



Figure 2 Patterning the roots. a, The differentiation of cells into endodermis and cortex in the *Arabidopsis* root depends on the movement of the SHORT-ROOT (SHR) protein from the stele to the adjacent cell layers. b, Nakajima *et al.*¹ placed the *SHR* gene under the control of the *SCR* promoter region, ensuring that *SHR* is expressed in the layers adjacent to the stele. The result is the formation of many layers of endodermis.

making it possible for researchers to produce a precise map of division patterns and cell fates (Fig. 1). The lineage of each cell type can be traced back to the ‘quiescent centre’, found in the growing root tip.

Cells in the quiescent centre rarely divide. But when they do, they produce different types of ‘initial cell’, which in turn supply more specialized cell types. Quiescent-centre cells divide downwards to produce the root cap, upwards to produce the stele (primary vascular tissues), and sideways to produce initial cells for the other three layers (from the outside inwards: epidermis, cortex and endodermis). The cortex and endodermis are derived from the same initial cell; this cell divides once to make a daughter cell that itself divides asymmetrically to produce a row of cortex and a row of endodermal cells (Fig. 1). One might think that the fate of each cell is determined by these strict patterns of division. However, studies in which different cell types were ablated from roots show that a cell’s position is more important than its lineage².

Two genes are required for the differentiation of endodermis and cortex: *SCR* and *SHR*. Plants with mutated *SCR* lack the crucial asymmetric cell division that leads to separate cortex and endodermis. The resulting single-celled layer differentiates into a combination of cortex and endodermis, as judged by the expression of cell-specific markers. In plants with mutations in *SHR*, this cell division again fails and the resulting cell layer lacks endodermal markers but has attributes of the cortex^{3,4}.

In normal plants, the daughter cell pro-

duced by the cortex–endodermal initial expresses *SCR* before it divides asymmetrically. Afterwards, *SCR* is expressed in the endodermal layer^{5,6}. Expression of *SCR* requires *SHR*. But the patterns of *SHR* expression are an enigma — *SHR* is transcribed in the stele, rather than in the endodermis where it presumably functions⁷. This led to speculation that *SHR* functions in a non-cell-autonomous way, meaning that it influences adjacent cells in which it is not transcribed⁷.

Non-autonomous action has been reported for several plant genes⁸. These non-autonomous effects were discovered in experiments involving chimaeric plants, in which adjacent cell layers had different genotypes (the gene of interest might be normal in one layer and mutated in the next). Often, the products of the genes might be produced in only one cell layer and yet be able to ‘rescue’ adjacent mutant cells. We already know that transcription factors can move between plant cells⁹ through the cell walls, which have small, dynamic pores called plasmodesmata that can open under certain conditions. But the question remained as to why protein movement is necessary, given that the proteins could be — and often are — expressed in both cells in the first place.

Using an antibody that recognizes *SHR*, as well as a fusion of *SHR* and green fluorescent protein, Nakajima *et al.*¹ now show that *SHR* protein is found in the stele, where it is transcribed⁷. It also moves to the adjacent layer, the endodermis. *SHR* is located in the nucleus of endodermal cells, and is found both inside and outside the nucleus in the stele. The authors also detected it in quiescent-centre cells and the cortex–endodermal initial and daughter cells (see Fig. 1b on page 308). These results explain *SHR*’s non-autonomous effects, but do not explain the need for such a system.

So Nakajima *et al.* went on to investigate what happens if *SHR* is expressed in the endodermis, rather than moving there. Using a regulatory region (the promoter) from the *SCR* gene, they drove expression of the *SHR* gene in the endodermis. This resulted in several layers that expressed endodermal markers (Fig. 2). Apparently, if the *SHR* protein is expressed in the endodermis, it moves one layer outwards and then initiates the transcription of *SCR*, which is then required for the asymmetric cell division leading to endodermis and cortex. Once the newly divided cells are specified as endodermis, the expression of *SHR*, under the control of the *SCR* promoter, begins again; the protein moves outwards once more, and so the autocatalytic cycle is perpetuated. The extra layers did not form in plants with mutations in *SCR*. So, proteins that are programmed to move one layer and regulate downstream genes are perfect candidates for positional signals. Directionality



100 YEARS AGO

Dr. Carl Lumholtz, the Norwegian explorer, who for the past five years has been travelling in the hitherto unknown regions of North-Western Mexico for the American Museum of Natural History, lectured before the Geographical Society in Christiania on September 12 and gave a description of his life and travels among the wild Indian tribes of the Western Sierra Madre... In order to study these interesting people he sent back the entire staff of his expedition and lived alone among them. At first the tribes objected to his taking up his abode in this way, but eventually he gained their confidence and was allowed to remain. He learnt their ways, their language and their songs, and joined in their dances... They are very intellectual, and are, according to Dr. Lumholtz, a far superior race to their kinsmen in the United States and South America. Among many of the tribes he found a higher degree of morality than in civilised countries.

From *Nature* 19 September 1901.

50 YEARS AGO

It is impossible to predict precisely the course of a great aurora, but what usually happens is as follows. At first, a glow, much like dawn (hence the name aurora borealis, northern dawn, which was first used by the French philosopher, Gassendi, in 1621), appears on the northern horizon... The glow then ascends from the horizon to form an arc, the lower border of which is at a height of about 100–110 km... The true colour of most arcs is probably green, for a predominant line in the spectrum is the green forbidden line 5577 Å. of atomic oxygen, and this happens to be in the region of maximum sensitivity of the retina. But, except in the case of very bright arcs, it appears to the eye to be grey-white, since the light intensity is below the threshold of colour perception. The arc may then brighten suddenly to an intensity above the threshold such that patches of vivid greens and reds can be seen here and there along its length. Simultaneously the lower border becomes extraordinarily sharply defined and is appreciably lower, all of which are signs that the arc is about to lose its regular shape and to show ray structure. It may then undulate to appear like the folds of a huge waving curtain, or it may take the form of a wide band, stretching irregularly across the sky.

From *Nature* 22 September 1951.