Response of the European Plant Science Organisation (EPSO) to the European Research Area proposal

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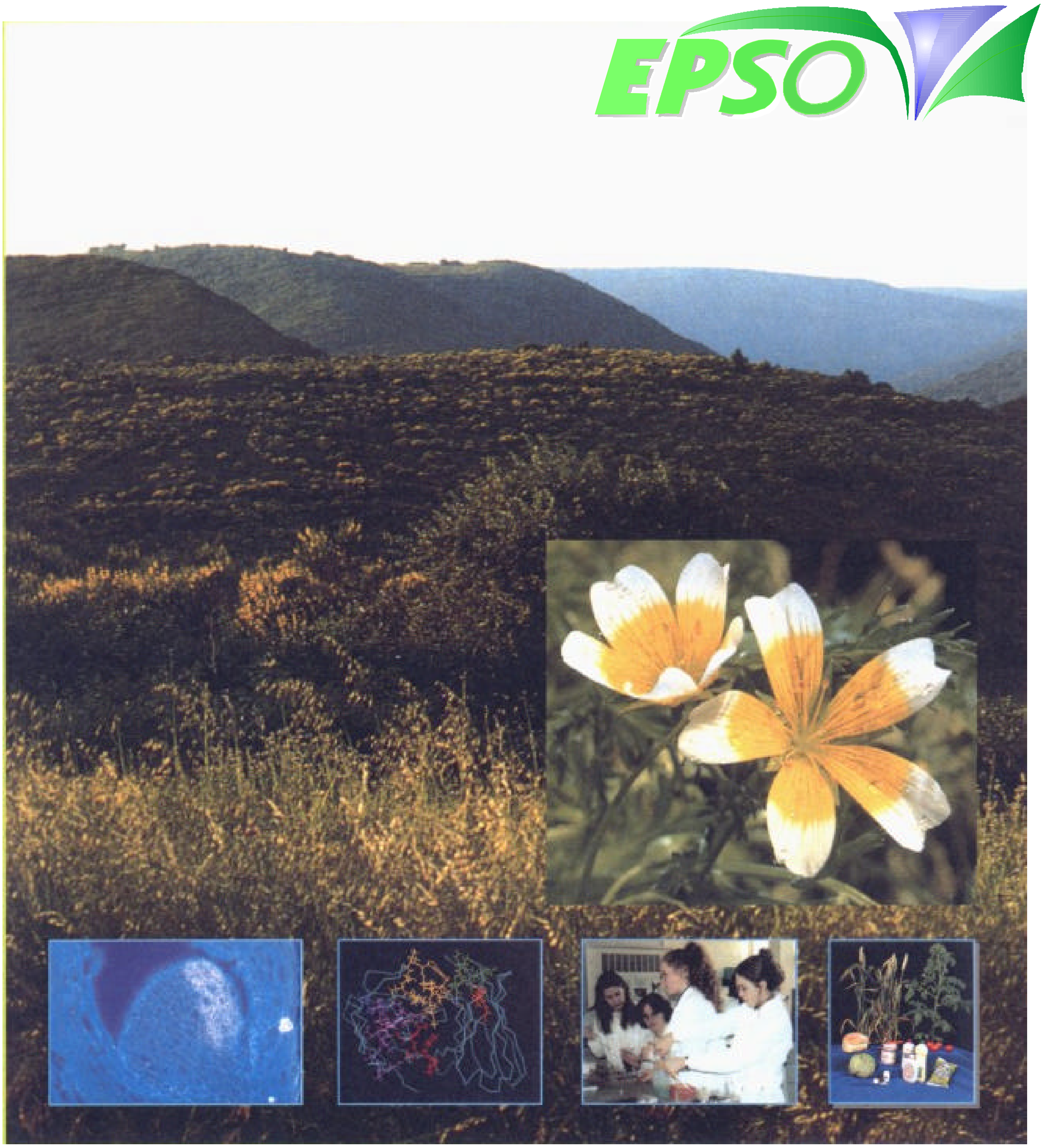

Securing the future of plant science in Europe

10 year vision for plant science in Europe – The Healthy Plant

cover:

