Flowering or wilting?

Europe has to find a new way to continue basic research in plant science

This is a critical time for plant science in Europe. The genomes of *Arabidopsis thaliana* and rice are almost completely sequenced. A range of techniques is poised to exploit this information, creating a new knowledge base that will revolutionize plant research and bring into being new possibilities for crop improvement. But public concern in Europe about plant biotechnology has contributed to severe cuts in European funding in this area. As a consequence, European plant scientists are finding it more difficult to obtain research money, and they watch with envy their American colleagues taking full advantage of rich funding opportunities offered by various initiatives such as the National Science Foundation (NSF)'s Plant Genome Research Program and the flourishing plant biotechnology industry.

European plant scientists are finding it more difficult to obtain research money

Against this backdrop, this February in Heidelberg, Germany, European plant scientists showed that their work is still at the forefront in many fields. The *EMBO Plant Sciences Sectoral Meeting: From Sequence to Function*, organized and chaired by Chris Leaver from the Department of Plant Sciences at the University of Oxford, UK, provided an opportunity for the majority of EMBO member plant scientists to consider both the science and politics of plant science in Europe. A range of speakers presented the development of platform technologies as well as examples of basic and applied plant science. The talks and discussions illuminated the necessity and potential of basic science to contribute to practical applica-

tions, and demonstrated that decreased funding could have dire consequences for the future of agricultural research and the associated biotechnology industry.

New platform technologies, such as genomics, proteomics and metanomics (metabolic profiling) are overcoming the existing limits of data production and are thus changing plant science itself. Thanks in part to efforts of European researchers such as Mike Bevan of the John Innes Centre and Michel Caboche from the Institut National de la Recherche Agronomique in Versailles, France, two of the five *Arabidopsis* chromosomes have been fully sequenced and are available for analysis. More than 70 000 insertion lines have been generated for reverse genetics approaches. With such huge resources and amounts of data available, collaborative efforts become all the more necessary for data mining and annotation.

Technological innovations leading to high-throughput technologies are reorienting plant science from hypothesis-driven research to approach-driven methods. The underlying principle is to accumulate enough data at various levels to understand an organism and its functions better and more quickly. This approach could be particularly helpful in understanding recalcitrant systems such as cell wall synthesis, where >1000 genes are likely to be involved. However, it also inherently means that science is becoming far more expensive and dependent upon trans-national collaborations involving research institutes and universities. There are potentially negative consequences for small laboratories with only limited resources. This could lead to an even greater polarization between countries and regions that invest resources in these technologies and those that do not.

In this time of important developments, it was viewed as ironic that the European

The outcome of cut resources

Commission has dramatically reduced funding in the plant field, essentially cutting in half their contributions to plant research. Furthermore, aspects essential for large-scale projects such as continuity and international collaboration have been neglected by the Framework V Programme. Although *Arabidopsis* functional genomics has been supported rather well, the European contribution to completing the *Arabidopsis* and rice genome projects has not. The USA, in contrast, inspired by the success of the innovative and more hypothesis-driven Framework IV Programme, is now trying to emulate it in various agriculture initiatives that have already provided a tremendous boost for American research—the NSF alone is currently spending \$250 million a year on plant genome research.

This reversal in funding is particularly unfortunate considering that European plant scientists are at the forefront in many of the most recent developments. Among the success stories presented in Heidelberg was the European contribution to the understanding of post-transcriptional gene silencing (PTGS). PTGS is manifested in many ways, most notably as co-suppression and antisense suppression in transgenic plants or as quelling in fungi. Giuseppe Macino from the University of Rome, Italy and Andrew Hamilton

from David Baulcombe's group at the John Innes Centre in Norwich, UK suggested that these mechanisms have evolved as a plant defence against viral infections.

Ferenc Nagy from the Plant Biology Institute in Szeged, Hungary, gave a demonstration of how an initially revolutionary—even heretical—observation is now becoming accepted. Nagy's laboratory is one of several that have shown that phytochromes are translocated to the nucleus upon light activation. This seems to be one of the key events in controlling the function of these light receptors, because a perfect correlation is observed between nuclear phytochrome levels and physiological response.

These are examples of discoveries coming out of basic research, but it is foreseeable that such knowledge will lead to improvements in agriculture. More immediate benefits may be reaped from the development of disease-resistant crops. Jonathan Jones and Chris Lamb, from the John Innes Centre, summarized challenges in understanding disease resistance. As Jones pointed out, although the basic biochemistry of these mechanisms still remains poorly understood, great progress has already been made in cloning resistance genes.

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In *Arabidopsis*, the major class of resistance genes is comprised of 100–150 nucleotide-binding leucine-rich-repeat proteins. As similar characteristics are observed for brassinosteroid hormone receptors, Lamb reported that hybrid molecules can be generated between disease resistance proteins and brassinosteroid receptors to generate a disease-resistance output from a hormonal input. Both Jones and Lamb stressed that more understanding of signal mobility, systemic signalling and non-host specific resistance (e.g. why barley is resistant to wheat pathogens) will be the basis for future applications in agriculture.

Although basic research as presented at the meeting will inevitably affect agricul-

ture in the long run, much of it cannot be funded in Europe under the current Framework Programme, which is too prescriptive and market-oriented. Furthermore, plant science is seen as minor in relation to medicine/health, and the mishandling of GM food concerns by regulatory authorities and associated scientists has further damaged the public perception of plant science. Consequently, many top European laboratories are choosing not to apply for European funding at all. The emphasis on near-market research

has also meant that industry is less willing to participate in Framework V projects—they also would prefer to see the European Union funding long-term basic research of strategic relevance.

