in a ring of 16 cells around the circumference of the root. As the cells divide, more and more cells are added, forming columns of cells extending out in 16 files. As the files extend farther and farther out, occasional side-ways divisions fill in the gaps that develop, forming new files.

Maintaining this simple architecture requires that the root maintains a tight control over the plane and rate of cell division. Because this rate is different for the two cell types, the root must also control the rate at which the cell types differentiate. Schiefelbein set out to learn how the root apex coordinates these two processes.

To get a handle on the process, Schiefelbein seized on a recently characterized root pattern mutant called *transparent testa glabra (TTG)*. This mutant changes the pattern of root hairs in *Arabidopsis*, and it has been proposed that it controls whether a cell becomes a trichoblast or an atrichoblast. But does it control the rate and orientation of cell division in the root meristem epidermis?

To answer this question, Schiefelbein's team used clonal analysis to microscopically identify individual cell types in the root epidermis, and set out to see if they indeed divide at different rates, and if the *TTG* mutation affects these rates differently. If so, there must be a link between cell differentiation and the control of cell division in plants.