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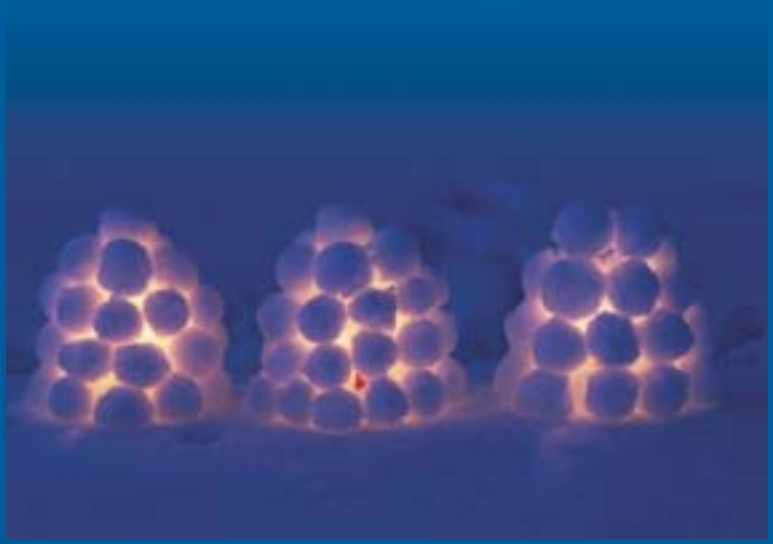
IMPACT OF PUBLIC RESEARCH FUNDING AND STRATEGIES FOR THE FUTURE

EVALUATION REPORT



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EVALUATION REPORT

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Ms. Sarah Sherwood

Academy of Finland in brief

The Academy of Finland is an expert organisation on research funding. The Academy seeks to enhance the high standard of Finnish research by long-term research funding, by expertise in science and science policy, and by strengthening the status of science in society at large.

The main focus of the Academy's development activities is on improving professional research career opportunities, providing preconditions for high-quality research environments and utilising international opportunities in all fields of research, research funding, and science policy.

The Academy's operations cover all scientific disciplines, from archaeology to space research, cell biology to psychology, and electronics to environmental research. The wide range of high-level basic research funded by the Academy provides a sound basis for innovative applied research and the exploitation of new knowledge.

For more information on the Academy of Finland go to www.aka.fi/eng/.

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EMBL

Laboratoire Européen de Biologie Moléculaire
European Molecular Biology Laboratory
Europäisches Laboratorium für Molekularbiologie

On behalf of the Evaluation Panel, I am honoured to present this evaluation of the impact of public research funding on biotechnology and related life sciences in Finland, which has been commissioned to serve as a basis for drafting the next national development programme for 2004-2006. We have prepared this report with a full understanding of the importance of the task before us, and have approached this responsibility seriously, with an objective and constructive spirit.

We would like to thank all those who prepared self-evaluations as background material for this report as well as those who participated in the oral presentations during the site visits. Their contributions were extremely informative and helpful. We would also like to thank the organisers of the evaluation for their professional support and warm hospitality during our visits to Finland.

Special thanks go to the local coordinators of the evaluation, Dr. Sakari Karjalainen until the end of April 2002, and Dr. Katri Haila thereafter. In particular, the Panel would like to recognise Dr. Haila for her invaluable effectiveness in organising the many visits to institutions across Finland, and also in the preparation of the factual sections of this report. She worked closely with the Panel to help us digest a large amount of data, while scrupulously avoiding any value judgements, thus safeguarding the objectivity of the review.

Fotis C. Kafatos
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Chairman of the Evaluation Panel

Heidelberg, November 14, 2002

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VIII. APPENDICES

I. EXECUTIVE SUMMARY

Finland has an enviable record in developing knowledge-based industry underpinned by strong public investment in research and training. The most obvious success is the Information and Communication Technology (ICT) sector. A wise decision was also made, beginning in the mid-1980's, to select biotechnology as a high priority sector for the future. The Biotechnology 2002 Evaluation, combining an internal self-assessment exercise with an external assessment by an international Expert Panel, aims to evaluate the current status of the biotechnology innovation system, from basic research and training to industrial development, and to propose improvements as appropriate. The outcome of the Evaluation is summarised in this Executive Summary, and in summary recommendations and responses in Chapters III, IV, V and VII.

I. A. Training and Fundamental Research

Knowledge is a deep human need; its pursuit and acquisition (research and training) are essential aspects of our culture. They are also vital foundations for modern industries, including biotechnology. Impressive progress has been made in the latter sector in Finland, but much remains to be done. The establishment of a network of Biocentres with earmarked funding has been an excellent initiative of the Ministry of Education; their continued development and special funding remain essential. The future apportionment of funding should take into account updated quality assessment rather than simply historical formulae. In one or two cases, regrettable frictions were encountered between a Biocentre and the corresponding University. The autonomy of both entities must be respected; their synergistic relationship (in research, training and core facilities, in particular) is mutually important and must be safeguarded.

The Ministry of Education and its independent agency, the Academy of Finland (essentially the National Research Council), play leading roles in developing the foundations for biotechnology, especially via the Universities, the Biocentres and other entities engaged in basic research and training.

Finnish Universities have begun an important process of modernisation, often stimulated by well-considered special programmes of the Ministry of Education (Graduate Schools) and the Academy of Finland (Centres of Excellence, Group Leader and Academy Professor appointments). Positive interactions with Biocentres can and have been very valuable in this process. Some problems of the Universities merit special attention. One is the funding formula, which is largely based on the number of degrees awarded; whilst training is obviously central to the mission of Universities, the underlying research mission should receive greater recognition, both by the State and by the University. A second problem is organisational and procedural rigidity. Thus, traditional faculty and curriculum structures need re-examination, to promote integration and expansion of the biosciences, and greater interdisciplinarity including closer links between biosciences, medicine, chemistry

and other disciplines. The human capital pipeline needs significant improvements at multiple levels. A great demand for higher education in the life sciences raises the question of investments to expand capacity. The establishment of Graduate Schools has been very successful; follow-up action to enhance their strength, cooperation and capacity is advisable. A detail that merits attention is numerical publication requirements for awarding the doctoral degree; these rigid requirements can misdirect the research effort towards "safe" projects of reduced innovation and impact. Much still remains to be done to strengthen postdoctoral training, establish young group leader appointments and internationalisation. Transition to a tenure-track system in the Universities is strongly recommended. Its absence and the steepness of the academic pyramid are strong disincentives for recruiting and retaining young group leaders, including foreigners.

The Academy of Finland has an exemplary, rigorous quality-based assessment system. A concern is shortage of funds, leading scientists to apply frequently for relatively small awards, with a consequent waste of effort.

I. B. APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT

Promoting the biotechnology innovation system is within the remit of the National Technology Agency, TEKES. This agency provides significant financial support to applicable research and industrial R&D. It has played an important role in fostering the innovation system in the information and communication sector (ICT), and could be a great asset for biotechnology development in Finland. However, it is strongly recommended that TEKES reconsider its present policy of reviewing in house the grant applications (especially for research institutes and Universities); the requisite in-house expertise is limited, and many opportunities may be overlooked while others may be exaggerated. Experience in other countries (*e.g.* USA, UK) shows that independent evaluation by external experts, even as it relates to industry, is fully compatible with confidentiality. The arrangement between the Academy and TEKES for co-funding applications that link basic and applied research is innovative and would be encouraged by the Panel, provided that expert peer review is used by both organizations. Otherwise, the Panel would recommend that the responsibility for this type of applications and the corresponding financial resources be transferred to the Academy.

TEKES and its parent entity (the Ministry of Trade and Industry) further support biotechnology via their funding the Technical Research Centre of Finland (VTT). Similarly, the Ministry of Social Affairs and Health makes important contributions via their specialised institutes, especially the National Public Health Institute (KTL). The Panel is concerned that the other Ministries with applied remits, in the agriculture, forestry and environment sectors, have not adequately recognised the opportunities for socially beneficial innovation via biotechnology. This represents significant lost opportunities for Finland.

The biotechnology innovation system shows two obvious gaps: well-developed mechanisms for technology transfer (TT) and support for broadly-needed research infrastructures. It would be sensible and desirable for TEKES to address these needs.

The gaps in TT are undoubtedly related to the low level of patenting in biotechnology in Finland, which is all the more important in biotechnology. Well-functioning TT requires a change in the legal framework at the national level, shifting ownership of intellectual property rights (IPR) from the individual inventor to the institution with appropriate benefits flowing back to the inventor. Equally, professional TT units are essential and must already be in place at the time of implementing this change, to enhance the process and sustain the entrepreneurial drive of individuals. TEKES is well suited to fund the training and promote the use of technology transfer professionals. It might also support the establishment of high quality TT entities or companies, which could address the needs of institutions in geographic areas, provided close interaction with researchers is maintained.

Increasingly, sophisticated instrumentation infrastructure is vital for biotechnology activities ranging from basic to industrial research and development. TEKES could provide an important stimulus to biotechnology by funding the establishment and operation of cost-effective shared facilities that are accessible to training, research and industrial entities.

I. C. THE INDUSTRIAL SECTOR

Finland is making impressive progress in positioning herself for success in biotechnology. As summarised above, the Panel has seen important achievements in the fundamentals of research and training, and recognises strengths in the applied research sectors for industrial biotechnology and health. It is hoped that the constructive critiques offered will help consolidate the strengths and fill in the gaps in these fundamentals.

The Panel also visited several quite successful companies at both an early stage and at the beginning of maturation; some of these are identified in the Report, merely as examples. There are clearly more successes than are being recognised. In this respect, the Panel wishes to emphasise that sustainable success in biotechnology requires considerable, sustained investment (up to eight or ten years after a company's creation), willingness to take risks and a long time horizon. The appropriate goals are to foster the development of a reasonable number of well-positioned enterprises, internationally competitive, with innovative strategies and product pipelines, with growth potential and with significant benefits to the economy and health of the nation (whether these benefits are income, high-value jobs or essential services and products such as drugs, diagnostics and vaccines).

Finland has experienced a burst of new biotechnology companies in recent years, and currently ranks sixth in terms of number of companies in Europe, after the UK, Germany, France, the Netherlands and Sweden. However, the number of companies is not an adequate indicator of success. A worrisome feature is that a high percentage of these companies are too small and unlikely to succeed as such; indeed, fragmentation hinders the creation of larger companies with more robust prospects. The plethora of small companies is also due, in part, to the lack of clear and appropriate policies concerning the ownership of IPR, and of sufficient well-trained TT professionals, as noted above. Related problems are likely to be overly facile

selection of candidate companies for seed investment; the dominant role of local funds in such investments; and inadequate appreciation of the advantages of merger and acquisition between companies with obvious synergies. It would be highly desirable for Finland to train managers in biotech, as well as business development specialists.

All biotechnology business models should be encouraged, but there might be scope for more emphasis on the field of drug discovery. Many biotechnology products and services will find their primary use in the health sector. This is an important reason (in addition to scientific opportunities) to foster the convergence between biology and medicine, with better integration in all steps of education and research.

To make seed financing more exacting and to sustain growth in the stronger companies as they mature, it will be important to create a broad investor base in Finland, coupled with the participation of international venture capital (VC) funds. Internationalisation is as desirable in this respect as in the research and training stages of the innovation system. Potential incentives to attract independent international VC funds into Finland should be considered.

SITRA, the national investment fund, is a highly creative concept and an evident success. Its public endowment coupled with essential independence represents clear foresight and an important comparative advantage of the Finnish innovation system. The critiques listed above are offered in a constructive spirit, to enhance success beyond what SITRA alone could deliver. SITRA has already taken a commendable initiative to co-invest with a small number of highly selected international biotech funds, specialized in early stage financing. Further relationships with non-Finnish investors would be desirable, to adequately expose the Finnish biotech system to international norms, and to foster co-funding of companies within Finland as they mature.

I. D. LOCAL INNOVATION ENVIRONMENTS

This chapter of the report takes account of the strong attention to regional development in Finland. It integrates the assessment of local Universities and research centres, the industrial activities, the institutional collaborations, the support by local government and the available integrative infrastructures. The summary assessment of the five major centres is as follows:

- *Helsinki* has the strongest innovation environment in Finland for biotechnology, based on its academic quality, vision of leadership and critical mass; the integration of basic and clinical/translational research; an exciting training environment; strength in classical biotechnology; and access to adequate human resources. However, the applied research on agriculture, forestry and environment is not impressive, and the physical dispersal of academic institutions on several campuses reduces synergies.

- *Turku* also has substantial strength as an innovation environment, in a different constellation. The strengths are the relatively large size of the academic

community (for the size of the city); the quality of the biosciences; the strength of the local pharmaceutical and diagnostics industry; an impressive collaborative spirit; the physical proximity of all partners in a compact urban centre; the emphasis on core facilities which deserve further support; the involvement of the city government; and an openness to multiculturalism. Conservative University structures (a general problem in Finland), such as the lack of a tenure-track system, as well as an apparent scarcity of resources and the modest size of the city, represent limits to this otherwise very attractive environment.

- *Oulu*'s strengths as an innovation environment represent a third different constellation. The massive development of the ICT industry is a favourable context for development of knowledge-driven companies based on the biosciences; the academic environment is strong, and in particular the Biocentre has exceptional qualities. There is an enviable but full incubator, and co-ordinated work from several constituencies (including TEKES and a financing company) to sustain a supportive infrastructure for innovation. Core facilities are limiting, and the size of the life sciences community may be below critical mass.

- With two Universities and a commercial validation entity, *Tampere* is a significant centre for research and high-tech industry, which has achieved high recognition in specialty niches. The new Biocentre has developed rapidly into a dynamic pole of high quality, in an academic community that has additional foci of quality. This is a small research community that achieves a lot through internal cohesion, ambition and high standards.

- *Kuopio* is the smallest of these centres, but it has a strong civic alliance in place that supports biotechnology and the development of its science park. There are outstanding foci of clinical research in the University, and a proactive Biocentre. A significant number of biotech companies (for a town of this size) have been formed. More attention needs to be placed on the human resources and the product pipeline of the companies.

I. E. CONCLUDING REMARKS

The Panel has been encouraged by the Steering Committee to be critical and forthright. We have appreciated this attitude, which reinforced our own commitment to identify whatever weaknesses and strengths exist. The overall picture convinced us that Finland has made an admirable start and has a very real chance to become one of the most successful small countries in the world in biotechnology, just as it is a model in the ICT sector. The requirements are to sustain the effort, with a long-term commitment and with attention to the weaknesses, which are identified in a constructive spirit.

II. INTRODUCTION TO THE REVIEW AND TO BIOTECHNOLOGY IN FINLAND

II.A. THE PROCESS AND REMIT OF THE REVIEW

II.A.1. BACKGROUND

In recent years, Finland has increased markedly the national investment in research and development; the 3.6% of the GDP that was devoted to R&D in 2001 is one of the highest percentages amongst OECD member countries. The country ranks as number one in the Growth Competitiveness Index (WEF Global Competitiveness Report 2001-2002), followed by the US, and as number two in World Competitiveness (IMD World Competitiveness Yearbook 2002), following the US. Approximately 73% of this expenditure is from the private sector, and the information and communication technology (ICT) sector is dominant; approximately one third of the total represents the R&D activities of Nokia. However, public expenditure is also considerable, approximately 1.0% of GDP (Source: Statistics Finland).

