The Role of Microtubules in Stomatal Opening

In contrast to most plant cells, the cortical microtubules of guard cells remain well organized even after microfibril deposition and cellular differentiation is complete. This has led some researchers to speculate that microtubules might play an important role in the regulation of stomatal function. However, recent pharmacological studies concerning the effects of microtubule inhibitors on stomatal opening have yielded seemingly contradictory findings. To gain insight into the role of microtubules in guard cell function, Marcus et al. (pp. 387–395) employ a microtubule reporter gene construct consisting of the microtubule-binding domain of the mammalian MAP4 protein fused to green fluorescent protein (GFP::MBD). Biologically-transformed guard cells expressing GFP::MBD display the distinctive microtubule arrays that characterize guard cells (Fig. 1), but no longer retain the ability to open in response to illumination (red, white, or blue) or low [CO₂]. Several microtubule-disrupting drugs, including propyzamide, colchicine, trifluralin, and oryzalin, also inhibit light-induced stomatal opening (colchicine less than the others). Fusicoccin, which directly leads to stomatal opening through its effects on H⁺ pump activation, was found to promote stomatal opening even in the presence of propyzamide or GFP::MBD. These results indicate that microtubules are not necessary for events occurring after H⁺ pump activation, but are required for one or more of the signal transduction events that occur prior to H⁺ pump activation. The authors speculate that a microtubule-associated protein may be critical for light-induced stomatal opening.

Cell Division Contributes to Apical Hook Formation

The emerging hypocotyl of a dark-grown Arabidopsis seedling forms an apical hook about 24 h after germination. The hook is formed by differential axial growth and is maintained for about the next 4 d after which the hypocotyl restrengthens itself and the hook is lost. Most differential growth responses, including apical hook formation, have traditionally been assumed to arise solely from differential cell elongation. In this issue, Raz and Koornneef (pp. 219–226) examine the possibility that differential cell division might also play a role in hook development. The authors employ an expression marker, cyclin1B tagged with β-glucosidase (Cyc1B-GUS), to identify dividing cells in the hypocotyl during hook development. Cyc1B-GUS expression in the hook region was found to be temporally restricted to the first 2 d of growth and spatially restricted to the subepidermal layers in the apical part of the hook (Fig. 2). As expected, Cyc1B-GUS expression did not occur in the apical hypocotyl region of several hookless mutants.

Nutrient Drain Hypothesis and Flowering in Fuchsia

Different carbohydrate sinks in plants compete for available Suc, the primary mobile assimilate of plants. The nutrient drain hypothesis proposes that it is the relative successes of these vying sinks in attaining Suc that determines whether certain plants flower or not. The strong import of Suc to the apex is thought to promote flowering, whereas diversion of Suc away from the apex by, for example, the application of gibberellic acid (GA), is thought to deter flowering. The long day (LD) plant Fuchsia hybrida (Fig. 3) is an interesting candidate for testing the nutrient drain hypothesis because its flowering is enhanced by increased photosynthetic irradiance even in short days. Both LD- and high irradiance-induced flowering are inhibited by applied GA. In this issue, King and Ben-Tal (pp. 488–496) use GC-MS–SIM to perform sensitive measurements of the Suc content of individual Fuchsia shoot apices. The authors found a very strong correlation (r = 0.93) between flowering in short days and shoot apex Suc content, indicating a florigenic role for Suc. In contrast, LD-induced flowering at low irradiance levels induced flowering, but there was no corresponding increase in shoot apical Suc levels. Suc, therefore, is florigenic in this species, but it is not the long-sought “florigen” that is produced in LDs. Consistent with the nutrient drain hypothesis, GA inhibited LD-induced flowering and led to a decrease in shoot apical Suc content.

Figure 1. The microtubular array of Vicia faba guard cells.

Figure 2. Subepidermal localization of dividing nuclei (arrowhead) in the apical hook.

Figure 3. Fuchsia hybrida flowers in response to LDs or high irradiance.
Salicylic Acid Activates Nuclear Protein Kinase CK2

Salicylic acid (SA) is an important secondary signal in plants that plays a major role in the activation of defense genes in response to pathogen attack. Two groups of SA-activated genes—early and late—can be distinguished. Among the early genes are those that encode for glutathione S-transferases, a multigene family involved in the detoxification of cytotoxic compounds produced during the defense reaction. Examples of late genes are those that encode for acidic pathogenesis-related proteins. DNA promoter elements called as-1-like elements control many of the early SA-activated genes. SA enhances the binding of tobacco nuclear factors to as-1 sequences in a process mediated by protein phosphorylation. In this issue, Hidalgo et al. (396–405) present evidence that this phosphorylation step may be mediated by nuclear protein kinase CK2. First, CK2 activity is enhanced in nuclear extracts of SA-treated tobacco. Second, a specific inhibitor of CK2 inhibits the activating effect of SA on the transcription of both a β-glucosidase reporter gene controlled by a tetramer of the as-1 element as well as several glutathione S-transferase genes. These results constitute the first evidence for the activation of a plant CK2 kinase by a stress-induced second messenger.

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