Elliot Meyerowitz and Christopher R. Somerville

Elliot Meyerowitz is currently George W. Beadle Professor of Biology and Chair at the California Institute of Technology, Division of Biology.

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2006 Balzan Prize for Plant Molecular Genetics

For their joint efforts in establishing Arabidopsis *as a model organism for plant molecular genetics. This has far reaching implications for plant science at both the fundamental level and in potential applications.*

Institutions Administering Research Funds:
California Institute of Technology (Caltech)
Carnegie Institution of Science
University of California, Berkeley

Adviser for the Balzan General Prize Committee: Marc Van Montagu

Live Imaging of Cellular Differentiation in Shoot Apical Meristems and in Cellulose Synthesis

Plants are remarkably dynamic, with rapidly changing metabolic processes (on the order of seconds), processes of genome readout (scale of minutes), and cellular differentiation (scale of hours). One novel suite of methods that is now being developed, both at Caltech and at Carnegie, involves live imaging of dynamic processes followed by computational image processing. Two key processes under study are cellular differentiation in shoot apical meristems and cellulose synthesis.

Elliot Meyerowitz initially involved Marcus Heisler, a pioneer of the new live imaging method. He works on the live imaging of growing shoot apical meristems and computational modeling of cell behavior and cell-cell communication during meristem growth. The orientation of cortical microtubule arrays in shoot apical meristem cells

under a variety of conditions has been live-imaged, and a set of rules whereby physical stress regulates their orientation has been derived. As the microtubule orientation affects the anisotropy of the cell wall (via regulation of cellulose deposition) and also cell division plane, this work is leading to a coherent theory of cell expansion and cell division in the shoot apical meristem. The first set of results was based on work done with collaborators at ENS Lyon, ENS Paris, the Université Denis-Diderot Paris 7 and Lunds Universitet. Published in *Science* in December 2008, it showed that the cortical microtubule array in meristematic cells aligns in response to the stress field, such that the microtubules align parallel to the principal direction of stress. A mathematical model of the stresses in the meristem was developed from the experimental data, and suggests future experiments that are in progress.

After Dr. Heisler departed from Caltech to establish his own laboratory at the European Molecular Biology Laboratory in Heidelberg; the project has involved two additional postdoctoral fellows, Dr. Wuxing Li and Dr. Paul Tarr. They carried the shoot apical meristem work forward by investigating the involvement of the plant hormones auxin and cytokinin in the control of cell expansion, division and gene expression, and therefore, to the contribution of these growth hormones to the interaction of physical and chemical signaling that controls meristem cell behavior. The work done in this part of the project has led to a new National Institutes of Health grant on the action of hormones in the shoot apical meristem, which will allow the work to continue.

Professor Somerville has involved three post-doctorate students in studies concerning the molecular mechanisms associated with the synthesis or depolymerization of cellulose. In spite of the abundance of cellulose in the terrestrial biosphere, and the importance to life processes, very little is known about how cellulose is made. The research program in the Somerville laboratory has been focused on understanding several aspects of the control of cellulose synthesis or depolymerization. In early 2013, postdoctoral fellow Patricia Bubner joined the Somerville groups following doctoral studies in Graz, Austria, and is studying the role of glycosylation on enzyme activity by using genetic methods to modify the amount and location of glycans on proteins. Former postdoctoral fellow Ying Gu studied the role of the microtubule cytoskeleton in orienting the deposition of cellulose microfibrils by analyzing mutants in which the deposition is altered. In order to identify proteins that mediate the interaction between cellulose synthase and microtubules, she used a two hybrid screen to search for candidate proteins and then characterized mutations in the genes corresponding

to the proteins that interact with cellulose synthase subunits. She identified a novel protein, named CSI1, and discovered that the protein is associated with the cellulose synthase complex using live cell imaging. This was published in the *Proceedings of the National Academy of Sciences* (PNAS Jan. 2012). She also screened directly for mutations that alter the deposition of cellulose, and has cloned two of the corresponding genes by map-based cloning. The first gene characterized proved to be a subunit of a large complex called the prefoldin complex, which is involved in folding tubulin. A manuscript describing the characterization of this mutant was published in *Proceedings of the National Academy of Sciences* (PNAS Nov. 2008). Gu is now an Assistant Professor at Pennsylvania State University.

Balzan funds were also used by Professor Somerville to support then postdoctoral fellow Seth DeBolt, who investigated the involvement of sterol glycosides in cellulose synthesis. This class of compounds had previously been suggested to act as primers for cellulose synthesis. However, Seth found that mutant lines with greatly reduced amounts of sterol glycosides had no effect on cellulose. The mutants did, however, have altered deposition of suberin, and the protein responsible for synthesis of the glycoside was found to be present in plasma membrane patches reminiscent of lipid rafts. His research on sterol glycosides was published in *Plant Physiology* in 2009. Seth is now an Associate Professor at the University of Kentucky.

In December 2007, Professor Somerville moved his laboratory from Carnegie to the University of California, Berkeley and, because of the administrative delays associated with moving funds from one institution to another, was unable to access the remaining Balzan funds until the summer of 2009. He has used the funds to partially support two graduate students, Adisorn Chaibang and Brad Dotson. Chaibang is examining the role of two laccase enzymes in lignin biosynthesis and Dotson is exploring the function of a family of proteins of unknown function that appear to play important roles in cell wall biosynthesis.

Researchers:
Professor Meyerowitz:
Marcus Heisler
Wuxing Li
Paul Tarr

Professor Somerville:
Patricia Bubner
Adisorn Chaibang
Seth DeBolt
Brad Dotson
Ying Gu

Publications:

Li S, Lei L, Somerville CR, Gu Y. 2012. Cellulose synthase interactive protein 1 (CSI1) links microtubules and cellulose synthase complexes. Proceedings of the National Academy of Science. 109 (1): 185-190.

DeBolt S, Scheible WR, Schrick K, Auer M, Beisson F, Bischoff V, Bouvier-Navé P, Carroll A, Hematy K, Li Y, Milne J, Nair M, Schaller H, Zemla M, Somerville CR. 2009. Mutations in UDP-glucose: sterol glucosyltransferase in Arabidopsis cause transparent testa phenotype and suberization defect in seeds. Plant Physiology. 151: 78-87.

Gu Y, Deng Z, Paredez AR, DeBolt S, Wang Z, Somerville C. 2008. Prefoldin j6 is required for normal microtubule dynamics and organization in *Arabidopsis*. Proceedings of the National Academy of Science. 105 (46): 18064-18069.

Hamant O, Heisler MG, Jönsson H, Krupinski P, Uyttewaal M, Bokov P, Corson F, Sahlin P, Boudaoud A, Meyerowitz EM, Couder Y, Traas J. 2008. Developmental Patterning by Mechanical Signals in *Arabidopsis*. Science. Vol. 322, no. 5908: 1650-1655.