The overall innovation support system in many ways can serve as a model for other countries. It pays attention to producers, users and their interaction, and it recognises the essential roles of education, research, development and international collaboration. A remarkable measure of the national attention to this system is the top strategic body, the Science and Technology Policy Council of Finland. It was established in 1987 (Act 1986) and has continued the traditions of an earlier Policy Council of Science, with slightly different emphasis on the tasks. The STPCF is chaired by the Prime Minister, and its membership includes the Minister of Education, the Minister of Trade and Industry, the Minister of Finance, several other Ministers as well as permanent experts from the different Ministries. Additional members include representatives of the Academy of Finland (essentially the National Research Council), TEKES (the National Technology Agency), industry, Universities, Research Institutes and an employee and employer organization. Its analyses, reports and recommendations are made public. They are taken into account in the initiatives and budgets of the ministries, while the third level of the system (Academy, TEKES and SITRA, the national venture capital fund) set their detailed priorities and implement policy through competitive funding and investment.

Biotechnology is the second priority area in Finland, after ICT. As defined provisionally by OECD, it is "*the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services*." A Working Group was established by the Ministry of Education in 2000 ("Biotechnology 2000") and commissioned an external evaluation of biotechnology in Finland, to be conducted by an international expert Evaluation Panel in 2002. The present report summarises observations, conclusions and recommendations of the Panel.

The mission of the evaluation exercise is to suggest improvements to the competitiveness of the Finnish innovation system in biotechnology, by assessing:

- the impact of public research funding, including the underlying basic research and training in the life sciences
- the applied research activities
- the biosciences industries.

Therefore, the remit of the review is dual: to evaluate this sector, and to advise national authorities, funding organizations, Universities, Research Institutes and industry on how to develop and focus biotechnology and life sciences R&D, so as to enhance its contributions to the public interest (*e.g.* skills, jobs, development of products and services, economic growth, *etc.*). For this purpose, it goes beyond a global evaluation to the level of individual institutions and other entities that are important in this sector.

The evaluation was undertaken as a joint exercise of the Ministry of Education, the Ministry of Trade and Industry, the Ministry of Agriculture and Forestry, the Ministry of Social Affairs and Health, the Ministry of the Environment, the Academy of Finland, TEKES, SITRA and the Finnish Bioindustries. The evaluation was conducted under the supervision of a Steering Committee chaired by Arvo Jäppinen, the Director-General of the Ministry of Education, and including members representing the participating entities. The Committee also included University representatives and experts from Statistics Finland and CSC-Scientific Computing Ltd. Full-time coordinators (Dr. Sakari Karjalainen until April 2002, Dr. Katri Haila from May 2002), appointed by the Steering Committee, admirably assisted the project. They provided us background valuable published and previously unpublished material, as well as specially commissioned documentation amounting to a self-evaluation of the biotechnology actors, as explained below.

II.A.2. Objectives of the Evaluation

As commissioned by the Steering Committee in the Terms of Reference (Appendix, Chapter VIII.A.), the external evaluation has two main objectives:

- to determine the scientific and socio-economic impact of the public funding on biotechnology research in Finland;
- to assess whether the strategies of public funding organisations, Universities, Research Institutes and other actors influencing technology transfer are appropriate to achieve scientific excellence and socio-economic impact in the field of biotechnology in Finland.

The results of the evaluation – conclusions and recommendations – will be used by the public funding organizations to develop their individual and joint strategies to promote biotechnology research and its application in Finland. As proposed by the Working Group “Biotechnology 2000”, the next national development programme

for biotechnology for 2004-2006 will be drafted on the basis of the recommendations of this evaluation. The feedback from the Evaluation Panel will also help Universities, Research Institutes and other organisations to develop their own strategies.

II.A.3. THE REVIEW PROCESS

The Evaluation Panel consisted of six independent high-level experts. The Steering Committee invited Professor Fotis C. Kafatos, Director-General of the European Molecular Biology Laboratory, to act as the Chair of the Panel. The other members of the Panel, selected jointly by the Chair and the Steering Committee, were Professor Konrad Beyreuther, University of Heidelberg (D); Professor Nam-Hai Chua, Rockefeller University, New York (US); Professor Bernard Mach, University of Geneva (Emeritus), Geneva (CH); Dr. David Owen, MRC Technology Transfer, London (UK); and Professor Joan Steitz, Yale University, New Haven (US). Sarah Sherwood (Office of Information and Public Affairs, EMBL) served as the Secretary to the Panel.

The evaluation consisted of three steps (Chapter VIII. A.-H.):

1. Panel members were invited to Helsinki on June 12, 2002 to take part in initial presentations by the members of the Steering Committee, representatives of the funding organizations and ministries, and the directors of Finland's six Biocentres. The goal of this presentation step was to introduce the Panel to many of the key players in the Finnish biotechnology innovation system, and to familiarise them with the objectives of the evaluation.

2. The second step of the evaluation focused on desk research, during which the Panel examined all relevant documentation as provided by the Steering Committee, such as descriptions of the Finnish innovation system, public documents, previous scientific evaluations of Universities, Institutes or research fields, and lists of publications. Important input came from answers to well-planned questionnaires prepared specifically for this evaluation; these answers constitute an important record, and are published separately as an electronic volume accompanying the evaluation report. The questionnaire forms and additional specific issues that the Panel requested the Universities and Biocentres to address during the site visits are presented in Chapter VIII. D.-F.

3. The third step of the evaluation consisted of site visits. Panel members interviewed biotechnology actors in five different cities across Finland during the week of September 24-28, 2002 (some preliminary interviews were conducted at the presentation stage on June 12, 2002). Each site was visited by half of the Panel members, and a total of 43 organizations (226 people) were interviewed (VIII.B.) Interviews were conducted with:

    - government and other officials who have been or are currently involved in planning and implementing public biotechnology funding

    - market actors such as representatives of biotechnology industries, regional technology centres and technology transfer companies

- Rectors of Universities, Directors of Biocentres or Research Institutes and other key players in basic biotechnology research and training

- a sample of researchers representing various phases of the researcher career. Interviews with pre- and postdoctoral fellows were conducted in the absence of senior faculty of the institutes.

II.A.4. The Report

The Panel wishes to underline that the scope and focus of its evaluation is the biotechnology innovation system in Finland. The word "system" emphasises that the evaluation focuses on the performance of the entire series of interconnected sectors, from fundamental research to industry. The concept of innovation is often misdirected solely to the applied research and industrial sectors; it is equally applicable to training and fundamental research which are so essential in biotechnology. Thus, the Panel has assessed qualitatively the structure, procedures, investments, staffing, activities, innovativeness and performance of the entire system of Finnish biotechnology. Systematic assessment of individual scientists and managers was not within the remit of the Panel. Comments about the structure, activities and level of performance of all important entities, and exceptionally about individual groups or specific companies, are included to exemplify concretely strengths and weaknesses of the system. The report was reviewed in draft form by the Steering Committee, to permit the Panel to correct any factual errors.

The present report begins with an Executive Summary (Chapter I). This is followed by an introductory Chapter II, which describes the process and remit of the review, gives the Panel's views on the nature of biotechnology and the setting of goals for biotechnology in Finland, and provides the Panel's understanding of the structure, funding and some key statistics of the biotechnology sectors, from fundamental research to industry, to provide a transparent background. The following three chapters span the sectors of the innovation process: (III) The foundations: Training and fundamental research, (IV) The translation process: Applied research and technology, and (V) The establishment and maturation of companies. Each of these chapters summarises and analyses the Panel's observations and conclusions, followed by specific recommendations. The next Chapter (VI) provides a synthesis, by discussing the innovation environment of the regions of the five cities that were visited by the Panel. The concluding Chapter (VII) recapitulates and summarises the conclusions and recommendations. It takes the form of answers to key questions posed by the Steering Committee. Appendices are found in Chapter VIII.

II.B. The Nature of Biotechnology

As noted in the previous section, and as the term is used in Finland and in this report, biotechnology refers to a broad range of life sciences (biosciences) and their utilization in medicine, primary production, industry and services. This use is felicitous, as is recognises the close connections between different biosciences as well as other disciplines, and between fundamental research and its applications.

The modern revolution in the biosciences has led to the crumbling of boundaries between historically separate (sometimes even parochial) disciplines. Discoveries in simple model organisms now illuminate the nature of much more complex organisms, including humans; similar genetic mechanisms are implicated in normal biological processes such as embryonic development, growth or cell division and in pathologies such as cancer. This restructuring of the science includes a momentous integration of medicine (from the study of basic mechanisms to the clinic) into the life sciences. Furthermore, technologies developed for molecular biology research, such as high-throughput DNA sequencing, protein structure determination or gene expression analysis on "DNA chips", are also used in ecology, agriculture, forestry, and the biotechnology and pharmaceutical industries. This unification of the biological sciences and their integration with medicine, chemistry, informatics, physics and other disciplines are proceeding apace, constrained only by the imagination of researchers. Restructuring academic departments to promote interdisciplinarity and reflect new scientific developments is an important requirement for a successful biotechnology strategy.

A related requirement to become or remain competitive in the biosciences is early and unhindered access to methods and instrumentation that are evolving rapidly. The cost of biotechnology research is increasing, and this must be taken into account in its funding. There are now substantial needs for large equipment infrastructure, which is of general utility and suitable for inclusion in core facilities. The most expensive equipment can, and should, be shared between institutions.

Biotechnology deals with a very broad range of phenomena, from molecules and cells to complex organisms and even ecosystems. It evolves rapidly, and its cultivation requires a large supply of broadly trained scientists, able to recognise and respond to diverse opportunities created through technological progress. A small country like Finland can address this challenge and achieve comparative advantages by modernising the educational system, by promoting its internationalisation and by focusing efforts on niches where it can assemble a critical mass. It is crucially important to support the creative ideas of its finest researchers regardless of field of interest, and not to rely exclusively on any planning process, however careful.

The specific nature and needs of biotechnology differ from those of information and communication technology. ICT certainly requires great creativity but, in this sector, exceptional talent and expertise combined with generic space plus computer and network infrastructure may lead directly to commercial products. Biotechnology usually requires rather laborious and time-consuming experimentation; it uses expensive materials and equipment, and must be performed in specially equipped laboratories. Innovation in biotechnology is intimately related to basic research. In the industrial applications of biotechnology the role of patents as compared to know-how is much greater than in ICT. Investment is needed on a larger scale and comes with higher risk. The benefits to the health and economy of the nation, as measured in terms of:

- improved products and services, *e.g.* more effective and/or safer drugs, diagnostics, vaccines *etc.*

- creation of high value jobs
- profitability

require a much longer time horizon.

II.C. SETTING GOALS FOR BIOTECHNOLOGY IN FINLAND

The analysis presented in the previous section is directly pertinent to the setting of goals for Finnish biotechnology. It emphasises that the investment required for success is large, must be sustained, and must be complemented with structural measures that are discussed elsewhere in this report. However, the Panel wishes to emphasise upfront that, in Finland, the national effort in biotechnology has made impressive progress.

Surprisingly, we heard repeatedly during the site visits that there are no biotechnology successes in Finland. On the contrary, we saw strong progress in the fundamentals of research and training, and visited several quite successful companies at both an early stage and at the beginning of maturation. There are clearly more successes than are being recognised, perhaps due to insufficient understanding of the nature of biotechnology, and to what might be called the "Bionokia complex".

Nokia would have been considered a huge success even in the USA. The fact that it was created in a small country like Finland looms even larger. In a sense, the Nokia paradigm may distort the setting of realistic objectives. Finnish biotechnology should not attempt to form a Bionokia; it could not do so even if working fantastically well. The nature of biotechnology dictates different goals.

The Panel sees as sensible goals to continue and strengthen the clear progress in the fundamentals of basic research and training; to build on the links between these fundamentals and applied research, by introducing changes in the process of assessing opportunities and major improvements in the technology transfer process; and to foster the development of a reasonable number of well-positioned enterprises with innovative strategies and product pipelines, with growth potential and with opportunities for high quality employment, rather than expect to achieve a single giant company. Merger and acquisition amongst the body of very small companies already in existence will become necessary and will provide a constructive basis for the growth and maturation of a strong biotechnology industry in Finland.

II.D. AN INTRODUCTION TO BIOTECHNOLOGY IN FINLAND

II.D.1. SCIENCE AND TECHNOLOGY POLICY COUNCIL

The impressive commitment of Finland to scientific and technological development is reflected at the political level in the existence of a top-echelon Science and Technology Policy Council, chaired by the Prime Minister. The Council is responsible for the strategic development and coordination of Finnish science

and technology policy as well as the national innovation system as a whole; it advises the government and the ministries related to science and technology. The current composition of the Council (March 1, 2002 - February 28, 2005) is as follows:

Chairman
- Paavo Lipponen (Prime Minister)

Deputy Chairmen
- Maija Rask (Minister of Education)
- Sinikka Mönkäre (Minister of Trade and Industry)

Members
- Sauli Niinistö (Minister of Finance)
- Jari Vilén (Foreign Trade Minister)
- Jan-Erik Enestam (Minister of Defence)
- Kaarina Dromberg (Minister of Culture)
- Suvi-Anne Siimes (Minister at the Ministry of Finance)

Government-appointed fixed-term members
- Pekka Ala-Pietilä (President, Nokia Corporation)
- Eija Hietanen (Development Manager, Central Organization of Finnish Trade Unions SAK)
- Lea Kauppi (Director-General, Finnish Environment Institute)
- Antti Kiikka (Chairman, Premix Oy)
- Erkki Leppävuori (Director-General, VTT Technical Research of Finland)
- Lea Pulkkinen (Academy Professor, University of Jyväskylä)
- Veli-Pekka Saarnivaara (Director-General, TEKES)
- Irma Thesleff (Academy Professor, University of Helsinki)
- Reijo Vihko (President, Academy of Finland)
- Keijo Virtanen (Rector, University of Turku)

Permanent experts
- Markku Linna (Permanent Secretary, Ministry of Education)
- Timo Kekkonen (Director-General, Ministry of Trade and Industry)
- Arvo Jäppinen (Director-General, Ministry of Education)
- Rauno Saari (State Secretary, Council of State)
- Erkki Virtanen (Permanent Secretary, Ministry of Trade and Industry)

Secretariat
- Kimmo Halme (Chief Planning Officer)
- Esko-Olavi Seppälä (Chief Planning Officer)

II.D.2. Facts and Figures Reported by Statistics Finland

An informative brochure published by Statistics Finland, "Biotechnology in Figures," is reproduced here as a convenient summary.

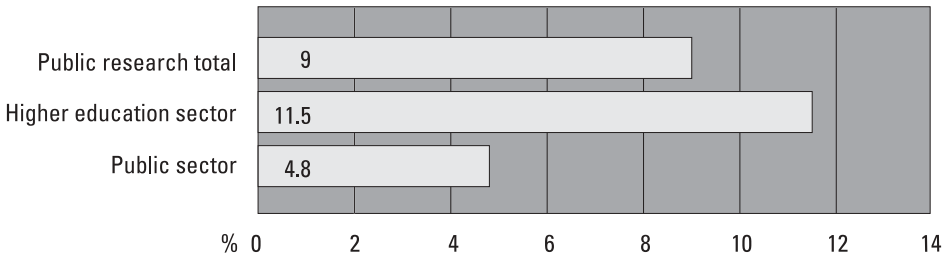
Public Sector and Universities

In the public sector, which consists of general government, public Research Institutes and the private, non-profit sector, the volume of biotechnological research in 2000 totaled 24.1 M€, or 4.8% of the total public sector R&D (497.4 M€). Among the most important research organizations were the institutes focusing on technical, agricultural and health research.

