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The Production and Uses of Genetically Transformed Plants: Concluding Remarks

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The production and uses of genetically transformed plants: concluding remarks

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This meeting at which the preceding collection of papers were presented occurred on the tenth anniversary of the development of techniques which have laid the foundation for modern plant biotechnology, namely the ability to transfer genes into plants and to direct their expression in appropriate cell types. The contributors have revealed many of the exciting and potentially important applications of gene transfer technology in crop plants arising from these earlier developments, and have also described new approaches which have engendered an ever-widening scope for crop improvement through the application of molecular biological methods. In the past ten years a wide variety of crop plants have been stably transformed, and it is clear that many of the major crops can now be transformed, although with widely different efficiencies.

Tim Hall's paper described his work on rice transformation, which is working sufficiently well for large-scale experiments on gene expression to be undertaken. The ability to transform rice is perhaps the most significant milestone in this field, given the central importance of this crop for a large proportion of the world's population and the considerable efforts dedicated to improving it via modern biological techniques. Organelle transformation has been accomplished in the laboratory of Pal Maliga, who gave an impressive address on the methods available for chloroplast transformation using homologous recombination. An immediate application could be in expressing high levels of protein in plants using chloroplast expression systems. The papers by Mike Bevan and John Brown, on transcriptional control and mechanisms of splicing, respectively, revealed how complex these processes are, and showed some of the differences between them in higher plants and other organisms. Presently there does not appear to be any barrier to expressing genes in the desired tissue at the desired time and in appropriate amounts, although more complex patterns of expression will need to be engineered in the future. The prospect of understanding and manipulating gene expression will soon allow co-ordinated expression of sets of genes, for example, which will be important in expressing new metabolic pathways in plants. The regulation of carbohydrate metabolism has begun to be investigated using transgenic plants for under- and over-expression of genes encoding enzymes in various pathways. Mark Stitt's paper offered a fascinating and provocative view of developments in a field which has generally been felt to be mature and have well-proven ideas of the control of metabolite flux. The incredible flexibility of interconnected metabolic reactions was revealed when down-regulation of supposed key regulatory steps using antisense methods had little effect on end-product accumulation. The notion that transcriptional control, perhaps modulated by metabolite levels, may have a greater role in determining enzyme levels and activities was discussed, and future work in this area has clear implications for engineering metabolite partitioning in plants. These findings draw the control of metabolism in plants closer to that found in yeast, where transcriptional control of basic metabolic processes is well known. Understanding and manipulating fruit ripening is relevant to agricultural productivity, and the work of Don Grierson on tomato fruit ripening and the role of ethylene in controlling this process provided the latest information in this area. Of particular interest was the identification of genes encoding enzymes of ethylene biosynthesis. In a clear demonstration of the power of molecular biological approaches compared to many years of effort using conventional biochemical methods, he described how ethylene-forming enzyme has been unambiguously identified. The way is now open for reverse genetical approaches to be applied to any system of interest in a wide variety of crop plants and model systems. Environmental stress contributes significantly to crop losses, and the extent and type of these stresses is increasing. Dirk Inze presented his group's work on how plants sense and combat oxidative stress. Overproduction of a Mn-superoxide dismutase alleviated the destructive effects of ozone in leaves, suggesting a solution to an increasing threat to plants. Considerable steps have also been made in understanding and combating cold-induced oxidative stress, which severely affects crop productivity in Europe. Plant responses to pathogens were addressed in the papers of Richard Broglie and John Bol. Broglie described his work on enhanced resistance to *Rhizoctonia*, an important fungal pathogen, by over-expression of endogenous 'defence genes' of plants such as chitinases and glucanases. Bol described work on expressing viral proteins in plants, in this case the coat protein and intercellular movement proteins from alfalfa mosaic virus. The coat protein protected against infection, whereas the movement protein did not, but was able to complement viruses defective in cell-to-cell movement. These papers represented a large body of work that has used transgenic plants both to engineer resistance to pathogens and to study the pathogen itself. Angharad Gatehouse presented work from the Durham group which has been successful at obtaining enhanced resistance to a variety of insect pests by ectopic expression of protease inhibitors normally expressed in seeds. A particularly interesting paper

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was presented by Chris Somerville on the isolation of genes encoding enzymes of fatty acid biosynthesis. Map-based methods have enabled the isolation of several of these genes from *Arabidopsis*, and he also described the random sequencing of cDNA to isolate other genes of fatty acid biosynthesis by recognizing their potential similarity to other desaturases and elongases. In a startlingly clear view of the future he also described how to make the U.S.A. independent of imported oil and to improve the profitability of farming (and removing the need for subsidies for inefficient production) by increasing the diversity of commodities produced from crop plants. Altering lipid composition is possible once the appropriate genes had been isolated. Gene isolation was the subject of Caroline Dean's paper. She described progress in her laboratory and elsewhere which was leading to a physical map of the *Arabidopsis* genome. With this information, it would be straightforward to isolate a gene knowing only its position relative to other markers in *Arabidopsis*. Progress in transposon tagging in *Arabidopsis* was also described; the maize element Ac has been engineered to be an effective mutagen, and a series of lines and protocols are now available for gene isolation by using this powerful technique. With such rapid and impressive progress it is now practically feasible to go from phenotype to isolated gene without an arduous chromosome walk. A major challenge now is to apply all of the depth and breadth of knowledge concerning fundamental aspects of plant growth and development in *Arabidopsis* to a wide variety of crop plants. Finally, in an appropriate series of papers that described the exploitation of discoveries for commercial benefit, industrialists from leading plant biotechnology companies spoke of recent developments in their respective fields. Rob Horsch gave an eloquent description of the pioneering work of Monsanto in bringing to market insect- and virus-resistant cotton, and of the benefits of herbicide-tolerant crops. Wolfgang Schuch described the many important issues facing the use of genetically engineered tomato for human consumption, and how a consortium of companies plan to introduce vastly improved tomato ketchup in the coming years. Peter van den Elzen described the results of field trials of fungus- and virus-resistant potatoes in Holland.

The results presented in this symposium have soundly discounted the notion that many of the early claims for plant biotechnology were overblown and unrealistic. On the contrary, there have been greater advances over a far wider front than many of us thought possible. Several of the papers have hinted at an ever-increasing rate of progress and diversification, such that, in the next five years, we will see many more new products in old plants, and a deeper understanding of plants themselves.

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