- Flowers of the poached egg plant (*Limanthes douglassii*): This species and its relative *Limanthes alba* (meadowfoam) are potential industrial oilseed crops. John Innes Centre, Corporate Plan
- Assymmetry in *Antirrhinum* flowers: Expression of cyc in a young floral meristem, as determined by RNA in situ hybridisation on a longitudinal section. Signal (pinkish-orange) is specific to the dorsal region of the meristem, even though there is no obvious morphological dorsoventral asymmetry at this stage. R. Carpenter & E. Coen, John Innes Centre Norwich
- Top view onto the antigen combining site of an antibody. R. Fischer, Fraunhofer Department for Molecular Biotechnology, Aachen
- Activities of the Teacher Network Association in the UK
- Users and beneficiaries of plant science.

Cover designed by Stijn Debruyne

Securing the future of plant science in Europe

The European Plant Science community has founded the European Plant Science Organisation (EPSO) to represent its future needs and interests. EPSO is presently composed of 34 members from 18 European nations who represent academic institutions and 5 advisers who represent industries active in plant science. At the invitation of EPSO, leading European scientists have met and formulated a vision and the needs of the European plant science community for the coming 10 years.

Opportunities and Challenges in the life sciences
We are in the midst of a revolution in life sciences. The availability of complete genome sequences of many species, including plants, is dramatically changing the scale and scope of experimental enquiry. This change now enables systematic analyses of complex biological processes using multidisciplinary approaches. These approaches require the concerted action and productive interaction of numerous research groups to achieve a comprehensive understanding of biological processes.
To meet the challenges and opportunities provided by these functional genomic approaches and the need to capture intellectual property in an internationally competitive manner, science in Europe and policies of funding need a radical and rapid change. National European programs and institutions need to be linked to achieve a productive scale of research. The policy of funding at European and national levels requires urgent adaptation to meet the new challenges of rapid changes in both scientific approaches and societal needs. These adaptations will encourage higher levels of co-operation between EU states while mobilising resources to compete effectively on the international scene.

Key objectives in European plant sciences
The technologies and skills at hand will allow us to tackle key objectives in the field of plant sciences in Europe. Plant sciences are of vital societal importance for the following reasons:

- Guaranteeing food security and quality in a period of global environmental change & responding to changing consumer demands in food production
- Understanding and protecting biodiversity
- Developing renewable resources and energy supplies

Recommendations
An EPSO sponsored meeting has resulted in the following recommendations for immediate action by national funding agencies and the EC, which can be actively supported by EPSO:

- Ensure continuity of funding for high quality, competitive basic science in Europe and provide longer term funding for resource and technology centres
- Mobilise and co-ordinate resources at national and European level necessary for competitive research in Europe
- Define the landscape of plant science in Europe and identify and support national centres of expertise
- Integrate national activities in plant science throughout Europe and establish a technology network for plant sciences
- Promote training and education and sponsor conferences on plant science to showcase European skills and discoveries
- Promote the creation of interfaces between academia and industry, including SMEs, to secure intellectual property protection and to transfer knowledge into products. Establish a supporting system for SMEs
- Contribute to improvements in review procedures based on expertise
- Establish opportunities for public dialogue on the applications of plant biotechnology
- Improve criteria for funding: avoid narrow predefined topics; leave size of networks open; have industrial participation inside a project really as an option not a necessity.

The EPSO 10-year vision statement describes these goals on the following pages.

10 year vision for plant science in Europe

1. Introduction
2. The Healthy Plant
3. Technology Networks
4. The European Dimension

1. Introduction

The genomics revolution

We are in the midst of a scientific revolution, where the impact of genomics in science is comparable to that of the internet. The complete sequences of a wide range of bacteria, *Drosophila*, *C. elegans*, yeast, and the plant *Arabidopsis* are now known. The sequence of mouse and human and many more microbes will be completed in the next 2-3 years. Analysis of these sequences is yielding the complete gene content of these organisms, allowing scientists for the first time to compare gene function between organisms and to describe biological processes in terms of the contribution of all genes. These analyses generate vast amounts of data that require sophisticated databases and application of novel biomathematical tools for analysis.