In the higher education sector, the volume of biotechnological research in 2000 was 91.1 M€, or 11.5% of the total higher education sector R&D (789.3 M€). Ten out of the 20 Universities in Finland are active in biotechnology research.

Thus, the overall share of biotechnology in all public research (public sector and higher education) was 9.0% in 2000.

Share of biotechnology in public research in 2000.



In the public sector, the relevant institutions were selected by expert opinion. Statistics Finland inquired about the proportion of biotechnology research in the selected units. The OECD definition of biotechnology was used in the instructions. As for the Universities, their departments and their activities in biotechnological research were evaluated by the Academy of Finland. Polytechnics and central University Hospitals were not included in the inquiry. Thereafter, the volume of biotechnology research was calculated from the R&D survey databases at Statistics Finland.

Business enterprises

Due to limitations of the study, only the total volume of R&D of the firms actively engaged in biotechnological research is available, which means that the proportion of biotechnology R&D in the business enterprise sector cannot be estimated. Thus, the figures constitute a kind of upper limit of biotechnological research in enterprises. Biotechnology firms account for about 7%, or 233 M€, of the total R&D expenditure. In all manufacturing firms with 10 or more employees, firms practising biotechnological R&D employ approximately 13,000 persons, or 3.3% of the total employment in manufacturing.

R&D in firms practising biotechnology by branch in 2000

Branch	Total R&D	R&D in firms practising biotechnology	
	€ million	€ million	%
Food products (SIC 15-16)	62.7	37.0	59.0
Chemicals, incl. Pharmaceuticals (SIC 24-25)	231.0	117.4	50.8
Research and development (SC 73)	135.8	24.8	18.2
Other branches	2 706.5	43.7	1.6
Business enterprises total	3 135.9	222.8	7.1

It seems that even if we could measure the proportion of biotechnological research, the chemical industry would dominate. The crucial contribution comes from the major pharmaceutical companies. The figure for the R&D branch probably closely reflects the true volume of biotechnology research, since the firms are rather small and usually oriented toward one field of research. In all, even though we have not been able to measure the exact proportion of biotechnological R&D, its role is small compared to electronics, the dominant industry in Finnish R&D, accounting for 55% of all R&D in business enterprises.

The firms that are active in biotechnological research were identified by Finnish Bioindustries, which is Finland's biotechnology industry association. The R&D figures were produced by Statistics Finland.

Patents

Applications for biotechnology patents only constitute a minor proportion of all domestic patent applications. During recent years their share has even fallen from 3 to 1.6%. One explanation may be that Finland joined the EPO (European Patent Office) in 1996, which also decreased the overall number of domestic patents.

Biotechnology patent applications filed in 1995, 1999 and 2000.

Year	Domestic total	Biotechnology applications	
	N	N	%
1995	6 762	194	2.9
1999	3 083	69	2.2
2000	3 137	50	1.6

The dominant field among the few biotechnology patent applications has been the IPC category C12N, microorganisms or enzymes, under which two-thirds of the annual applications have been classed.

Even by international comparison, Finland has a rather low rate of biotechnology patenting. According to OECD figures for 1997, biotechnology patents accounted for 1.3% of the total number of Finnish patents filed at the EPO. This is clearly below the OECD average of 3.5%.

The data source for patent applications is the National Board of Patents and Registration of Finland. Biotechnology patent classes (IPC) are selected according to the OECD definitions (STD Scoreboard 2001, P.32): C12M, C12N, C12P, C12Q and C12S.

II.D.3. FUNDING OF BIOTECHNOLOGY BY MINISTRIES

Ministry of Education

Finnish science policy is based on the government's five-year development plans for education and research, and the triennial reviews of the Science and Technology Policy Council of Finland. The Ministry of Education's main responsibility in science policy is to promote the development of basic research and its infrastructure (*e.g.* equipment, data networks, scientific computing and libraries). The Ministry of Education oversees Finland's 20 Universities and the Academy of Finland, the central financing and planning body in basic research (equivalent to a National Research Council).

Development of biotechnology research and training has been a priority area for this ministry since the mid-1980's. The strategy has been shaped by working groups, evaluations and follow-up national development programmes, as follows:

- First MoE Working Group 1987
- Funding Programmes 1988-1997 (1st phase)
- EMBO Evaluation 1996
- MoE Follow-up Group 1997
- Funding Programme 1998-2000 (2nd phase)
- MoE "Biotechnology 2000" Working Group 2000
- Funding Programme 2001-2003 (extension of the 2nd phase)
- Biotech 2002 Evaluation

The funding provided by the Ministry of Education for biotechnology can be summarised under three headings: *University budget funding*, *earmarked funding*, and *competitive funding*. The earmarked funding of the Ministry of Education was 16.6 M€ in 2001 [NB: All funding figures in this report are expressed in Euros]. The competitive funding allocated by the Academy of Finland was 39.2 M€, plus 7.1 M€ for graduate schools (evaluated by the Academy, but allocated by the Ministry of Education). Universities are autonomous, and the proportions of their budgets that are properly assigned to graduate training and research in biotechnology in 2001 was estimated as 26.1 M€ from their responses to the questionnaires, as summarised below.

Table IIa. The University's budget funding for biotechnology research in 2001.

	University	Budget funding (in K€) for biotechnology research in 2001
Universities with Biocentres	University of Helsinki	9 286
	University of Kuopio	2 112
	University of Oulu	5 721
	University of Tampere	2 950
	University of Turku	3 943
	Åbo Akademi University	1 226
Universities without Biocentres	Helsinki University of Technology*	374
	Tampere University of Technology	445
	University of Joensuu	30
	University of Jyväskylä	–

An independent check started with the figure of 91.1 M€ provided by Statistics Finland for biotechnological research in the University sector in 2000; by subtraction of the above total for earmarked and competitive funding (62.9 M€) in 2001, the biotechnology research funded from the University budgets may be estimated indirectly as approximately 28.2 M€ per year, in reasonable agreement with the Universities' responses. The above totals include the following funds for biotechnology in the five Universities without Biocentres: 849 K€ for budget funding and 284 K€ for biotechnology graduate schools (in the University of Jyväskylä, Helsinki University of Technology and Tampere University of Technology).

Ministry of Trade and Industry

The National Technology Agency (TEKES) and the Technical Research Centre of Finland (VTT) are funded by this Ministry. In addition to the R&D funding, which goes through TEKES (funding for biotechnology 39.9 M€ in total in 2001) and budget funding of VTT (3.7 M€ for biotechnology in 2001), the Ministry provides some direct financing to the biotechnology sector. This 3.0 M€ funding in 2001 was allocated to biotraining programmes and support for investments in the field of bio/food companies.

Ministry of Social Affairs and Health

This ministry funds directly its own institutes (KTL and FIOH). In 2001, the total funding to KTL was 21 M€, and the share for biotechnology was 4.7 M€, or 22%. FIOH was funded by the Ministry with 33.8 M€, including 117 K€ directed specifically to biotechnology/molecular biology research (FIOH actually spent 2.0 – 2.5 M€ on research applying molecular biology, by utilizing other parts of its budget plus external funds).

Ministry of Agriculture and Forestry

The Ministry of Agriculture and Forestry does not provide budget funding for biotechnology, but funds peer-reviewed biotechnology research projects in the

Ministry's institutes and the Universities (412 K€ in 2001). This amount is not earmarked yearly, but is based on the quality of biotechnology project proposals.

Ministry of Environment

The Ministry of Environment's biotechnology R&D funding allocated to the Finnish Environment Institute (SYKE) was 30 K€ in 2001; additionally, environmental biotechnology research projects at research institutes (*e.g.* SYKE, VTT) and Universities were funded by 42 K€ in total.

II.D.4. Funding of Biotechnology Research and Training in Universities and Biocentres

From the above, it is clear that funding for biotechnology R&D and training in the public sector comes largely from the Ministry of Education, directly or through the University budgets or through the Academy of Finland; the Ministry of Trade and Industry (directly or via TEKES) is the second most important funder, and the Ministry of Social Affairs and Health is the third. The Ministry of Agriculture and Forestry and the Ministry of Environment devote surprisingly little to biotechnology R&D.

Training and fundamental research are the foundations of biotechnology and their performance is analysed in Chapter III. Most of these activities are carried out in the Universities, the University-affiliated Biocentres and one non-University institute of the Ministry of Social Affairs and Health (KTL, a branch of which is located within a University). Funding for these activities per institution is analysed here, as a backdrop of evaluating the activities in Chapter III. Unfortunately, transparent statistics on the use of University budgets were not available. Therefore, the analysis that follows is based only on the special biotechnology funding by the Ministry of Education and on biotechnology funding by the Academy of Finland and TEKES.

The earmarked funds of the Ministry of Education (16.6 M€ in 2001) are mostly directed to the six Biocentres of Finland (the Ministry's major investment in promoting biotechnology research), according to a historically established formula. The Ministry of Education also funds the recently established Graduate Schools directly, but following evaluation by the Academy of Finland (7.1 M€ in 2001). The Ministry does not have specific allocations for equipment, and institutions are expected to use their funding for this and other needs as appropriate. The funding provided by the Academy of Finland is strictly peer reviewed; the level of funding of the various sectors (such as biotechnology) is not established in advance, but is determined by the aggregate evaluations of applications in the various sectors, according to the peer review system of the Academy. The only special channeling to a particular field is achieved in competitive funding under field-specific Research Programmes. Overall, the Academy's biotechnology funding decisions amounted to 39.2 M€ in 2001 (21% of the Academy's budget of 184 M€). This amount corresponds to seven funding instruments, as follows:

• Research programmes (targeted to stimulate a field)	4 473
• Research projects (non-targeted)	16 904
• Research posts (Academy Professors, 5-yr Group Leaders)	4 419
• Researcher training (Postdocs, Grad School courses)	5 011
• International researcher exchange	933
• Centres of Excellence	6 593
• International membership fees	834
Total	**39 168**

In addition, the funding instruments of TEKES (Section IV.C) provided 22.6 M€ of competitive funding to Universities and Biocentres. The Table (IIb) below shows the distribution per institution of competitive funding from the various instruments of the Academy of Finland (excluding international membership fees) and TEKES. In total, the share that goes to the Biocentres is 49% of the Academy funding and 39% of the TEKES funding. Table IIf in Section II.F. summarises the success of different institutions in competing for Centres of Excellence and Academy Professors.

Table IIb. External biotechnology funding (K€) from the Academy of Finland and TEKES (in 2001) to academic institutions.

	Academy of Finland	TEKES
Biocentrum Helsinki	4 252	1 592
Inst. Biotechnology, Helsinki	3 834	1 357
AI Virtanen Institute, Kuopio	1 399	370
Biocentre Oulu	2 784	349
IMT, Tampere	786	5
BioCity Turku	5 879	5 188
Subtotal Biocentres	**18 934** ***(48.8%)***	**8 791** ***(38.9%)***
U. Helsinki	11 483	4 217
U. Kuopio	1 683	1 408
U. Oulu	2 947	1 411
U. Tampere	905	362
U. Turku	1 176	4 094
Åbo Akademi	749	344
HUT	73	967
TUT	418	476
U. Joensuu	341	294
U. Jyväskylä	105	247
Subtotal Universities	**19 88** ***(51.2%)***	**13 820** ***(61.1%)***
TOTAL	**38 814**	**22 611**

* Funds received, as reported by the Universities and Biocentres themselves.

II.E. BIOTECHNOLOGY AND RELATED INDUSTRIES IN FINLAND

The Finnish biotechnology industry has grown considerably over the recent years, mostly due to the commitment to R&D at the national level and to an increase in venture capital investments, both public and private. The programmes run by the Academy of Finland and TEKES have strengthened Finland's biotechnological research base, allowing businesses to develop and receive additional support from TEKES and investments (largely from SITRA). Finland's strategy has been to focus on areas in which it has a strong research base – pharmaceuticals, diagnostics, biomaterials, functional foods and enzymes.

According to the ETLA Survey on Finnish Biotechnology firms, completed in Autumn 2002 and presented to the Panel for this evaluation, 134 firms active in biotechnology (including service businesses) had been established by the end of 2001 in Finland. Of these, 119 are currently active. According to the Finnish Bioindustries this represents approximately 10% of Europe's biotechnology companies, and makes Finland sixth in terms of number of biotechnology companies in Europe, after the UK, Germany, France, the Netherlands and Sweden.

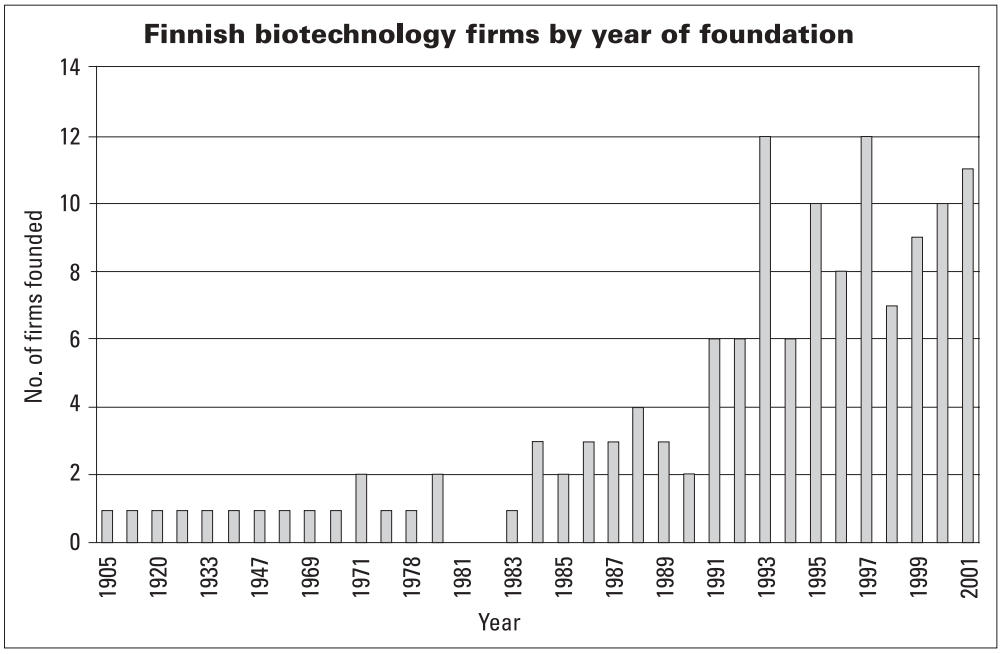


Figure IIa. Finnish biotechnology firms by year of foundation (Source: ETLA 2002).

About 65% of these 119 companies are clustered in the Helsinki (39%) and Turku (25%) regions or their immediate surroundings. Other regional clusters are located in Kuopio (13%), Oulu (8%) and Tampere (7%), in order of decreasing numbers; these cities are endowed with biotechnology-related research centres. The clusters focus on research areas as follows: Helsinki, genetics and molecular biology; Kuopio, molecular biology and animal biotechnology; Oulu, molecular and cellular biology; Tampere, health technology; Turku, pharmaceuticals, diagnostics and biomaterials.