The emerging platform technologies can potentiate research by providing new methods but they will never be a substitute for a brilliant problem-solving mind, which is necessary to perform basic, hypothesis-driven science. The traditional approach of understanding a system by perturbing it and analyzing the consequences is as

Ten challenges for plant biology

As William S. Gilbert wrote in *The Mikado*, 'I've got a little list—I've got a little list...', well, so have I. I showed it at the inaugural EMBO plant sectoral meeting to illustrate what I think are important future directions for plant research. It reflects two converging lines of discussion within the plant science community. The first is about the directions that post-genomic plant science will take—how whole genome sequences will re-energize biochemistry, cell biology and physiology, and how plant scientists might use this information to understand how complex protein machines work in three and four dimensions.

The second line of discussion is everyone's increasing disenchantment with the EU Framework V Programme, with its strict adherence to policy- and application-driven science. The reluctance to accept that basic science could at the same time generate valuable intellectual property for Europe and underpin answers to key agronomic problems is beginning to irritate those working in plant science.

My little list is simply a rapid, personal and idiosyncratic stab at defining some key areas of basic plant science, which, if tackled collaboratively at a European level, could deliver major insights and commercial opportunities for agribusiness in Europe.

I'm fully aware of the dangers of putting your head above the parapet, so I list these points not so much as a solemn offering but as a light-hearted way of stimulating the discussion of where we want plant science in Europe to go in the future.

- Growth and size control at plant and cell level
- Symmetry breaking, cell polarity and cell shaping
- Networking of growth factor signalling pathways
- Cell cycle controls and division plane alignment
- Supracellular controls on plant morphology
- Polysaccharide biosynthesis and its control
- Environmental sensing and links with other intracellular signalling pathways
- Long-range signalling
- Pluripotency and somatic embryogenesis
- Control of meristem activity and positional information.

If we look at some of the key limitations for European agriculture, and the scientific challenges that they represent, then certainly among them would be reproductive strategies, pathogen and pest resistance, plant architecture or habit, fibre and biomass quality, salt and drought tolerance, and abiotic stress resistance. By tackling some of the problems reflected in my list we could help deliver solutions for these challenges. Understanding the wide range of signalling inputs for example, and how downstream signal transduction pathways are networked and integrated, underpins any attempts to engineer solutions to the agricultural problems listed above.

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important as ever. Multiparallel high-throughput technologies will provide only new methods for doing so. Another concern for plant scientists in Europe is therefore the need to attract talented young researchers.

Given the current controversy in Europe over the introduction of transgenic food plants, it is essential that European plant scientists help to reorient political and public thinking about this topic. Perhaps the best approach is to make a clearer distinction between basic plant science and the agricultural applications that follow by exploiting the knowledge created. European plant scientists have recognized the urgent need to inform the

public and to lobby policy makers. As one outcome of the current funding crisis, several major European plant research institutions established the European Plant Science Organization (EPSO) in February. Chaired by Marc Zabeau from the University of Gent in Belgium, EPSO will primarily form a multinational platform of plant scientists to increase the visibility and impact of plant science on business and society by advising funding agencies at the European and national levels on long-term strategies to support plant science. To continue the success story of basic plant science in Europe, there has to be a broader understanding and appreciation this research for its own sake.

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World Wide Wisdom

Electronic publishing is moving ahead

The story of publicly funded electronic publishing in the life sciences reads like an old-testament pedigree: E-BioMed begets PubMed Central, which begets PubMed Central Express, both of which are sisters of PubMed and are related to BioMed Central, which is almost family and collectively they inspire the creation of E-Biosci. This saga will eventually affect the work of all practising scientists and has already raised very fundamental questions about the way we have been communicating our results. Issues such as the effectiveness of peer review, the power of editors, the intrusion of commercialism, the altruistic role of scientists in reviewing manuscripts, the physical limitations of printed papers, adaptations of the systems to communicate large data sets, even the limits of the ill-defined area called life sciences are problems that will return in the future but are part of the genesis of this story.

It is a truism that the e-world will have an impact on all areas and activities of society, and the Gutenberg-based method of announcing our scientific results cannot be an exception. But how an internet-based product will look and feel and how we will get there still has to be worked out. By collecting abstracts of a large number of articles and presenting them in

a readily screened manner, Medline and PubMed have already shown the way forward. The popularity of this free, current and increasingly complete compilation of material led to a proposal that there should be a single site where the *full text* of all papers in a certain area of research could be searched at no cost.

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E-BioMed, the first attempt to establish such a system, was brought to the attention of a wide community by David Lipmann from the National Institutes of Health, MD, and Pat Brown from Stanford University, CA, at a Banbury conference at the end of 1998. It was then given the important impetus of Harold Varmus's active support when he was the Director of the NIH. David Lipmann has since been at the core of the development of this electronic service and its delivery by the NIH, and deserves additional credit for pushing forward an ambitious agenda for electronic publishing that will eventu-

ally benefit scientists world-wide. As Lipmann is also the person responsible for the USA component of the international DNA database, the outcome most expected from the Banbury announcement would have been some similar system where the Europeans, Asians and others would have worked out protocols with the NIH to achieve a 'single' electronic publication service.

But the original presentation of E-BioMed attracted a disconcerting amount of criticism, which prevented its rapid implementation. Major concerns were the potential limitation to medical research, the suggestion that peer review could become optional in life science/medical research publications, a lack of realism in terms of distributing, without charge, content owned by others, and the fact that learned societies rely on the income from their journals. The discussions with the European Molecular Biology Organization, which was leading the analysis from a European perspective, were abruptly stopped when PubMed Central, into which E-BioMed had changed in the meantime, decided to launch under its own terms early in 2000, a date that coincided with the end of Harold Varmus's term at the NIH.