These new approaches in biological enquiry are leading to a shift from hypothesis-driven/ reductionist approaches to systematic/holistic descriptions of biological phenomena. Nevertheless, a reductionist approach is still required to understand in detail what candidate proteins, identified by proteomics, do. This gives a current emphasis on gaining a wide understanding of basic processes underlying biological processes to develop a complete knowledge base, leading to firm foundations for value creation.

The capacity to adapt policies to meet the rapid change towards this new systematic approach to biology will define European competitiveness in this important subject. One important consequence of this paradigm shift in science is that research today should not be driven by short term applications, but rather by a renewed focus on basic science. It is the knowledge generated from basic science that will be the foundation of future applications and socio-economic value creation. Europe is not yet at a disadvantage, but needs to develop and enhance aspects of science organisation to both contribute to and reap the benefits of the genomics revolution. In particular:

- There is a need for improved expertise and support for knowledge transfer and exploiting scientific discoveries, and there is a need to establish organisational infrastructures necessary for the systematic application of results of basic science in Europe.
- The USA is dramatically increasing funding for basic science that will allow them to capture a large fraction of future Intellectual Property, which could lead to a permanent disadvantage to European businesses.
- Co-ordination of European research must be improved to avoid fragmentation of efforts, redundancy and internal competition, and to promote large-scale transnational research projects. Europe should aim to create a Plant Science Research Institute Without Walls.

The role of plants in society

Plants provide the oxygen we breathe and, directly or indirectly, all human nutrition. They are key components of the biosphere, regulating the carbon and nutrient cycles and providing habitats for biodiversity. The well-being of the planetary ecosystem requires detailed knowledge of plant function that can be provided by the genomics revolution. Agriculture is a substantial part of human development. Already centuries ago people selected plants optimal for their purposes. Plant breeders developed crop plants that have many advantages compared to natural (wild) plants in quality, quantity and farming practise. Nowadays scientists again harness the new technologies to make even better crop plants, one precise and advanced method being molecular genetic improvement. Three key priorities for plant science are clear:

- There is an urgent requirement for high-level plant science research to underpin food security, quality, safety and health promoting aspects. If this is not done non-European companies will dominate food production. In addition Europe will be able to contribute to balanced global food production through plant sciences. The present widespread use of chemicals to maintain food security is environmentally unsound and unsustainable and further research is needed to maintain productivity with less input.

- Plant science is needed to appreciate, understand, and thereby conserve biodiversity in a rational way. Improved knowledge of plants in the environment will help develop management strategies for conservation that will have a far-reaching impact on the environment.
- Plants are the key component in the global carbon cycle and can be used to address the imminent energy problem and provide industrial feedstock such as plastics, fibre and fuel.

The combination of "The Healthy Plant" and Technology Networks

The vision of plant science in the coming 10 years encompasses the integration of two complementary approaches: the study of the biology of "The Healthy Plant" together with the establishment of "Technology Networks" and platforms underpinning this scientific endeavour. In the following sections this vision will be articulated in detail.

2. Key goals in plant biology in the next 10 years towards an understanding of "The Healthy Plant"

The objectives set out in the Introduction (food quality and security, renewable resources, understanding biodiversity) can only be achieved in a rational and cost-effective way with an appropriate knowledge base that covers all relevant aspects of plant biology – the system of "The Healthy Plant".

What is a "Healthy Plant"? Before we can change plants in defined ways we have to learn how plants function, including their development, response to the environment and interactions with other organisms, as well as the genetic basis of their biological diversity.

High-throughput technologies provide the starting point for analysing the healthy plant. Before the end of year 2000, large-scale genome sequencing will reveal all genes of the model plant, *Arabidopsis thaliana*. It is widely believed that the genomes of crop plants contain homologues of most, if not all, genes present in the *Arabidopsis* genome. A striking example is the *Arabidopsis* gibberellin-response gene *GAI* and its orthologues in wheat, which give shorter varieties and increase grain yield at the expense of straw biomass ("green revolution" genes). Nevertheless it is still an open question whether *Arabidopsis* is, in general, a valid model for crop plant biology. At the genetic level, large-scale sequencing of cDNA clones from selected crop species can assess similarities and differences between Arabidopsis and crop plants. Another problem that can be addressed with current genetic technologies is the enormous diversity of wild plant species. This approach would identify genetic components involved in the adaptation to different environments. Again, *Arabidopsis* is an excellent model for this type of analysis because of the wide range of geographic isolates ("ecotypes") which differ in various quantitative traits (QTLs), including flowering time and seed size. The value of a model plant is also to be seen in the ease with which high-throughput technologies, such as micro arrays or gene chips, enable the analysis of gene expression patterns under several growth conditions that affect plant health, including pathogen defence or response to drought or salt stress. The feasibility of this approach has been demonstrated for gene expression in response to pathogen attack in *Arabidopsis*. Such studies can be extended to crop plants when collections of cDNA clones become available. Important biological questions can be addressed also in other plant species when *Arabidopsis* is not an option. In addition, a comparative approach could be used to explore the extent to which *Arabidopsis* is relevant as a model for plants in general.