Table IIc. Biotechnology companies by regional clusters

SME* biotechnology company (total 106)	Personnel (total 1,735)	Sales of biotechnology products and services (total 141 M€)
Helsinki region	39%	60%
Turku region	33%	10%
Other regions	28%	30%
Dedicated biotechnology company (incl. SMEs) (total 119)	**Personnel (total 8,179)**	**Sales of biotechnology products and services (total 768 M€)**
Helsinki region	65%	67%
Turku region	14%	17%
Other regions	21%	16%

** SME = Small and medium-sized enterprise, fewer than 250 employees, turnover is less than 40 M€ or total balance is up to 27 M€ (Source: ETLA 2002).*

Finnish biotechnology companies currently provide approximately 4,200 jobs. Most companies are relatively new, and have not yet put their products on the market. Consequently the turnover of the industry (700 M€) has not yet reached a significant volume. If big pharmaceutical industries are included in the calculations, however, turnover reaches 1,860 M€ and employment figures rise to 10,800. Additional information about the companies is summarised below.

Table IId. Bioindustry in Finland in 2000.

Sector	Companies	Turnover (M€)	Personnel
Pharma (small/med)	17	19	335
Pharma (big)	3	1 197	6 615
Diagnostics	30	254	2 020
Biomaterials	9	14	136
Food and feed	12	250	1 000
Industrial enzymes	3	73	287
Agro	6	11	50
Service companies	28	27	270
Other	15	15	100
Total (incl. big pharma)	123	1 860	10 813
Total (excl. big pharma)	**120**	**663**	**4 178**

Source: "The biotechnology industry and its development; Venture capital financing"

The Academy of Finland and TEKES appear to play an increasingly important role in funding research ideas to the foundation of firms.

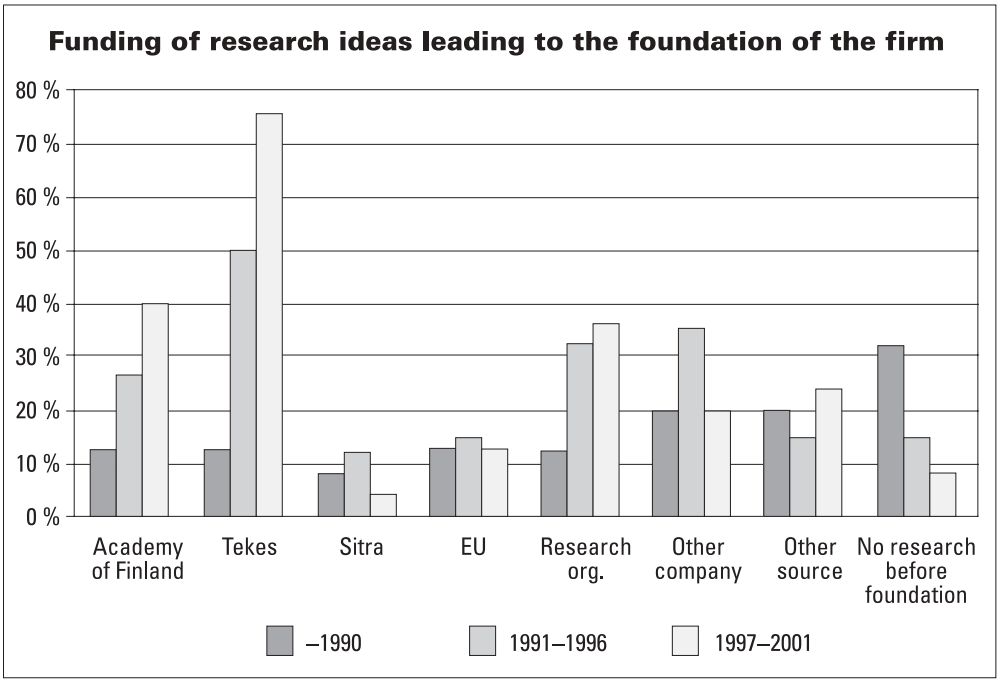


Figure IIb. Funding of research ideas leading to the foundation of the firm (Source: ETLA 2002).

In 2001, Finnish venture capital investors made 449 investments worth a total of 340 M€ (84% private investment, 16% government-related investment). There are currently 51 Venture Capital companies in Finland (46 private, 5 public). Of these, 22 (18 private, 4 public) invest in the life sciences. However, in terms of volume of investment, the public investors account for 40% of the total, and SITRA alone for more than 35%. As seen in the Table below (IIe), the level of investment of Venture Capital in the life sciences is now approaching the figure for ICT (of course, this comparison does not include internal investments, which are vastly larger in ICT).

Table IIe. Venture capital investments in Finland in 2001 by industry sector.

	2001	2001	Total portfolio	Total portfolio
	M€ %	number %	M€ %	number %
Life Sciences	24	21	22	20
ICT Industry	27	31	23	25
Other fields	289	397	1 199	976
Total M€	340	449	1244	1021

Source: "The biotechnology industry and its development; Venture capital financing"

II.F. SOME PERFORMANCE INDICATORS OF INSTITUTIONS

As described earlier, the Panel's evaluation process included both desk research and site visits. The visits included listening to presentations; discussion sessions with leaders of the institutions and key researchers; closed sessions with graduate students/postdoctoral fellows/young group leaders designated by the institutions; and in-depth discussion of the Panel, face to face *in camera* as well as by exchange of written comments. The text of this report was approved unanimously by the Panel members.

After the views of the Panel had been written down, a cross-check was undertaken by analyzing in a uniform manner three types of data that had been provided to the Panel: (a) the publications that the institutions themselves chose to profile their activities (normally 30 published papers selected by each entity); (b) the numbers of their competitive distinctions (their Centres of Excellence and Academy Professors), together with an R&D index, calculated as the reported percent of expenditure by Universities (including Biocentres) on R&D from both their own budget and external funds; and (c) participation in EU programmes. This analysis is presented below, and is in good agreement with the conclusions of the Panel.

II.F.1. PUBLICATIONS PROFILING THE INSTITUTIONS

The publications provided by the institutions themselves were tabulated by the journal in which they appeared, in order of descending impact factor. It is known that average impact factors differ in different fields, with those in molecular and cell biology higher than in fields of more traditional biotechnology. Nevertheless, impact factor analysis remains a useful tool for analysis of quality, and is especially valuable for comparing similar institutions. It should be noted that the Biocentres show a high impact factor profile, with the majority of their selected publications appearing in journals of impact factor greater than 6.0 (ranging from 60% of the total publications for AIVI, to 100% for Biocentre Oulu). The corresponding Universities showed an interesting profile: many of the publications in the highest impact factor journals that they selected were authored by Biocentre-affiliated faculty and appeared under the Biocentre publications as well; many of the rest of the University publications were from journals of intermediate impact factor. The rather high quality of biotechnology in the Universities of Joensuu and Jyväskylä that the Panel noted in the interviews was also reflected in the publications (37% in journals of impact factor greater than 6). By the same criterion, KTL (50%) belonged to the top league. The applied non-Biocentre faculties of the University of Helsinki, the technical Universities and most of the applied institutes showed lower impact factors, partly reflecting the field-specificity of the impact factor criterion.

Table IIe. Selected publications profiling the research institutions in biotechnology research

Impact factor	Journal	B. Helsinki	IBH	AIVI	B. Oulu	IMT	B. Turku	UH (Science)	UH (Agri & Forest)	UH (Vet Med)	UH (FGC)	U Kuopio	U Oulu	UTampere	U Turku	ÅA	HUT	U Joensuu	TUT	U Jyväskylä	MTT	SYKE	METLA	FIOH	KTL	EELA	VTT
29.600	Nat Genetics	2				5	1				2			4	1										2		
29.219	Cell				1	1							1	1													
29.065	New Engl J Med													1											1		
27.955	Nature	2	1		1			1					1														
27.906	Nat Medicine			2		2						2		1										1			
23.329	Science		1		2								3												2		
20.880	Genes Dev	1	1		1								1					1									
18.866	Immunity						1								1												
17.569	JAMA				1								1														
16.611	Mol Cell	1	1		2			1					1														
15.340	J Exp Med					1	1								1										1		
14.329	Trends Biochem Sci			1	2							1						1									
14.240	J Natl Cancer Inst					1																		1	1		
14.153	Neuron		1																								
14.118	J Clin Invest						1							1	1												
13.251	Lancet													2											1		
13.020	Gastroenterology					2								1													
12.915	J Cell Biol	2	3					1					1							1							
12.459	EMBO J	3	3		6	1	2	1					4		2	1		2									
12.157	Immunol Today					2								1													
11.394	Trends Pharmacol Sci			1								1	1														
11.310	Nat Biotechnol	1					1	1					1		1												
11.081	Plant Cell	2	3				1								1												
10.896	PNAS	4	3	4	7		1	1				5	2		1						1				1		1
10.542	Am J Hum Genet	1			3		1				3		4		1									1			
10.517	Circulation			2	2							2	1	1													
9.836	Mol Cell Biol	1	1		1	2	1							1	1												
9.318	Hum Mol Genet	1				1					2							1							2		
9.237	Blood					1	1								1												
9.000	FEMS Microbiol Rev																				1						
8.817	FASEB J			1			3					1			3	2											
8.624	Development	2	1		1																						
8.559	Genome Res																				1						
8.481	Ann Neurol												1	1													
8.302	Cancer Res	1		1		5	1					1		5	1									2			
8.178	J Neurosci		2	2												1											
8.096	Hepatology															1											
7.700	Diabetes						1						1	1	1												
7.700	Mol Biol Cell	3	1																								
7.460	Curr Biol		1			1								1													
7.389	Arthritis Rheum						1								1												
7.258	J Biol Chem	1	5	2		2	3	1	1			3	2	2	3	5	1	3		9					1		2
7.103	Am J Pathol					1								2													
7.065	J Immunol			1																				1	1		
6.881	AIDS																								1		
6.725	Mol Endocrin													1													
6.578	Cereb Cortex			1																							
6.398	Mol Microbiol						2	1	2	2					2										1		
6.373	Nucleic Acids Res						2								2			3									
6.230	J Bone Mine Res						1					1			1												
6.213	J Cell Sci															1				1							
6.170	Gut										1																
6.134	Hum Mutat										1																
6.046	EMBO Rep													1													
TOTAL		28	28	18	30	28	26	8	3	2	9	17	26	28	26	11	1	11	0	11	3	0	0	6	15	0	3

Impact factor	Journal	B. Helsinki	IBH	AIVI	B. Oulu	IMT	B. Turku	UH (Science)	UH (Agri & Forest)	UH (Vet Med)	UH (FGC)	U Kuopio	U Oulu	UTampere	U Turku	ÅA	HUT	U Joensuu	TUT	U Jyväskylä	MTT	SYKE	METLA	FIOH	KTL	EELA	VTT
5.956	Am J Resp Crit Care										1													1	1		
5.893	Gene Ther						1								1					1								
5.826	J Mol Biol															1												
5.792	Plant J	2	1					1	1																			
5.751	Hum Gene Ther			3								2																
5.622	J Virol					1								1		2				4								
5.506	J Allergy Clin Immun																							4				
5.477	J Cereb Blood F Met			2																								
5.477	J Gen Physiol						1								1													
5.446	Mol Cell Neurosci			2								2																
5.357	Mol Biol Evol								1				1															
5.297	Mol Pharmacol			2			1								1	2									1			
5.212	Neurology											1												1				
5.167	Adv Genet					1								1														
5.160	J Clin Endocrin Metab																								1			
5.105	Plant Physiol																	1			1							
5.098	J Med Genet										5																	
5.006	Trends Biotech																			1								
4.990	Eur J Immunol						1								1	1										1		
4.834	J Neurochem			1								1				1												
4.645	J Invest Dermatol			1							1																	
4.636	Biophys J															1												
4.614	Chem Eur J																	1										
4.562	Antimicrob Agents Chemotherapy																								1			
4.487	Neurobiol Disease															1												
4.371	Pharmacogenet																							6				
4.326	Biochem J																1											
4.233	Int J Cancer																							3				
4.212	Infect Immun																				1					1		
4.163	Am J Resp Cell Mol												2											1					
4.114	Biochemistry																	1							1			
3.984	J Bacteriol																				2				1			
3.966	Cancer Epidem Biomar Rev																						1	1				
3.965	J Clin Microbiol											1													2	1		
3.894	Proteins															2		1										
3.855	Mol Plant-Microbe Interact							2	1																			
3.826	Clin Exp Allergy																							1				
3.688	Appl Environ Microb								6	6			1				3				2	1				2	2	
3.671	J Struct Biol																	1										
3.644	FEBS Lett							1	1											3				1				
3.592	Plant Mol Biol																										1	
3.558	Int J Syst Bacteriol									1																		
3.508	Biol Reprod																				1							
3.485	Dev Dynam															1												
3.472	Protein Sci																	1										
3.464	Eur J Nucl Med																		1									
3.460	Eur J Cancer																							1				
3.418	Genomics										3																	
3.349	Planta							1																				
3.342	J Neuroimmunol															1												
3.270	Virology															1				1					1			
3.265	Mol Carcinog																							1				
3.248	J Gen Virol																									1		
3.219	Neuroscience							1																				
3.173	Eur J Hum Genet										2																	

Impact factor	Journal	B. Helsinki	IBH	AIVI	B. Oulu	IMT	B. Turku	UH (Science)	UH (Agri & Forest)	UH (Vet Med)	UH (FGC)	U Kuopio	U Oulu	UTampere	U Turku	ÅA	HUT	U Joensuu	TUT	U Jyväskylä	MTT	SYKE	METLA	FIOH	KTL	EELA	VTT
3.044	Bioconjugate Chem											1															
3.041	Gene																										1
2.989	Eur Resp J																								1		
2.946	Biochem Bioph Res Comm								1										1					1			
2.943	Vaccine																				1				1	1	
2.894	Fungal Genet Biol																						1				
2.891	Micro Ecol Ther																									1	
2.849	Eur J Biochem							1				1								1							1
2.847	FEMS Microbiol Ecol																					3					
2.793	J Chromatography A															1											
2.766	J Comput Chem																										1
2.756	Cancer Gene Ther			1																							
2.718	J Histochem Cytochem										1																
2.718	Protein Engineering							1										1									
2.714	Arch Dermatol										1																
2.707	Environ Sci Technol																		2			2					
2.656	Immunology																									1	
2.619	J Sleep Research																		1								
2.600	Microb Drug Res																									1	
2.591	J Rheumatol										1																
2.545	Mutat Res																							2			
2.540	Yeast																										3
2.530	New Phytologist							1																			
2.523	AIDS Res Hum Retrov																								1		
2.489	Biomaterials																		1								
2.478	Mol Ecology																						1				
2.477	Histochem Cell Biol										1																
2.472	Mol Gen Genet																				1	1					1
2.463	Am J Bot																						1				
2.438	Theor Appl Genet																				1		1				
2.433	J Exp Botany																						1				
2.430	Mol Breeding								1									1			1						
2.332	J Magn Reson		1																								
2.318	Mammalian Genome																				2						
2.309	Tree Physiol																						2				
2.297	Heredity																					1					
2.276	Environ Mol Mutagen																							1			
2.244	Eur J Cell Biol																			1							
2.156	Arch Microbiol																		1								
2.124	Acta Cryst D							1												2							
2.054	Syst Appl Microbiol								1													1					
2.037	Biotechnol Bioeng																2										
2.019	Anal Biochem																			1							
2.003	Analyst																							1			
1.975	Structure															1											
1.973	Occup Environ Med																							2			
1.965	Theriogeneology																				1						
1.924	J Cereal Sci								1								1										
1.885	Curr Genet																										1
1.822	Genet Epidemiol										2																
1.810	J Microb Methods																1					1					

