The Cytoskeleton Becomes Multidisciplinary

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It is now becoming clear that the plant cytoskeleton is not just involved in fundamental processes like mitosis, cytokinesis, cell polarity, and intracellular trafficking. For many years, the cortical cytoskeleton’s specialized function in plant cell wall construction and morphogenesis has been investigated, but other unique attributes of plants, such as the regulation of water loss through stomatal guard cell movements, pollen tube growth through female reproductive tissue, and elaborations like trichomes and root hairs, also depend on the cytoskeleton. Today it is apparent that the plant cytoskeleton plays an active role in modulating the response of plants to changes in their environment, including encounters with other organisms. It is therefore not surprising that the cytoskeleton is no longer confined to the field of cell biology and that research in a wide range of plant science disciplines, including macromolecular structure, development, hormone action, and environmental stress, will all include important studies on the cytoskeleton. With Plant Physiology’s coverage of this wide range of plant science disciplines, a focus issue on the cytoskeleton is timely. Our focus on the cytoskeleton issue begins with four Update articles and includes nine research articles spanning a wide range of disciplines.

It is well established that several hormones including auxins, gibberellins, brassinosteroids, and ethylene influence the organization of cortical actin microfilaments and/or microtubules, implicating a role for these cytoskeletal arrays in hormonal responses. A paper in the November issue of Plant Physiology from Mike Bevan’s group (Li et al., 2004) shows that Arabidopsis (Arabidopsis thaliana) mutants, in which a NAP-like gene is knocked out, are affected in sugar responses, implicating actin in the regulation of this process. NAP (NCK-associated protein) is a subunit of the WASP family verprolin homologous protein complex that regulates the conserved actin nucleating Arp2/3 complex. The cytoskeleton has also been implicated in abiotic stress responses such as in osmotic regulation and is known to modulate the activity of ion channels. Both plant-pathogen and symbiotic interactions involve changes in cell polarity and cellular trafficking in plants and thus are intimately associated with the reorganization of the cytoskeleton. An Update article in this issue by Daigo Takemoto and Adrienne Hardham (Takemoto and Hardham, 2004) discusses cytoskeletal responses and functions during encounters between plants and other organisms.

Specific functions of the cytoskeleton depend on how microtubules and microfilaments are distributed and arranged, and how their behavior is modified by proteins that directly associate with both intact polymers and their subunit monomers (Wasteneys and Galway, 2003; Sedbrook, 2004). Significant progress has been made in the identification and functional analysis of cytoskeleton-associated proteins involved in nucleation, membrane anchoring, dynamics (e.g., growing and shrinking of polymers), severing, and polymer cross-linking. In this issue, we highlight the most recent work on the factors influencing microtubule and actin microfilament behavior, and discuss the advantages and limitations of live probes to investigate previously undescribed cytoskeletal functions (Wasteneys and Yang, 2004). Sherryl Bigrrove, Whitney Hable, and Darryl Kropf (Bigrrove et al., 2004) update plus-end tracking proteins, an emerging group of diverse microtubule-associated proteins that may hold the key to understanding how microtubule polarity is put to work in cells. And recent progress in understanding plant motor proteins, including an astounding complement of kinesins and myosins, is covered in an article by Yueh-Ru Lee and Bo Liu (Lee and Liu, 2004).

Two research articles in this issue advance our knowledge of how microtubule-associated proteins (MAPs) work in plant cells. Van Damme et al. (2004; see cover) demonstrate that green fluorescent protein (GFP)-tagged MAP65-1 and MAP65-5 are localized to different subpopulations of cortical microtubules in tobacco BY-2 cells, whereas GFP-MAP65-4 is localized to a specific array of microtubules that rearranged to form spindles. Shoji et al. (2004) identify the SPIRAL2 protein and confirm that this 94-kD HEAT repeat-containing protein interacts with cortical microtubules. Two intriguing findings of this study are that the spr2 mutants have heightened sensitivity to microtubule-disrupting herbicides that target tubulin, and despite the propensity for right-handed twisting in spr2 mutants, when combined with the lefty alpha tubulin point mutations (Thitamadee et al., 2002), left-handed organ twisting is accentuated. The long-recognized technological significance of point mutations in tubulins for effective herbicide use in agriculture is highlighted by

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Delye and coworkers, who explore the molecular basis for herbicide sensitivity and cross resistance (Delye et al., 2004). It is now clear that microtubule dynamics play an important role in tip-growing root hairs, and in this issue, Van Bruaene et al. (2004) use a MAP4 microtubule binding site-GFP line to follow microtubule organization and behavior. They show for the first time in Arabidopsis root hairs an extensive array of endoplasmic microtubules, and highlight likely search and capture behavior of microtubules in these tip-growing protuberances of root epidermal cells.


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