Genetic technologies will provide the list of ingredients for making a plant. However, even if all genes are known, as in the case of the model plant *Arabidopsis*, we still need to discover the "recipe" which uses the genetic information to make a plant. Moreover, if the lists of ingredients turn out to be very similar between plant species, different recipes may account for the differences between the model plant and crop plants. What then is the recipe? The read-out of the genetic information provides gene products, proteins, that perform a broad range of functions in different cells, tissues and organs at different times of development and under diverse growth conditions. Proteins regulate gene activities, catalyse metabolic reactions or serve as structural and functional elements, including e.g. the cytoskeleton, signal pathways or membrane trafficking, and thus bring about all activities of the healthy plant. The recipe represents the orchestration of protein synthesis, localisation and activities in time and space, which determines co-ordinated cell behaviour in development and physiology. To decipher the recipe requires the analysis of biological processes from several angles and approaches, such as cell biology, biochemistry and developmental biology, with the support of genetic & molecular technologies.

Strategies of analysis

It will be necessary to analyse plant life at several levels of complexity and integration: cell, organism and population. Cellular activities, such as division, expansion and differentiation, are based on molecular interactions, regulatory networks and subcellular structures. Different cell types are integrated into tissues and organs that, in turn, are co-ordinated by interactions to form the healthy plant and to ensure reproduction. Individual plants are genetically diverse members of a population that interacts with other populations.

For practical reasons, the complexity of the problem needs to be broken down into different aspects, each of which can be analysed separately. At least three broad areas of research can be defined: biological processes, biomolecules and biodiversity. Cellular and developmental processes bring about plant architecture; enzymatic catalysis and transport processes determine the synthesis and distribution of metabolites; interactions with microbes result in defence responses or symbiotic relations; sensing of environmental cues triggers growth and adaptation. Related biomolecules, which mediate very diverse processes, include for example hormones, transcription factor families, membrane trafficking proteins and signals. Biodiversity can be studied from several angles, for example population structure and dynamics, gene flow and interactions between different plant species. This list of strategies is by no means exhaustive.

<u>Areas of research:</u>

1. Biological processes
- cell- and developmental biology & reproduction
- metabolism
- response to abiotic changes in the environment (e.g. temperature, water, salinity)
- responses to biotic changes in the environment (e.g. symbioses, defence)

2. Biomolecules
- hormones
- Transcription factor families
- Membrane & traffacing proteins
- signals

3. Biodiversity
- population structure
- population dynamics
- gene flow
- interaction between different plant species

To provide the optimal research strategy to tackle a particular problem, one of the three research areas can be chosen. The choice depends on the weight of processes, molecules or diversity for a particular problem. This is not an uncoupling of the three research areas. It provides the opportunity that a well designed research programme does not need disturbing modification or reduction to fit a narrow topic. For example, as part of “Biological processes”, the analysis of flower development can include the investigation of related transcription factors. As part of “Biomolecules”, the analysis of many different families of transcription factors, including those involved in plant development as well as in response to a changing environment, can be tackled.

Deliverables in 10 years
Concerted efforts towards the analysis of the healthy plant are likely to provide the knowledge base required for changing plants in defined ways. Although specific results with high application potential are difficult to predict over a period of 10 years, a mechanistic understanding of the biological problems outlined above will strongly increase the competitiveness of European plant science, agriculture, horticulture, forestry and ecology in several areas of practical relevance, such as plant architecture, flowering time, stress tolerance, pathogen defence, yield improvement and maintenance & use of biodiversity.