Impact factor	Journal	B. Helsinki	IBH	AIVI	B. Oulu	IMT	B. Turku	UH (Science)	UH (Agri & Forest)	UH (Vet Med)	UH (FGC)	U Kuopio	U Oulu	UTampere	U Turku	ÅA	HUT	U Joensuu	TUT	U Jyväskylä	MTT	SYKE	METLA	FIOH	KTL	EELA	VTT
1.808	J Food Protection								1	7																	1
1.782	Biochim et Biophys Acta											1						1									
1.768	J Virol Methods															1											
1.762	J Med Microbiol									1																	
1.760	Physiol Plantarum							1	1									2					2				
1.755	Soil Biol Biochem																					2	1				
1.754	Appl Microbiol Biot								1								2		1								4
1.711	Arch Virol																				1					1	
1.691	J Dairy Sci								2			1									2						
1.653	Dis Aquat Organ																									1	
1.651	J Biotechnol															1	2	1		2							2
1.647	Vet Microbiol																									2	
1.604	Mycologia																						2				
1.593	Ann NY Acad Sci																1										
1.590	Scand J Work Environ Health																							1			
1.579	Int J Food Microbiol								1	8																1	
1.576	J Agri Food Chem											1					3										
1.561	FEMS Immunol Med Mic									2																	
1.560	Environ Pollut											1							1			2					
1.529	Cancer Genet Cytogen																							1			
1.506	Enzyme Microb Tech																3										
1.500	Epidemiol Rev																								1		
1.497	Prot Express Purif																			2							
1.488	Hum Hered										1																
1.488	J Exp Zoo																				1						
1.479	J Appl Microbiol									1												2				4	
1.467	Mycorrhiza																						1				
1.462	Epidemiol Infect									1																2	
1.436	Plast Reconstr Surg																		1								
1.434	Proc Instr Mech Engrs H																		1								
1.429	J Chem Ecol																	1									
1.408	J Mol Catal B																										1
1.396	Sci Total Environment							1																			
1.384	Plant Sci																						1				
1.379	Carbohyd Res															1											1
1.379	Trends Food Sci Tech																										1
1.376	Water Research																		2			1					
1.375	Plant Cell Rep																	1			1		1				
1.374	J Dairy Res																									1	
1.346	Mycol Res																				2		5				
1.299	J Am Oil Chemists Soc																1										
1.281	Cryobiology																						1				
1.271	Cytogenet Cell Genet								1		1																
1.265	J Vet Diagn Invest																									1	
1.255	Nat Toxins																									1	
1.250	Z Lebensm Unters Forsch A																1									1	
1.181	Ecoscience																	1									
1.175	Cereal Chem																4										1
1.172	Med Biol Eng Comp																		1								
1.154	Poultry Sci																				2						

Impact factor	Journal	B. Helsinki	IBH	AVI	B. Oulu	IMT	B. Turku	UH (Science)	UH (Agri & Forest)	UH (Vet Med)	UH (FGC)	U Kuopio	U Oulu	UTampere	U Turku	ÅA	HUT	U Joensuu	TUT	U Jyväskylä	MTT	SYKE	METLA	FIOH	KTL	EELA	VTT
1.151	Lett Appl Microbiol									1																1	
1.145	Vet Rec																									1	
1.139	Brit Poultry Sci																									1	
1.119	J Hered																				1						
1.108	Can J Forest Res																						2				
1.108	Scand J Infect Dis																								1		
1.087	Bio Fert Soils																						1				
1.081	Oral Microbiol Immun																				1						
1.079	Emerg Infect Dis																								1		
1.071	Can J Microbiol																1					2					
1.062	Environ Toxicol																					2					
1.040	Am J Vet Res																									1	
1.020	Animal Genet								2													1					
0.969	Res Vet Sci							1																		1	
0.957	Food Res Int																									1	
0.922	J Am Soc Hort Sci																				1						
0.921	J Food Sci																									1	
0.869	Process Biochem																										1
0.863	Pharmacol Res																									1	
0.848	Cellulose																										1
0.831	Biodegradation																		1								
0.828	Appl Biochem Biotech																1										
0.815	J Am Soc Brew Chem																										1
0.791	Eur J Food Res Technology																1									1	
0.728	Anim Feed Sci Tech								1																		
0.728	J Mater Sci																		2								
0.722	Scan J Urol Nephrol																		1								
0.703	Acta Vet Scand																									2	
0.645	Milchwissens								1																		
0.614	IEEE Eng Med Biol																		1								
0.605	Water Sci Technol																					1					
0.603	Arch Lebensmittelhyg									1																	
0.594	DNA Sequence								1																		
0.582	Int Biodeter Biodegrad																		1								
0.550	Microbiology								1																		
0.490	Vet Res Comm									1																	
0.473	Vet Hum Toxicol																									1	
0.431	J Vet Med																									1	
0.369	Tappi J																										1
0.248	Appl Biochem Micro																1										
0.176	Forest Pathol																						2				
-	Annu Rev Genomics Hum Genet										1																
-	Bioremediation J																					1					
-	Boreal Environ Research																		1								
-	Exp Botany																				1						
-	Finnish Environ																					1					
-	Forest Genet																						2				
-	Int J Biomed Comput																		1								
-	J Appl Signal Process																										

Impact factor	Journal	B. Helsinki	IBH	AIVI	B. Oulu	IMT	B. Turku	UH (Science)	UH (Agri & Forest)	UH (Vet Med)	UH (FGC)	U Kuopio	U Oulu	UTampere	U Turku	ÅA	HUT	U Joensuu	TUT	U Jyväskylä	MTT	SYKE	METLA	FIOH	KTL	EELA	VTT
-	J Orthopaedic Sci																		1								
-	J Soils Sediments																						1				
-	Metab Eng																										1
-	Suomen Eläinlääkärilehti																									1	
-	Book chapters and other publications																		4			1	2				
TOTAL		30	30	30	30	30	30	21	30	32	30	30	30	30	30	30	30	26	27	30	30	26	32	36	30	39	30

B Helsinki, Biocentre Helsinki; IBH, Institute of Biotechnology Helsinki; AIVI, AI Virtanen Institute; B Oulu, Biocentre Oulu; IMT, Institute of Medical Technology; B Turku, Biocity Turku; UH, University of Helsinki; UH (Agri & Forst), University of Helsinki, Faculty of Agriculture and Forestry; UH (Vet Med), University of Helsinki, Faculty of Veterinary Medicine; UH (FGC), University of Helsinki, Finnish Genome Centre; U Kuopio, University of Kuopio; U Oulu, University of Oulu; U Tampere, University of Tampere, U Turku, University of Turku, ÅA, Åbo Akademi; HUT, Helsinki University of Technology; U Joensuu; University of Joensuu; TUT, Tampere University of Technology; U Jyväskylä, University of Jyväskylä; MTT, Agrifood Research Finland; SYKE, Finnish Environment Institute; METLA, Finnish Forest Research Institute; FIOH, Finnish Institute of Occupational Health; KTL, National Public Health Institute; EELA, National Veterinary and Food Research Institute; VTT, Technical Research Centre of Finland - Biotechnology

Helsinki area
Kuopio area
Oulu area
Tampere area
Turku area
National Research Institutes with laboratories in different regions

II.F.2. Success in Competitive Academy of Finland Funding Instruments

The Panel considered in depth the peer review system of the Academy of Finland and judges it to be very strong; the only improvement we would suggest is to eliminate the legal provision that specific reviewers may be identified to the applicant, as this is not a widespread practice internationally, and may compromise objectivity in small communities like Finland's. Therefore two of the most prestigious awards can be considered a measure of an institution's distinction. These distinctions are Academy Professorships (currently 38 in all fields and in the entire country), and the Centres of Excellence (42 in total). The distinctions in biotechnology are distributed as shown in Table IIf below. This distribution reinforces the Panel's conclusions that the Helsinki area predominates in biotechnology, followed by Oulu and Turku, and then Tampere and Kuopio. Although the significance of these comparisons is limited by small numbers, it is interesting that this qualitative ranking correlates well with the R&D index of the Universities (including Biocentres).

The distribution of graduate schools is also of interest. However, only Universities are eligible. The Ministry of Education had 20 Graduate Schools with 280 student positions specialised in biotechnology (in 2001, 93 schools with 1,276 positions in total). The distribution in all fields is as follows (numbers in parentheses indicate graduate schools closely affiliated with Biocentres): University of Helsinki 19 in all fields (3*), University of Kuopio 6 (1), University of Oulu 4 (1), University of Tampere 7 (1), University of Turku 12 (7). The numbers of PhD students trained in each city with Ministry of Education fellowships were 245 in all fields (55), 56 (15), 83 (28), 79 (12) and 173 (52.5), respectively.

* In addition to these three schools, there are other graduate schools and fellowships in biosciences at the University of Helsinki. The Biocentrum Helsinki organisation's graduate schools (3) in the Viikki and Meilahti campuses have in total 90 places, about 30% of these go to graduate students outside the Biocentrum Helsinki. The 55 positions also include funding from the University of Helsinki's other graduate schools in biosciences outside the Biocentrum Helsinki.

Table IIf. Success (in biotechnology) in competitive Academy of Finland funding instruments.

City	Academy Professors	Centres of Excellence	R&D Index (%)
HELSINKI			
• Biocentrum (BM)[a]	2	2.5*§+	
• Inst. Biotechn.[b]	4	4.5§	
• Univ. Helsinki	4	1+	28.6
• HUT	-	1	13.2
KUOPIO			
• Biocentre (AIVI)	-	1	
• Univ. Kuopio	-	-	4.5
• Univ. Joensuu^	-	-	3.5
OULU			
• Biocentre	-	1	
• Univ. Oulu	-	1	10.6
TAMPERE			
• Biocentre (IMT)	-	1+	
• Univ. Tampere	-	-	5.8
• TUT	-	1+	6.8
• Univ. Jyväskylä^	-	-	5.9
TURKU			
• Biocity	2	2	
• Univ. Turku	-	-	8.7
• ÅA	-	-	4.0
OTHERS			
• KTL	-	1	
• VTT	-	1	
• MTT	-	-	
• SYKE	-	-	
• METLA	-	-	
• FIOH	-	-	
• EELA	-	-	
TOTAL	12	18	

In universities with a biocentre, the figures are shown separately for a biocentre and the university outside the biocentre.
[a] Biocentrum Helsinki (Biomedicum, Meilahti campus)
[b] Institute of Biotechnology (Viikki campus)

* Two CoEs directed and counted in Tampere also have members working at Helsinki Biocentrum (BM)

§ One CoE is shared equally between the Biocentrum (BM) and Institute of Biotechnology in Helsinki

+ One CoE directed in the Psychology Department, Univ. Helsinki, is not counted but has members working in the Biocentrum Helsinki (Meilahti campus, Biomedicum)

^ For practical reasons, the University of Joensuu is included in the Kuopio grouping, and the University of Jyväskylä in the Tampere grouping, though the Panel is aware they are in other nearby regions.

II.F.3. PARTICIPATION IN EU BIOTECHNOLOGY PROJECTS

One indication of the international competitiveness of the R&D efforts in Finland is the success in applications to the EU biotechnology programmes. Irrespective of caveats, this indicator is pertinent to the evaluation of prospects in the EU's Sixth Framework Programme (see Chapter VII). Participation as coordinator is often an indication of peer respect. Finland participated intensely in these programmes in 1996-2001 (446 participations, 106 as coordinator). The highest participation was seen in the Helsinki region (136 participations), with the Turku regions a strong second (41) and the regions of Tampere, Oulu and Kuopio lower. Among individual institutions, the University of Helsinki predominated (136 participations, with the University and Biocentres combined; 30% of the total); the University of Turku/Åbo Akademi complex was second (96 participations, 22%), VTT Biotechnology was third (67 participations, 15%), University of Tampere/IMT was fourth (35 participations, 8%) and KTL was fifth (32 participations, 7%).

Table IIg. Success in EU Biotechnology projects (1996-2001)

	Institution	as coordinator	as partner	total
Biocentres	B Helsinki	6	16	22
	IBH	1	10	11
	AI Virtanen Institute	3	4	7
	B Oulu	5	7	12
	IMT	8	8	16
	B Turku	4	43	47
Universities with Biocentres	U Helsinki	18	85	103
	U Kuopio	6	11	17
	U Oulu	9	10	19
	U Tampere	11	8	19
	U Turku	4	42	46
	ÅA	1	2	3
Universities without Biocentres	HUT	0	0	0
	U Joensuu	0	1	1
	TUT	0	4	4
	U Jyväskylä	1	1	2
Research Institutes	MTT	1	3	4
	SYKE	0	1	1
	METLA	1	0	1
	FIOH	3	5	8
	KTL	14	18	32
	EELA	0	4	4
	VTT Biotechnology	10	57	67
TOTAL		106	340	446

B Helsinki, Biocentre Helsinki; IBH, Institute of Biotechnology Helsinki; U Kuopio, University of Kuopio; U Oulu, University of Oulu; U Tampere, University of Tampere, U Turku, University of Turku, ÅA, Åbo Akademi; HUT, Helsinki University of Technology; U Joensuu; University of Joensuu; TUT, Tampere University of Technology; U Jyväskylä, University of Jyväskylä; MTT, Agrifood Research Finland; SYKE, Finnish Environment Institute; METLA, Finnish Forest Research Institute; FIOH, Finnish Institute of Occupational Health; KTL, National Public Health Institute; EELA, National Veterinary and Food Research Institute; VTT, Technical Research Centre of Finland - Biotechnology

Helsinki area
Kuopio area
Oulu area
Tampere area
Turku area
National Research Institutes with laboratories in different regions

III. THE FOUNDATIONS: FUNDAMENTAL RESEARCH AND TRAINING

III.A. BIOCENTRES & RELATED INSTITUTIONS

In this section we focus primarily on Biocentres, as they are recipients of the special Biotechnology programme funds; they are considered alphabetically by city. The KTL institute is also considered, as it is comparable in size and orientation. Biocentres are autonomous units either within or affiliated with certain Universities. Universities are also commented upon in this Chapter (Sections A. and C.) and in Chapter VII. They are crucially important for the biotechnology system, as they are responsible for undergraduate and graduate education, and provide the majority of the principal investigators in the Biocentres. Of course they are multidisciplinary and large institutions that cover many disciplines other than the biosciences; only a small part of their activities are within the remit of this Panel. More in-depth comparisons were not feasible, given the complexity of the Universities and time limitations. However, comparable questionnaires were available from both Universities and Biocentres, permitting direct comparison of bibliometric profiles (Section II.F.). Specific comments on 4 Universities that are not affiliated with Biocentres are included in Section III.B.

The Panel wishes to express its deep appreciation of the thoughtfulness that the Ministry of Education and the Academy of Finland exhibit in creating special funding instruments, strongly oriented towards excellence. They deserve recognition for the vital role that they play (and must continue to play) in building up these foundations of biotechnology in Finland. The nature of the funding instruments and their volume were summarised in Chapter II, and do not need to be reviewed here.

The Biocentre programme originated in the mid-1980s when it was recognised that the life sciences in Finland needed a major jolt. The Panel saw clear evidence that the programme has had very positive effects. Overall, Biocentres have played important roles in the modernisation of University structures and graduate training. To have a refuge where excellent science can be done without the intervention of University politics is important. With a properly positive relationship between University and Biocentre, devoid of polemics or arrogance, the scientific success of the latter can stimulate parallel success in the former, and vice-versa. This has been the case in most instances, although we have also encountered unfortunate cases of tension originating from one side or the other. Interestingly, the ways in which the different Biocentres have been configured is quite varied. This experimentation is welcome, as a sign of flexibility, although comments are made on advantages and disadvantages.

