Elliot Meyerowitz and Chris Somerville

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.*

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

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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 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 have 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 the University of Lund. 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. As Marcus Heisler accepted a Group Leader position at the European Molecular Biology Laboratory in Heidelberg in 2009, the continuing work now includes one additional institution.

Chris Somerville involved two post-doctorate students in studies concerning the molecular mechanisms involved in synthesis 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. Postdoctoral fellow Ying Gu has been studying 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. The research describing the discovery and analysis of the CSI1 protein has been submitted to "Science" for publication. 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 has recently been published in "Proceedings of the National Academy of Sciences" (PNAS 2008). Ying recently accepted a faculty position at Pennsylvania State University and began work there in January 2010. Since moving to Berkeley she has been supported on funds provided by Berkeley but she has continued work begun with Balzan support.

Balzan funds were also used by Professor Somerville to support postdoctoral fellow Seth DeBolt who investigated the involvement of sterol glucosides 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 glucosides 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 glucosides was recently published in "Plant Physiology". Seth recently moved to the University of Kentucky to assume a faculty position. 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 is now using the funds to partially support two second-year graduate students, Adisorn Chaibang and Brad Dotson. Adisorn is exam-

ining the role of two laccase enzymes in lignin biosynthesis and Brad is exploring the function of a family of proteins of unknown function that appear to play important roles in cell wall biosynthesis.

Publications:

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

- Gu, Y., Deng, Z., Paredez, A.R., DeBolt, S., Wang, Z., and Somerville, C., *Prefoldin6 is required for proper microtubule dynamics and organization in Arabidopsis*, "Proceedings of the National Academy of Science", 2008.

- Hamant, O., Heisler, M.G. Jönsson, H., Krupinski, P., Uyttewaal, M., Bokov, P., Corson, F., Sahlin, P., Boudaoud, A., Meyerowitz, E.M. Couder, Y., and Traas, J., *Developmental Patterning by Mechanical Signals in Arabidopsis*, "Science", 2008.

Statement by the Prizewinners: *Our contribution, and that of our colleagues in the* Arabidopsis *world, has been to speed and organize the gathering of data about the molecular mechanisms of plants. The time has now come to speed and organize the use of this information by developing a mathematical and computational infrastructure that will allow vast amounts of specific information about plants at the atomic, molecular, organelle, cell, and whole plant levels to be integrated into working models that can make specific experimental predictions. We envision that a future generation of biologists will have access to a "virtual plant" in which a computer model will integrate detailed molecular information to create a dynamic simulation of a plant throughout its lifecycle. We recognize that such a vision seems impractical at present. However, one of the things that we have learned during the past twenty-five years is the importance of setting seemingly impossible goals as a stimulus to scientific creativity and ambition.* Chris Somerville and Elliot Meyerowitz (Rome, 23.11.2006)