3. Technology Networks

The development and distribution of new technologies underpins the genomics revolution, as many new techniques in the life sciences require access to special equipment and resources that are beyond the scope of most individual laboratories. To ensure the future competitiveness of European plant science, EPSO recommends the formation of a network of technology centres across Europe that will be responsible for delivering relevant technology to all user groups and developing novel approaches to defining gene function. The wide distribution of up-to-date technology across Europe, and the capture of data generated from multiple users, will ensure high common standards and international competitiveness.
The successful development and implementation of the European Plant Science Technology Network requires innovation, determination, multidisciplinary approaches, and an aggressive stance. Links with pharmaceutical, biomedical and agro industries will be essential to promote interdisciplinary approaches and to provide lessons in scale and throughput.
EPSO will:

- Identify technologies and centres of expertise.
- Define modes of access to the technology and promote development of new technologies.

The technologies required for a comprehensive technology network can be classified thus:

High throughput technologies
Automated sequencing
Reverse genetics resources, insertions and gene silencing
Proteomics- peptide and protein sequencing
Transcript profiling, microarray and chip technology
Metabolite profiling and analysis GC-MS and LC-MS and NMR
Protein-protein interactions, via yeast two-hybrid analyses and proteomics
Marker polymorphism detection
Chemical genomics, for example screens for phenotypes in response to chemicals
High throughput screening and imaging systems

Resources
Seed and stock centres to provide seeds, clone and mutant libraries, and other DNA resources.
A central database containing annotated sequence data sets and reverse genetics resources
Specialised databases containing more complex data sets, such as expression array data captured from a wide range of laboratories.
Access to specialist bioinformatics expertise and computing facilities to extract meaning from complex data sets, to model phylogenies and identify homologies.

Low throughput technologies
Protein structure determination
Protein modification analysis
Structural analysis of complex polysaccharides and proteoglycans
Polysaccharide synthesis chemistry
Lipid modification and synthesis

New analytical tools
Determining in vitro function of proteins (presently limited to soluble proteins)
Imaging – *in vivo* protein localisation and interactions. Imaging cellular functions of proteins.

Develop and link centres for high throughput technologies
Sequencing is quite well established in EU networks. Every country needs access to a sequencing node for cost-effective sequencing. A test of success will be promoting large scale sequencing. Microarray technology to fabricate arrays for analysing gene expression in model and crop plants. Access to be widespread, with pooling of data whenever possible.
Proteomics has very high throughput, therefore only a few specialised centres in EU are needed.
Polymorphism detection systems have high throughput and can be widely distributed.
Metabolite profiling in both specialised centres and distributed, as the machines are quite expensive.
Chemical genomics requires access to combinatorial chemistry and high throughput screening.

High throughput projects
Yeast 2 Hybrid protein interactions
Reverse genetics analysis aims at an insertion in every gene. In Arabidopsis these techniques are well developed and being applied on a large scale. In other plants new technology needs to be developed.
Seed stock and resource centres established for major plants.
Bioinformatics- database for Arabidopsis genome sequence established in EU, and specialised databases to be promoted (e.g. REGIA and EXOTIC)

High throughput technologies, new tools
These need to be developed at their own pace, e.g. recombinant libraries for models and crops, misexpression systems.
There is an urgent need to promote bioinformatics and biomathematics solutions to challenges and opportunities in plant sciences.

Prioritising technologies
This requires consultation with user groups and identification of centres of expertise.

Define access and use
The guiding philosophy of EPSO is to spread access to resources as widely as possible, especially to new member states. There should be no threshold for use, small or larger users can get equal access. There should be an obligation to provide raw data to relevant central databases after publication and IP protection. Users should pay for some services and include costs in grant applications. Ultimately successful technologies should be developed into businesses to market service provision. To make sure technology resources match biological priorities and to make sure biologists are aware of technology and can gain access, activities will be co-ordinated via a steering committee.
Funding needs to be extended beyond the usual 3-year cycle for resource centres and databases- these need a long-term commitment to funding, subject to meeting performance criteria. Finally, specific funds for technology development should be available.