III.A.1. HELSINKI BIOCENTRES

Helsinki, the capital and by far the largest city in Finland, hosts two Biocentres. One is called *Biocentrum Helsinki* and the other *Institute of Biotechnology*. Further confusion for the uninitiated comes from the fact that they overlap. Biocentrum Helsinki is an

umbrella organisation, whose 20 research groups (23 principal investigators) include 10 groups (12 principal investigators) housed in the Institute of Biotechnology; the rest of the Biocentrum is located on a separate campus, in the Biomedicum building. Despite the redundancy, the two Biocentres will be discussed separately, as they are somewhat different, as well as physically separate.

The Institute of Biotechnology, founded in 1989, is the second oldest Biocentre (after Oulu), while the Biocentrum Helsinki was founded in 1994. The combined excellence of the Helsinki Biocentres is reflected in the fact that they house 8 Centres of Excellence specialised in biotechnology (of a total of 17 in biotechnology in Finland), as well as 6 biotechnology Graduate Schools (of a total of 20 in biotechnology in Finland). They also have 7 Academy Professors (see Table IIf, Chapter II.F). These Biocentres are loosely coordinated by their Directors, meeting annually with the University Rector to discuss future plans, priorities and University-wide issues related to biotechnology, and to allocate the earmarked funds. Both Directors, as well as the University Rector, are impressive leaders in charge of impressive institutions. The Rector is extremely supportive of the Biocentres. It appears that this interlocking structure has succeeded in better integrating the Biocentres with the University faculties and avoiding tensions of the type encountered in some other cities.

The two Biocentres of Helsinki operate at two campuses: the medical campus at Meilahti and the science campus at Viikki. For the umbrella Biocentrum as a whole, the files of 50 applicant research groups were evaluated in 2000 by an *ad hoc* high quality panel assembled by EMBO, resulting in selection of the present members, with concomitant turnover of 25% of the previous groups. The *Biocentrum at Meilahti* is housed in the new and impressive science building of the medical school, the *Biomedicum*, which also includes teaching facilities and space assigned to the institutes of public health, genetics, cardiology, and to clinical labs. On this campus the Biocentrum has made a real impact on integrating clinicians into research, and excels in medically-related fields (*e.g.* cancer, androgen receptors) as well as in developmental biology. It operates three active Graduate Schools and a set of core facilities (microarrays, *etc.*). An external advisory board exists on paper but has not yet met. The publication record of the individual laboratories in the Biomedicum is excellent. A clear interest in translational research is evident, and several start-up companies are also housed within the Biomedicum building. This trend is encouraged by the head of the Biocentrum.

The *Institute of Biotechnology at Viikki* is also housed in an impressive building and is a biotechnology powerhouse. It has over 350 scientific and technical personnel, 29 principal investigators (some of whom are appointed separately from the Biocentrum system), 81 senior or postdoctoral researchers and 130 graduate students. Approximately 20% of the personnel are foreign citizens, a feature which is rare in Finland and has been maintained through the years. An external scientific advisory board provides advice on appointments which are for 5-7 years but renewable. The Institute is organised into 6 research programmes, representing fundamental fields and interesting new interfaces in biology. The programmes include plant molecular biology, forest biotechnology, molecular neurobiology,

cellular biotechnology, developmental biology and structural biology and biophysics. The last programme uses both NMR (with a machine shared with VTT) and cryo-EM. In general, the Institute helps to open new research approaches and scientific areas in Finland. The molecular neurobiology group is helping launch a new neurosciences institute. Bioinformatics/biocomputing is being set up, with a graduate school that operates in collaboration with Tampere, Turku and a Helsinki University Centre of Excellence. The forest biotechnology group collaborates with the University of Joensuu in assembling ESTs of various tree species. A programme on stem cell research is also planned, and a young group leader is proposed for a systems biology unit. The institute has established a number of widely accessible core facilities. There is a proteomics unit and a functioning transgenic unit with 120 mouse lines, although integration with the medical school is not as advanced as at the Biomedicum. Some of its members have been active in curriculum revision at the University, and the Institute has served as one of the catalysts for the formation of the new Faculty of Biosciences, a long overdue modernisation of the classical faculty structure of the University. Spin-offs of the institute have yielded 34 patent families, 17 collaborations with companies, and 5 start-up companies producing molecular biology tools on the global market.

III.A.2. Kuopio Biocentre

The Biocentre of the University of Kuopio is *the A.I. Virtanen Institute (AIVI) for Molecular Sciences*. The Rector of the University is proud of AIVI and notes that the Institute is responsible for 20% of the publications but receives only 10% of the funds of the University. The Institute includes 8 professors and 200 employees. Its groups have proven expertise in establishing transgenic animals, vector construction for gene therapy, neural stem cells and bio-NMR. AIVI is engaged in increasing the understanding of biotechnology and has a high reputation in Kuopio. The Institute argues to double its budgeted positions (32 at present) and for direct allocation of funds to the Institute. The Panel noted an isolationist tendency and sense of superiority in the AIVI, which are not warranted and are weak points to be improved. The strongest research programmes are at the University, on obesity, type II diabetes, atherosclerosis and neurodegenerative diseases; they are highly relevant and utilise unique patient populations, but unfortunately are not included in the AIVI. Another reported problem is in attracting graduate students and postdoctoral fellows from the rest of Finland and abroad. Solutions may include a special effort in preparing and recruiting University of Kuopio students for graduate training, or offering special fellowships at the AIVI Graduate School. A national recruitment or repatriation programme may be needed to bring postdoctoral fellows from abroad to Kuopio and elsewhere. Recruitment problems may be related to multiple factors, including location.

III.A.3. Oulu Biocentre

This Biocentre was the first to be established and continues to be excellent. It is affiliated with the second largest University in the country, in this capital of northern Finland which also is important for ICT. The Panel was impressed by the outstanding qualities, clear leadership skills and exceptionally good vision of the

Director. She gave an impressive analysis of the ambitions, activities, future strategy, funding concerns and development plans for the Biocentre, and a clear and balanced view of the strengths and weaknesses of the Biocentre and the rest of the local environment. She gave the clearest answers that the Panel heard in Finland to the questions that it posed (Section VIII.F.), including those on quality assessment, decision making and rewarding excellence; *e.g.* 91% of the funding allocated by this Biocentre to senior groups is based on bibliometric analysis, and support is higher for new projects and starter groups. A "Discovery of the Year Student Award" is given annually. The 10 group leaders of the Biocentre have three-year appointments, which turn over or are renewed depending on reviews by international experts. The Biocentre benefits from an active international advisory committee and an accountable structure, bringing in and turning over good people. They have been able to attract good scientists from abroad and collaborate extensively both within and outside the University. They are thinking broadly about education and would like to change the curriculum to add, for example, more physical chemistry and establish strong connections with the new NMR competence in the Chemistry Department. Although the two campuses of the University are separated by six kilometers, the Biocentre has presence on both sites, successfully bringing together activities in the University Hospital and in the medical, technical and science faculties (but currently not the Biology Department). It operates some core facilities open to all scientists, but has no national-scale core facilities. The Biocentre has an international scientific profile, especially in extracellular matrix research, and also in protein structure and transgenic functional studies. Its publication record is outstanding, and was further strengthened (quantitatively/qualitatively) beginning in approximately 1994.

The Panel met with the Rector, Vice Rector and other senior University staff. We learned that the University has chosen four areas for emphasis: IT, environment, biotechnology and Northern Issues, and has substantial successes. The Rector was anxious to stress the excellence of researchers within the University who had not been included within the Biocentre. Whilst the Panel is in no position to judge individual scientists and does not wish to imply that excellence is lacking outside the Biocentre, it must support proven and sustained excellence as the prime criterion for participation in the Biocentre. The management of the Biocentre and no doubt the University recognise this critical requirement.

Given the impressive picture encountered at the Biocentre (and with due allowance for shortage of time at the meeting with the University authorities), the Panel was disappointed that the Rector, while voicing support for the Biocentre, chose as his main message that earmarked funding for biotechnology and the Biocentre should be given to the University, which "knows how best to distribute it," as in the case for funds earmarked for information technology. Evidently there were tensions concerning control of resources and non-inclusion of some University faculty members in the Biocentre. Without contesting the excellence of the University, the Panel is convinced that the University ought to be proud of Biocentre Oulu. Loss of autonomy of this Biocentre would seem to be a recipe for destruction of a focused, well-functioning small centre of both educational and research excellence.

III.A.4. TAMPERE BIOCENTRE

The fifth Biocentre is the *Institute of Medical Technology (IMT)* at the University of Tampere, which is strongly supported by the Rector. There is a remarkable interaction between groups in the University (the medical faculty in particular) and the Biocentre. The programmes on tissue arrays of prostatectomies, tissue engineering and cell banking and cell testing facilities at the University would not have been possible without the IMT. A distinctive set of research programmes exists in the Biocentre. Currently it has 14 (11 principal and 3 affiliated) young and dynamic research groups, which get most of their funding from outside. These teams are very productive in the field of cancer research, mitochondrial research, cell signaling, regulation of the immune response and bioinformatics. An additional important collaboration is with the Tampere University of Technology (TUT), as reflected in their establishment of a Joint Biotechnology Curriculum. Groups at the IMT collaborate with groups at the University Hospital, Medical School, Technical University of Tampere, and VTT (the Technical Research Centre of Finland), as well as other Biocentres and groups from abroad. They are attractive to numerous foreign postdoctoral fellows. The youth and dynamism of its group leaders is crucial for the success of the IMT, as is the recruitment of its professors and other group leaders by a selection committee that seeks the advice of an international scientific advisory board. It is also seen as a positive feature that the positions of the Director and all group leaders are on a rolling tenure, five-year basis. Unlike most places in Finland, IMT has a high ratio of postdoctoral fellows to graduate students (between 1:1 and 1:2). This level of excellence is reached with only 3.05% of the total funding for Finnish Biocentres (figure quoted for 2002). Funding for development of the Joint Biotechnology Curriculum is still pending; it is essential to expand the teaching/ training activities at the TUT, which are remarkable. A number of service units are also missing and would enhance the scientific competitiveness of IMT: these include transgenic, proteomic and imaging units. The Panel believes that creation of these units would be well deserved, and that they should be accessible to all groups working in biotechnology in Tampere. We are impressed with how much such a small research community with internal cohesion, ambition and high standards can accomplish.

III.A.5. TURKU BIOCENTRE

The University of Turku has a major focus on the biosciences, which account for 70% of the external funding. There are several foci of excellence, and the research in biochemistry and molecular biology, including immunology and receptor biology groups, is at world-class standard. There is good collaboration with the Åbo Akademi, the University of the Swedish minority of Finland, which brings complementary strengths with assistance by the Åbo Akademi Foundation. In this case, with the support of both Universities, the Biocentre funding has been entirely devoted to core facilities. This has created an open structure (*Biocity Turku*) that provides access to vitally important technologies for the large biosciences research community, and is also accessible to the local biotech companies (which pay for their use). Quality control is assured by self-interest: oversight is provided by professors for whose work the respective core facilities are critically important. This

system may be precarious: some of the group leaders who are in daily charge of facilities have only 5-year appointments. In the concrete constellation of Turku (see Chapter VI), this use of earmarked biotechnology funds is sensible. Nonetheless, it has the downside that these funds are not available to catalyse new research directions, create critical mass in specific areas, and increase international recruitment which is felt to be a problem. Recognition of how beneficial a concerted system of core facilities such as the one in Turku can be has stimulated the Panel to propose that TEKES fund robust facilities of this type, open to both academic and industrial use, in all significant biotechnology centres in Finland. This would be a major boost to the development of biotechnology.

III.A.6. KTL, National Public Health Institute, Helsinki

Exceptionally, we discuss this institute here because of the similarity of its research branch to a Biocentre (KTL cannot have this designation as it belongs to the Ministry of Social Affairs and Health, not the Ministry of Education). In addition to the similarity, one KTL department (the Department of Molecular Medicine with more than 100 people) is housed in the Biomedicum building together with the Biocentrum Helsinki. KTL is very important in one of the areas of strength of Finnish biosciences, human genetics and epidemiology. It performs basic and goal oriented research in molecular genetics, cell biology, molecular microbiology, immunology and epidemiology. KTL combines strong scientific expertise, including many of the latest tools of biotechnology, with access to large collections of samples (systematic data collection in multiple large population cohorts). It tests vaccines, develops methods in diagnostics and genetic predisposition to diseases, creates tools for epidemiological studies and is thus able to provide major contributions to important medical and public health problems. These strengths should be sustained, but augmented by complementary strengths in molecular biology, molecular genetics and functional genomics. KTL also includes service and reference laboratories, has an advisory role for the government, and aims to exploit research results with industry. Significant external funding, including several EU-funded projects, account for 40% of the budget. Biotechnology research is performed by a total of 309 personnel.

One of the most successful KTL research laboratories is in the field of genetic predisposition to disease. This laboratory is also affiliated with the University of Helsinki and the Folkhälsan Institute of Genetics, and has the status of National Centre of Excellence. It has an impressive publication record and is known internationally for its work on molecular epidemiology and human genetics, in particular in the field of atherosclerosis. It has accumulated some of the most valuable collections of human samples (sera, DNA and cells).

III.B. Universities without Biocentres

Interviews were conducted with representatives of two former teacher education Universities that do not house Biocentres. The *University of Joensuu* (established in 1969) includes six faculties and has nearly 6,900 students. The city of Joensuu is located in Northern Karelia 130 km east of Kuopio, and 430 km north-east of

Helsinki. The University of Joensuu has no strategic plan to develop biotechnology, but does have a focus on high technology as one of its four research priority areas. Faculty members complain that teaching of biotechnology depends on too few individuals short of resources. One group collaborates with the Institute of Biotechnology in Helsinki in generating ESTs of various tree species. The University of Joensuu has interesting and productive biotechnology research, meeting international standards, in the fields of protein crystallography, DNA repair and plant growth control.

The *University of Jyväskylä* was established in 1934, on the foundation of a teacher's education institution that dates back to 1863. It has seven faculties and 15,000 students. The city of Jyväskylä is located in Central Finland 150 km north of Tampere and 290 km north of Helsinki. This University is also doing well. It has some high quality research groups working on biotechnology projects, as well as a nanoscience centre. They educate 30 students (most then go to the IMT) and could easily double this number if they had more professors. Many more students are applying than can be accommodated. Investments would give good return in human resources. The Universities of Joensuu and Jyväskylä represent good nuclei that lack critical mass but make up for it with their determination to succeed. Some type of "trans-regio" research networking programme, linking them with larger centres would help encourage excellence in these Universities, which are otherwise faced with the possibility of faculty brain drain; resorting to the formation of more Biocentres is not a viable option.

Another solution to the problem of small nuclei is cooperation of institutions located in the same city. The already mentioned Joint Biotechnology Curriculum, between the University of Tampere and the Tampere University of Technology, is a positive example; another is a multidisciplinary network in cell and tissue engineering which links UT, TUT, the Tampere University Hospital and the local branch of VTT. The TUT lacks its own Biocentre but contributes collaboratively through its productive groups in Environmental Biotechnology, Biomaterials Technology and Biological Signal Processing. The studies of processing, microstructure and properties of bioabsorbable polymers and composites are not only world-renowned but also have led to excellent industrial links. At TUT, inter- and multi-disciplinary research has integrated engineering with biochemistry and biotechnology, a rare occurrence in Finland. As a consequence, external funding for research is way above average.

