Interaction of cytokinin with auxin and ethylene in the control of primary root growth

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Cytokinin inhibits primary root growth in Arabidopsis through effects on both cell elongation and cell proliferation. Inhibition of cell elongation by cytokinin requires the auxin importer AUX1, *AUX1* mutants specifically affecting the ability of cytokinin to inhibit cell elongation but not cell proliferation. AUX1 is required for cytokinin-dependent changes of auxin activity in the lateral root cap and epidermal layer of the transition zone. Cytokinin directly regulates expression of *AUX1*, pointing to a mechanism by which cytokinin can alter auxin transport and auxin activity. The regulation of root cell elongation by cytokinin operates through ethylene- dependent and independent mechanisms, both hormonal signals converging on AUX1 as a regulatory hub. Inhibition of root cell proliferation by cytokinin was previously shown to involve SHY2, a negative regulator of auxin signaling. Recently ethylene has been determined to regulate cell proliferation as well as cell elongation at the root tip and, like cytokinin, converges on the regulation SHY2 as a mechanism to reduce auxin signaling and inhibit cell proliferation. Mutant-based analysis indicates that ethylene contributes to the effects of cytokinin in the inhibition of cell proliferation. Our results support a general model for the control of primary root growth that involves two main features: (1) independent roles for shootward auxin transport in the control of cell elongation and of rootward auxin transport in the control of cell proliferation; and (2) convergence of the phytohormones cytokinin and ethylene on a shared set of targets to regulate auxin activity and thus cell proliferation and elongation in the primary root.