4. The European Dimension

European Strength in plant research
European plant scientists are internationally competitive in several important areas of research. In particular areas of European strength include:
Plant development; e.g. plant architecture, reproduction, and cell cycle
Plant-environment interactions, e.g. Plant-microbe interactions (pathogen-resistance, molecular virology), abiotic stress
Plant biochemistry, e.g. Secondary metabolism, photosynthesis

Plant biophysics

Gene regulation & silencing, e.g. DNA metabolism & recombination

Inter – and intracellular movement

Plant biotechnology, e.g. transformation & tissue culture, molecular farming

Traditional plant sciences, e.g. taxonomy, physiology (mechanism of actions of hormones), biology of the organelle (mitochondria & plastids)

Human potential, but Europe needs to become more attractive to promote the flow (back) to Europe

European weaknesses in plant research

We need to make a unified Europe work. Only if one succeeds in organising diversity by making different labs in different countries work together and establishes a working network, will Europe be competitive.

Another issue that has to be resolved is national versus international support for research. Certain countries in Europe are using peer review to decide whether or not a given research should be supported. Only if Europe manages to organise a similar system can one hope to be competitive. One should also follow the example of the U.S. where one uses the most qualified researchers worldwide to do the peer review. This will mean to use English as a language (no translations!) and unavoidably many experts from the U.S.

EPSO will establish a directory of European plant science, noting relative strengths and weaknesses, and will advise national funding agencies and the EC of perceived strategic opportunities and weaknesses, to identify opportunities for creating synergies.

Education

In the past decade international collaborations in plant science have been particularly successful in education and training of graduate students and postdocs. The Human Capital and Mobility programme later followed by the Marie Curie Training and Mobility Research programme have been successful and should be extended. International PhD programmes should be supported and requirements for PhD studies should be standardised where possible.

Special teaching programmes for PhDs and postdocs from new member states need to be developed and supported in a pan-European system. PhD students and post-docs from those countries should be given the opportunity to spend training courses in host laboratories.

These can be organised around special themes relevant to the needs of new member states, which usually have great potential for modern agriculture but often lack present-day technologies. In those areas where there is a shortage of skills such as bioinformatics and several other emerging new fields, but also more classical areas such as general plant biology, plant biochemistry and plant pathology special courses should be taught.

For postdocs who have obtained international research experience in high standard laboratories in Europe or the USA, further opportunities should be provided to initiate small independent research groups in any European country. Too often talented and experienced postdocs find no suitable possibilities to further develop a career in plant science, and represent a permanent loss of European skills. The means to start up such groups in several highly qualified institutes in Europe should be promoted by the EU.

Present-day technologies such as plant biotechnology need efficient and balanced communication to politicians and laymen. Young scientists who are talented in communication should be stimulated to further develop their skills. Special Fellowships should be provided to students to follow courses to fulfil these needs.

In order to make European scientists more confident in their contributions to life sciences and particularly in plant sciences, regular European conferences should be organised which are in style comparable to the Gordon and Keystone conferences yearly held in the USA. These could be organised by EPSO and called “EPSO meetings”.

Linking of new plant (genomics, functional genomics) initiatives in Europe
The developing and introduction of new technologies in Europe often encounter problems that rarely appear in the USA, or are more easily solved there. One example is the introduction and developing of plant genome projects. The larger countries such as Germany, France and the UK have already launched genomics and functional genomics programmes such as GABI, GENOPLANTE and GARNET, respectively. These national initiatives have been established without reference to each other and consequently have different goals. For example in GENOPLANTE private industry is heavily involved, in contrast to the GARNET network which places data directly into the public domain and links different model organisms. In Belgium, the Netherlands and Sweden smaller local initiatives will soon be launched or have been launched already. EPSO aims to forge links between these networks and integrate their work with emerging national and EC-funding networks such as EXOTIC and REGIA. The development of publicly accessible databases containing functional genomics data is a further goal of EPSO. Another goal of EPSO is to provide evidence for the high value of maintaining long-term support for infrastructure supporting biology in Europe. Finally, EPSO will develop a database of existing expertises and research programmes in European Plant Science to promote interaction throughout Europe.