A fourth University not connected with a Biocentre is the Helsinki University of Technology (HUT). It is a large institution (a staff of 3,000 and a student body of 14,270, of whom 2,510 are doctoral students), which focuses on industry-oriented research. Much of their research is directed toward the food industry, and they are also developing a new department of combinatorial chemistry. They have a recognised competence in large scale production of recombinant proteins, and are committed to using molecular biology in biotechnology. There is a funded Centre of Excellence in bio- and nanopolymers. The publications are in appropriate specialist journals (with generally low impact factors). Surprisingly, there was no participation in EU programmes, reportedly because of a limited budget.

However, HUT has an active internal technology transfer office (10 full-time employees). They also do most teaching in English, a sign of internationalisation. Graduates from HUT (2.9% in biotech) and doctoral students (4.7% in biotech) are highly competitive, and are often offered jobs in industry before they finish their degrees. They are an important contribution to the food industry, which in Finland has 300,000 employees. The Panel sees a good case for continuing support of classical biotechnology and fermentation technology at HUT.

It is evident from this and the preceding section that major differences exist amongst Finnish Universities in terms of the level and quality of research activities in biotechnology, as well as their orientation. These institutions vary, being largely teaching universities, technical universities or multidisciplinary universities. We noted considerable strengths, of different nature in different institutions, as well as some consistent problems to which we will return in the next section.

III.C. THE HUMAN CAPITAL PIPELINE

Like ICT and other technologically advanced sectors, biotechnology depends on well-educated and talented people at all steps of the innovation chain. Therefore, the Panel paid special attention to the educational and professional development system in Finland as it relates to biotechnology. During the site visits we inquired about all phases of the "human capital pipeline", from undergraduate education to the faculty career path and recruitment of leading specialists in Universities, research institutes and companies. Closed meetings with graduate students, postdoctoral fellows and young group leaders were particularly useful in complementing the information gathered from discussions at more senior levels. Although this was a survey rather than a systematic study, the consistency of views that the Panel encountered supports the following conclusions and recommendations.

Undergraduate & Master-Level Education

These first steps in bioscience training have strengths but, if biotechnology is indeed a priority, quantitative and qualitative improvements are needed.

The level of demand for training appears to exceed capacity substantially. For example, in 2002 the University of Helsinki had 773 applicants for 101 positions in biology, and 120 applicants for 15 positions in biochemistry; the University of Oulu had 157 applicants for 51 positions in biochemistry, 328 applicants for 55 positions in biology, and 479 applicants for 123 positions in medicine; the University of Turku had 322 applicants for 40 positions in biochemistry, 331 applicants for 35 positions in biology, and 634 applicants for 160 positions in medicine; and the University of Jyväskylä also reported large oversubscription for its Masters of Science programme in Biological and Environmental Science. (In these statistics, "applicants" are those who had the indicated institution as their first choice.)

A stronger concern is that conservatism in the University structures (faculties, departments) may hinder the continuous modernisation of teaching which is necessary in this era of rapid change in the Biosciences. The Biocentres as well as the

new Graduate Schools have been instrumental in improving research and graduate training, and are helping create the necessary modern interfaces, both within the biosciences and with other sciences. The Panel would strongly recommend similar improvements in the undergraduate curriculum and the underlying University structures. Encouraging examples are the creation of a new biosciences faculty at the University of Helsinki, and the initiative of members of the Institute of Biotechnology to put together a cell and molecular biology course for undergraduates. The best researchers should be encouraged to innovate in education, rather than being asked to deliver four or five assigned lectures in old-fashioned courses.

Doctoral-level Education

Finland has a rigorous doctoral education, in the Scandinavian tradition. Reduction in its previously excessive duration has been achieved. As indicated above, the Panel saw clear evidence that the Graduate Schools and Biocentres have enormously improved the quality of graduate education; the formal courses, the guidance/tutoring provided, the opportunities to participate in courses and meetings abroad, the strengthening of the research environment, are all important and much appreciated; the Panel warmly endorses these achievements. The students have reacted positively to the experimental ferment created by the new graduate schools; for the next phase more fellowships are needed, but also a more streamlined operation that works across all the artificial boundaries presented by the existing academic system. The following further improvements are recommended, in the direction of creating a graduate student community with greater cohesion and more intellectual challenge:

- Graduate students are initially selected at the level of individual groups, and funding is then secured either by additional selection for a Graduate School fellowship or from research funds available to the group. The Panel would recommend that initial selection be through a Graduate Programme, coordinated by the Graduate School(s) and involving multiple interviews and committee-based acceptance of candidates. The possibility of laboratory rotations before deciding on a final thesis should also be considered.

- Greater uniformity in the advising system and improved dissemination of information (about seminars, techniques and materials available, *etc.*) would be helpful. Journal clubs should encourage broader participation and coverage. Reportedly there are too many secretaries in different compartments for full and smooth information dissemination and for building a sense of coherence. Special efforts are needed in Helsinki because of the size and the complex organization of the community.

A strong message received from graduate students at all institutions is that the formal rules are too inflexible and emphasise quantity more that quality. Specifically, the four-papers-in-four-years requirement for the PhD shifts the emphasis towards safe, uncreative science. Since “failure is not allowed,” students must undertake their PhD work with a strategy that ensures production of sufficient publications. This is a recipe to avoid the challenge of novelty. Since research in Finland is largely done by graduate students, the situation creates significant

negative feedback into the quality and competitiveness of the overall research enterprise. Moreover, the impact on the development of future intellectual capital is negative. Training of scientists should aim to raise their level of ambition to tackle difficult and important problems, where success is not inevitable and is judged by content rather than the number of publications.

MD/PhD Training

The convergence of biology and medicine is a momentous development in our time. This convergence needs to be promoted at all levels of the research and training system. While the Universities in Finland (as in much of Europe) offer PhD opportunities for MDs, integrated MD/PhD programmes have been very successful in the US and some other countries. The Panel recommends such integrated programmes for all the large biotech centres in Finland.

Postdoctoral Training

There is a gaping hole in the human pipeline at the level of postdoctoral training in Finland. Whereas the best Helsinki laboratories have a ratio of nearly 1:1 students to postdoctoral fellows, in laboratories of comparable quality at other Universities that number is as high as 5:1. Even the graduate students realise that the presence of postdocs would enhance their education. Apparently, the major source of funding for postdocs is research grants. Many Finnish PhDs go abroad for postdoctoral training, and a substantial fraction of them never return. With few exceptions which are noted elsewhere, recruitment of foreign postdocs is quite limited. These problems need urgent attention.

Starting Faculty

A similar gap exists in the academic career structure. There is an acute need for a tenure-track system and for specific opportunities for young group leaders. Ironically, the problem seems to have been exacerbated by the recent conversion of Associate Professors to Professors. Although the issue of having only a few Professors at the very top has been alleviated, a psychological gap has been created with no obvious mechanism for young scientists to enter the faculty track. Even the small number of young group leaders funded by the Academy of Finland have a non-renewable five-year term, no guarantee of space and no real prospect of being able to compete for University professorial positions at the end of this initial period. Without seriously addressing the problem, Finland has no chance to adequately recruit the invaluable talents of young independent scientists, both Finnish and foreign.

III.D. SUMMARY RECOMMENDATIONS

- The Ministry of Education should conduct an evaluation of whether its number of slots for basic training in biology should be increased.

- Curricular change is clearly underway for PhD students with the advent of the Graduate Schools and the Biocentres. Undergraduate education in Biology needs

to be comparably modernised, and the best scientists in the Biocentres as well as the rest of the University should be encouraged to be involved in this process.

- The new graduate schools have been an excellent device for both improving training and encouraging shorter times to PhD. The number of places in the graduate schools should be increased (rather than increasing the number of students funded through research grants). More cooperation between graduate schools at the same institution should be encouraged.

- Establishment of a formal MD/PhD programme in all the major biotech centres is recommended.

- Inflexible criteria for awarding the PhD must be altered, shifting the emphasis to evaluation of quality.

- The Ministry of Education together with the Academy of Finland and the research Universities should work out a coordinated plan to increase the number of excellent postdoctoral fellows, both Finnish and foreign.

- In both the Universities and Biocentres, research excellence should be further strengthened by encouraging work at the interfaces of biology with medicine, as well as with chemistry and computational science; for specific areas, the interfaces with physics and engineering should be reinforced.

- A proactive programme is recommended to bring back excellent young scientists, and to recruit a greater number of foreigners to Finland.

- Beyond the one-off, five-year starting positions, a tenure-track system for University faculties needs to be developed that puts in place opportunities for advancing in steps to more senior levels, subject to stringent performance assessment and competition.

- Infrastructure for biotechnology research should receive substantially better support, so that access to modern equipment and technologies is not rate-limiting in either the Universities or the Biocentres. As we suggest elsewhere, a TEKES programme for shared infrastructure support should be considered, to prepare the knowledge base and also to facilitate applied research and industrial R&D. The Ministry of Education and the Academy of Finland should also be involved more actively in infrastructure support.

IV. THE TRANSLATION PROCESS: APPLIED RESEARCH AND TECHNOLOGY

During the course of the review, the Panel was shown examples of effective applied research leading to technology transfer from academia to industry, with subsequent benefit to Finland through the creation of new jobs and the imminent prospect of important new drugs and other products. These successes reflect a mix of personal initiative on the part of individual research scientists coupled with some formal processes to foster their initiative.

An effective interface between basic and applied research is a crucial prerequisite for national success in biotechnology. The Panel found examples of successes at this interface, but also identified opportunities to enhance the relationships and build on the undoubted commitment of many Finnish research scientists to participate in the translation of their research findings into economic gain.

The present chapter considers the roles and ownership of intellectual property; the role of technology transfer professionals to link basic and applied research; the activities of TEKES which has a pivotal mission to support this interface and promote industrial R&D; and the institutes with a clear applied research mission.

IV.A. LINKING BASIC AND APPLIED RESEARCH

In the context of economic development, the key role of basic research is to generate new knowledge and understanding that can provide the basis for applied research to create significant commercialisation opportunities. Recognising when basic research has progressed to the point that it justifies applied research or direct application is difficult, but nonetheless essential.

Technology Transfer Professionals (TTPs: see also Section IV.B. below) are absolutely crucial for success in this transition. Their roles should be to foster links between basic and applied research, file new patent applications when appropriate and to drive consideration, and then implementation, of the specific strategy to be followed for each opportunity. Strategic options and some Panel observations are as follows:

- **pursuit of industrial funding for an agreed Collaborative Research programme.** This is often an effective approach. The Panel was surprised that, although there are a number of desirable Collaborative Research programmes between academic laboratories and small local companies, hardly any examples were shown of Collaborative Research programmes funded by, and in partnership with, major international companies, *e.g.* the pharmaceutical industry (a positive actual example is contracts with major multinational pharmaceutical companies to conduct large phase III field trials, to test efficacy of vaccines). Additional collaborative research programmes would be facilitated

by a well-developed cadre of TTPs. In addition to securing industrial funding, stronger collaboration with international companies would introduce further expertise into the Finnish academic research community.

- **identification of further applied research to be conducted by the originating researchers.** Finland has shown a creative approach to the funding of applied research for all technology sectors, via TEKES. However, the Panel is convinced that changes are required to optimize this funding mechanism, especially for biotechnology (see Sections IV.C. and IV.F.).

- **licensing IP/IPR (technology) to existing companies.** This will often be the most suitable course of action, but the confused position with respect to ownership of IP/IPR (see below) has not favoured well-considered patent decision-making and consequently limited licensing activity.

- **company formation.** Opportunities to found robust companies will arise, sometimes from basic research and more frequently from its follow-up, applied research. Proper assessment of these opportunities, and safeguarding the value of the spin-out company before funding, again will require clear ownership of IP/IPR and the involvement of effective TTPs.

At present, intellectual property rights derived from work supported by public funds in Universities and University-affiliated institutes such as Biocentres belong to the inventor. In contrast, research institutes not affiliated with Universities own all IPR produced by their employees. The Panel is convinced that it is essential to establish a single and uniform policy: that all IPR belong to the institution, which in turn is obligated to provide the inventor with an appropriate share of the benefits. The present hybrid policy:

- has inhibited/delayed the development of the necessary cadre of experienced and competent technology transfer professionals

- is an obstacle to effective commercialisation of technology. The Panel saw evidence that the current owners of IP/IPR (academic researchers at the Universities) have, with a few notable exceptions, little or no knowledge of the patenting process, its international diversity, its need to maintain confidentiality until filing is made, its need for high-quality, certified record keeping *etc*.

- has compromised the broad national strategic approach to commercialisation of research findings by leaving a key part of the process to the discretion of individuals.

- inhibited the development of both (a) strategies for technology transfer on the part of Universities and Biocentres and (b) the full spectrum of strategies to exploit specific technologies.

IV.B. TECHNOLOGY TRANSFER

The many countries where commercial exploitation of academia-derived science and technology is recognised to be effective, have developed a cadre of experienced and increasingly expert TTPs. Working in *partnership* with research scientists, they:

- take responsibility for the quality and filing of patent applications
- drive discussions to determine the strategic approach to exploit each opportunity
- implement that strategy.

At present, Finland has a rather small community of expert TTPs. The Universities have Technology Transfer offices but in most of them the few individuals with this experience/expertise appear to lack appropriate status within their institutions. It may be worth noting that the UK Treasury recently recognised the essential role of TTPs, and recommended that research organisations should consider whether to enhance salary scales specifically for TTPs, to ensure the recruitment and retention of high quality individuals. The development of licensing companies, (*e.g.* Licentia) is to be welcomed but their success will depend on their providing visible, competent and timely services to researchers in each University/research institute with which they are associated, or linking up effectively with TTPs in these institutions.

Effective management of technology transfer clearly sits within the objectives of TEKES, and to its credit TEKES recognises the weaknesses of the present system. It is recommended that TEKES take on the challenge of creating mechanisms/training processes to build a strong cadre of TTPs, and to support their activities within the institutions. There are a growing number of training courses in technology transfer (see for example: www.astp.net, www.autm.net, www.praxis.org.uk). TEKES investment to finance attendance at such training courses and conferences by Finland-based TTPs should represent good value.

The present gaps in effective TT policies and infrastructure in Finland are undoubtedly related to the low rate of patenting in biotechnology relative to all fields, whether nationally or at the European Patent Office (where the percentage of Finnish patents in biotechnology vs. other fields is three-fold lower than the OECD average).

IV.C. TEKES AND THE RESEARCH INTERFACE

IV.C.1. ROLES AND ACTIVITIES OF TEKES

TEKES, the National Technology Agency, is the principal source of public funding for applied technological research. The agency's primary mission is to promote the competitiveness of Finnish industry and the service sector by technological means; this is accomplished by providing grants and risk loans to research and development. In their strategy, TEKES considers biotechnology one of five key technologies (along with new communication technologies, production technology

and processes, materials technologies, and business know-how in networked economy). The TEKES funding instruments, which dispensed 387 M€ (for all fields), and 39.9 M€ for biotechnology (10% of total) in 2001, are as follows:

- *Industrial R&D grants for companies*, covering 25-50% of the costs of salaries, raw materials, machinery, subcontracting, travel and patents. These grants are allocated for projects with a strong research content, and totaled 160 M€ in 2001 for all fields (11 M€ for biotech).

- *Capital loans for R&D for companies*, covering 35-60% of the costs as above. Capital loans are available for SMEs, especially for start-up companies with low income and high R&D costs, and totaled 34 M€ in 2001 for all fields (6.3 M€ for biotech).