The European Research Landscape
In addition to linking European initiatives in (functional) genomics as mentioned above, special centres of expertise will be identified and promoted by EPSO. These will provide a comprehensive range of facilities, resources, and training. These could involve research groups working in research areas such as bioinformatics, proteomics and metabolics as described above, with access modes defined by the user community as described above.

EPSO member representatives

Marjori Matzke & Erwin Heberle-Bors, Austria; Marc van Montagu, Marc Zabeau*, Dirk Inze & Karin Metzlaff**, Belgium; Atanas Atanassova, Bulgaria; Milos Ondrej, Czech Republic; John Mundy, Denmark; Frank Gannon & Andrew Moore, EMBO; Teemu Teeri, Finland; Michel Caboche, Christian Dumas & Michel Dron, France; Jeff Schell, Paul Schulze-Lefert, Francesco Salamini, Bernd Reiss, Lothar Willmitzer, Gerd Juergens & Rainer Fischer, Germany; Nickolas Panopoulos & Mina Tsagris, Greece; Denes Dudits, Hungary; Gwilym Williams, Ireland; Mauro Cresti & Chris Bowler, Italy; Pierre de Wit & Arjen van Tunen, The Netherlands; Odd-Arne Rognli, Norway; Maria Pais, Portugal; Anna Pretova, Slovakia; Javier Paz-Ares, Spain; Goran Samualsson, Sweden; Thomas Hohn & Jean-Pierre Zryd, Switzerland; Caroline Dean, Michael Bevan, Chris Leaver & Dianna Bowles, UK.
* Chairman, ** communication manager

EPSO office: EPSO, University of Gent, VIB; Ledeganckstraat 35, 9000 Gent, Belgium; Tel/Fax: +32-9-264-8724/5335; e-mail: karin.metzlaff@gengenp.rug.ac.be

EPSO has links to the European Life Science Forum (ELSF).

EPSO advisers:
Jan Leemans, Belgium; Georges Freyssinet & Richard De Rose, France; Reinhard Nehls & Harald Seulberger, Germany.

Founding Members of the European Plant Science Organisation (EPSO) are:

Austria:	Vienna University
	Institute of Molecular Biology, Salzburg, Austrian Academy of Science
Belgium:	Flanders Interuniversity Institute for Biotechnology,VIB, Gent
Bulgaria:	Institute of Genetic Engineering, Kostinbrod
Denmark:	Institute of Molecular Biology, Copenhagen University
	Institute of Molecular and Structural Biology, Aarhus University
EMBO	European Molecular Biology Organisation, EMBO, Heidelberg
Finland:	Institute of Biotechnology, Helsinki University
	Department of Biology, Turku University
France:	Institute des Sciences Vegetale, Gif-sur-Yvette, CNRS
	Ecole Normale Superieure de Lyon, INRA & CNRS
	INRA – Versailles, INRA
	CIRAD, Paris
Germany:	Max-Planck-Institut für Züchtungsforschung, Cologne, Max-Planck-society
	Zentrum für Molekularbiologie der Pflanzen, ZMBP, Tuebingen
	Max-Planck-Institut für molekulare Pflanzenphysiologie, Golm, Max-Planck-society
	Fraunhofer Institute for Molecular Biotechnology, Aachen, Fraunhofer society
Greece:	Institute of Molecular Biology and Biotechnology, Heraklion, FORTH
Hungary:	Biological Research Centre, Szeged, Hungarian Academy of Sciences
Ireland:	BioResearch Ireland, BRI, Dublin
Italy:	Universita di Roma 'La Sapienza'
	Stazione Zoologica, Napoli
	Universita Sienna
Netherlands:	Wageningen University / EPS
	Plant Research International, Wageningen
Norway:	Agricultural University of Norway, Aas
Slovakia:	Institute of Plant Genetics and Biotechnology, Nitra, Slovak Academy of Sciences
Spain:	Consejo Superior de Investigaciones Cientificas-CSIC, Madrid
Sweden:	Umea Plant Science Centre, the two Umea universities
Switzerland:	Basel Plant Science, Basel University and Friedrich Miescher Institute
	University of Lausanne
UK:	John Innes Centre, Norwich, BBSRC
	Department of Plant Sciences, Oxford University
	University of York.