- *Industrial R&D risk loans for companies*, covering 50-70% of the costs as above. Risk loans are available for projects with a clear research application, and totaled 47 M€ in 2001 for all fields (2.8 M€ for biotech).

- *Research funding for research institutes and Universities*, covering 50-100% of the costs as above. These grants totaled 146 M€ in 2001 for all fields (19.8 M€ for biotech).

Thus, in 2001 biotech accounted for 8.3% of the TEKES funding through the first three instruments (industrial R&D), and for 13.6% of their funding to research institutes and Universities.

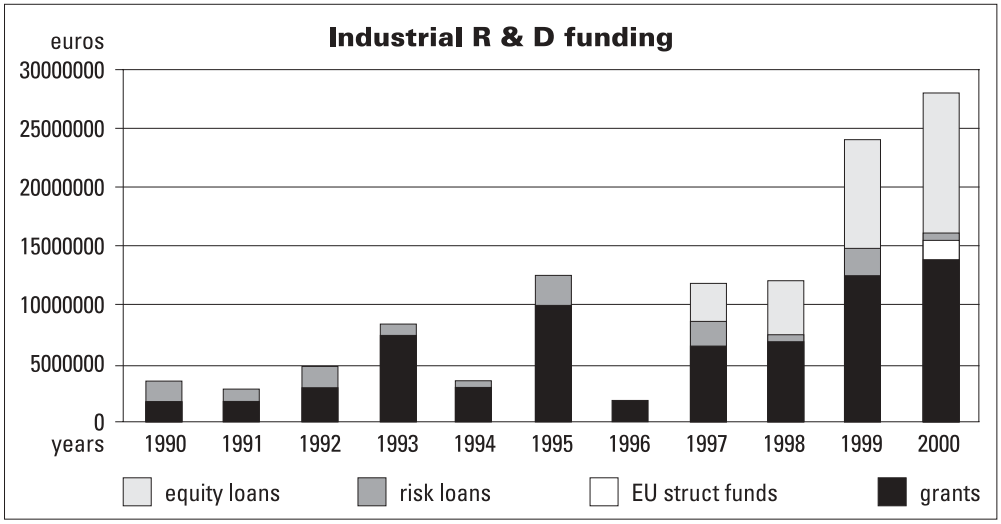


Figure IV a. Industrial R&D funding (Source: TEKES' questionnaire).

The total funding of TEKES to biotechnology enterprises through grants, risk and capital loans was 113 M€ in the years 1990-2000; of this, 69 M€ were as grants, 13 M€ was risk loans and 29 M€ as equity loans. Altogether, there were about 450 individual funding decisions to companies.

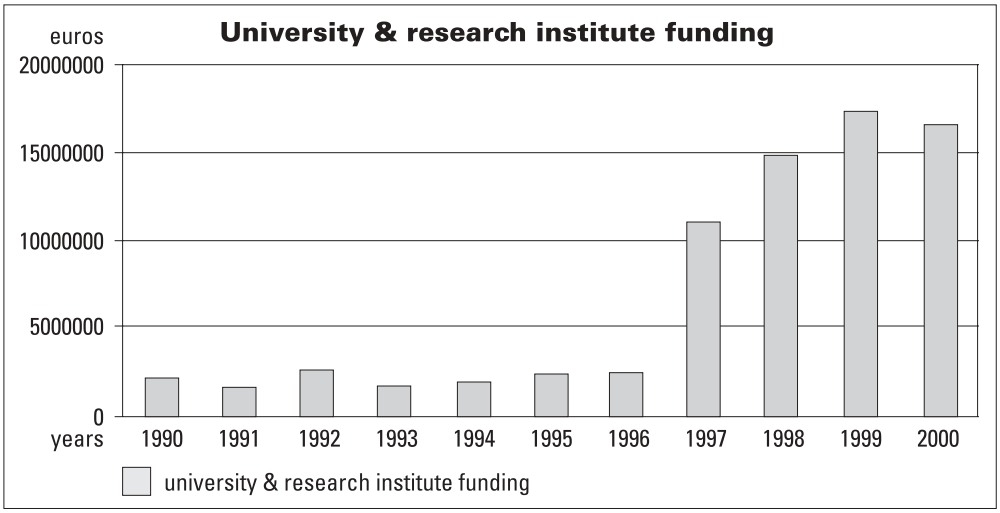


Figure IV b. University and research institute funding (Source: TEKES' questionnaire).

The funding possibilities of TEKES were strongly enhanced by the decision made by the Government in 1996 to allocate additional 500 M€ to research and development. About half these new appropriations were allocated through TEKES, enabling them to increase markedly the funding of biotechnology. The simultaneous founding of new biotechnology companies during the last decade has resulted in progressively increasing demand for biotechnology R&D funding.

In conjunction with other Ministries, the Academy of Finland, and other entities, TEKES plans, organizes, manages and sponsors special technology programmes which aim at promoting development in specific sectors. In 1996-2001, these included New Biotechnology, Innovation in Foods, Diagnostics programmes, Drug programmes, Polymers for the Future, and the Finnish Forest Cluster Research Programme. TEKES also participates in some research programmes of the Academy of Finland which include biotechnology projects. Currently such programmes include the Structural Biology Research Programme (total budget 5 M€), the Biological Functions Research Programme – Life 2000 (14 M€), the Finnish Biodiversity Research Programme – FIBRE (20 M€), the Global Change Research Programme - FIGARE (7 M€) and the Research Programme on Finnish Companies and the Challenge of Globalisation – LIIKE (6 M€). The Panel was pleased to learn about this collaboration between the Academy and TEKES in co-funding research projects with the potential to create future opportunities for application. This attractive collaboration can yield substantial benefits, provided that TEKES has an adequate system to review such projects and a long-term view on their nature.

As TEKES has the mission to promote translation from basic to applied research and then to development, it would be most appropriate for this agency to support instrumentation infrastructure that is now becoming critically important along the entire biotechnology system, from basic research to industry. A prototype of shared facilities that are open to industry has been established in Turku with Biocentre funds (which otherwise would have funded basic research and training). TEKES

support for such regional and even national core facilities available for use by both academic and industry-based researchers would require a change in the current policy of TEKES (which supports research costs, but not capital investment in instrumentation) but would contribute to both national needs and the TEKES objectives, in a cost-effective manner.

IV.C.2. Evaluating the Performance of TEKES, and Quality Assessment by TEKES

TEKES has as its mission to support the competitiveness of the Finnish industrial and service sectors by technological means; therefore funding takes into account relevance as well as excellence. The Panel is fully cognisant of the differences between this mission and that of the Academy of Finland (which is to promote the best in science); moreover, some of the Panel members are experts in applied research and the promotion of novel industries. The questions and recommendations that follow are meant as a constructive input for improving performance in this critical and difficult interface between basic research and industrial development in Finland.

The Panel heard a great deal about the substantial contribution of TEKES to the development of the exceptionally successful ICT industry in Finland. Such a record emphasises that TEKES can be an important actor towards industrial development. TEKES is also aware of the weaknesses of the present technology transfer system (see IV.B.). Importantly, TEKES contributes significantly to applied research in the life sciences and to the R&D effort in related industries. One successful component of this record is TEKES support for a successful applied biotechnology institute, VTT Biotechnology, the activities of which are described below (section IV.D.).

The central question that the Panel wishes to raise concerns the processes that TEKES uses for decisions in its external grants scheme. The evaluation and quality control processes are internal, and the Panel found them opaque and difficult to assess, despite two separate presentations by TEKES representatives. Nor was it feasible and appropriate to assess these processes by independent comparison of funded and non-funded external grant applications (from research entities or industry); in any case, the significance of such a comparison would have been limited by the major player position of TEKES in this domain. Moreover, the Panel was troubled by the lack of evidence in the interviews with TEKES that the special nature of the biotechnology sector is adequately appreciated. With the information at hand, the Panel is not convinced that the agency's approach to biotechnology grants is optimal, or that it matches the ambitious objectives and potential of the many capable research scientists whom we met.

Representatives of TEKES and some bioscientists that the Panel met justified in-house evaluation as necessary for confidentiality in the review of applied research and industrial R&D grant proposals. The Panel members believe this is a "red herring", and point to the more open approaches used by similar funding mechanisms elsewhere (*e.g.* SBIR in the USA and LINK in the UK), which are effective without compromising confidentiality. Independent peer review of *all* applications is important for achieving the desirable quality assurance. This assurance is

particularly important, as the domain of the innovation chain where TEKES is dominant affects the utilisation of other major investments, both upstream (in basic research) and downstream (in industry).

From the questionnaire and the interviews, the Panel learned that the approval rate for biotechnology grant applications is low and activation becomes difficult (about 20% in "Neo Bio"); that University and Research Institute funding jumped from 2 to 3 M € till 1996 to a new plateau of 15 – 18 M € in 1998-2000; and that industrial R&D funding continued to increase through 2000. A possible implication, that funding for biotechnology is constrained by the limited number of satisfactory applications, would be surprising, in view of the high quality of the basic work funded by the Academy. The Panel wonders whether opportunities may be lost because of (i) a lack of guidance of scientists by TTPs about the necessity of applied research to strengthen the IPR position, (ii) a risk-averse funding process within TEKES or (iii) an imbalance between funds available to the Academy for basic research in the life sciences relative to funds at TEKES for applied research.

IV.D. VTT BIOTECHNOLOGY, HELSINKI

VTT Biotechnology is one of the six research institutes of VTT (Technical Research Centre of Finland), which belongs to the Ministry of Trade and Industry and was established in 1942. Research at VTT Biotechnology receives substantial funding through budget funding (31%), industry (31%), and TEKES (21%). The other sources include the Academy of Finland (6.1%) and the EU (4.5%). VTT Biotechnology has 340 staff members (82% females). The staff includes about 150 scientists and 30 PhD students, as well as students working for their Master thesis. Thus VTT Biotechnology has established itself as an important centre for training human resources in biotechnology. The institute's programme in Industrial Biotechnology has been recognised as a Centre of Excellence of the Academy of Finland. This programme has considerable strength and expertise in the area of high-throughput drug screening and protein production, including some very novel and effective approaches. These technologies focus on downstream processes and fill an important gap in the biotechnology value chain; they are not well represented elsewhere in Finland. The Panel appreciates the sharing of the NMR facility between VTT Biotechnology and the Institute of Biotechnology at Viikki. It also welcomes VTT Biotechnology's activity in drug development that has recently been started outside of Helsinki, in Turku. Similarly, it would favour the request from Oulu that a branch of VTT Biotechnology be established there.

In the past, VTT Biotechnology, which owns the intellectual property rights of an invention (the inventor gets 10-30 % after deduction of direct patent costs), was not allowed to be a shareholder in spin-offs. Fortunately, this rule is being changed, and as the Panel learned from the Executive Director, new biotechnology companies are planned to start at the beginning of 2003.

VTT Biotechnology has proven highly competitive in attracting EU funding. Its publication record in refereed journals is comparable to that of the Helsinki University of Technology (although HUT does not report participation in EU

programmes). VTT Biotechnology is also active in collaborations with industry. The new activities on tailored technologies for future foods are worth deepening, since this type of agricultural biotechnology is well suited for a country with the infrastructure of Finland.

IV.E. CSC, SCIENTIFIC COMPUTING LTD.

CSC is Finland's Information Technology Centre for Science, and is structured as a company owned by the Ministry of Education. It offers computational services to the University sector free of charge, and to the research institutes and industry at cost. CSC has the most powerful supercomputing system in Finland, and the second largest system in Europe dedicated to academic use. They maintain the Finnish University and Research Network. CSC has a staff of more than 20 PhDs working in different fields of computational science (bioinformatics, chemistry, physics, earth sciences, engineering, linguistics), which allows them to collaborate effectively with experts in academia. One of their declared goals is to facilitate collaboration between Universities and industry. This is accomplished through joint research projects, coordination and dissemination tasks, and courses and seminars. Several collaborations that CSC has had with academic researchers have led to industrial TEKES-sponsored projects.

While bioscientists use only 4% of CSC's total computing capacity (compared to physicists who use 50%), they represent the single largest user group: 800 of CSC's 2500 customers are from the biosciences, and access their supercomputing, database and microarray services. The centre licenses 200 scientific software programmes, and maintains 60 scientific databases (30 of which are for the biosciences). Integration of chemoinformatic databases in these offerings would be desirable. The importance of medical and epidemiological databases should be taken into account. The Panel notes that though Finland has exceptional computational services, little effort appears to have been made to exploit the nation's strengths in epidemiology.

CSC has a small but competitive bioinformatics group (5 members). They maintain two servers dedicated to biosciences research (Blast searches and microarray data analysis), and provide support for sequence and linkage analysis, structural biology and molecular modeling, as well as phylogenetics. Recently they have become active in the informatics of microarrays and proteomics, but do not yet provide mass spectrometry-related services. Though one of their main functions is to provide support for the Finnish research community, they also have several international collaborations, and participate in many networks. The Panel believes that this small but motivated group could be expanded to take on new projects, and to help the CSC to become a fully competent centre in bioinformatics.

IV.F. OTHER APPLIED INSTITUTES

In addition to VTT Biotechnology and CSC, the Panel interviewed representatives of a number of applied institutes: SYKE (Ministry of Environment), KTL and FIOH (Ministry of Social Affairs & Health) and MTT, MELTA and EELA (Ministry of

Agriculture and Forestry). Of these, KTL has already been discussed in Section III.A.6. The rest are discussed here more briefly, as their present involvement in biotechnology research is relatively minor.

IV.F.1. FINNISH INSTITUTE OF OCCUPATIONAL HEALTH (FIOH)

This institute is located in Helsinki and is affiliated with the Ministry of Social Affairs and Health. Its publication record and participation in EU programmes are good. It performs top quality research on some selected important occupational pathologies, including allergies to latex. It demonstrates a strong competence in molecular biology and molecular immunology, with interesting recent work on the involvement of chemokines in allergic reactions. The panel was impressed to see sophisticated modern biotechnology performed in a field that is frequently dealt with in a more conventional way.

IV.F.2. FINNISH ENVIRONMENT INSTITUTE (SYKE)

This institute channels less than 10% of the total research funding into biotech-related activities, which is roughly in proportion to the number of research personnel (16 out of 180) dedicated to these projects. The projects receive external funding from the Academy of Finland and TEKES. There are three main lines of work: bioremediation, risks of GM plants and microbes to the environment, and molecular methods for environmental "diagnosis". One project is being performed in collaboration with a company. The laboratory of SYKE is geographically isolated, away from their main office and from other national core facilities, which poses a hurdle for collaboration. Reportedly there is strong interest among students for work in the environmental sector.

IV.F.3. AGRIFOOD RESEARCH INSTITUTE (MTT)

MTT is active in food research, plant production and embryo production. For animals, they focus on improving quality of embryos. Researchers are forward looking and want to upgrade their analytical techniques using genomics and microarrays, but are limited by resources. They are applying genomics and array technology to evaluate methods of preparing and freezing embryos, using gene expression analysis to define normal patterns. They are trying to increase funding for applied research, but have limited access to facilities, and face severe competition for highly-skilled staff.

IV.F.4. FINNISH FOREST RESEARCH (METLA)

At this institute, the Panel encountered active anti-intervention attitudes. The view is that Finland has only a low level of forest pathogens, and that semi-natural regeneration would take care of things; that there is no point in doing genomic research on trees because all is fine, natural propagation is good enough for Finnish purposes. There is no appreciation of new analytical techniques that can analyse tree development so that they can select for better trees and for reduction of polluting wood constituents.

IV.F.5. National Veterinary and Food Research (EELA)

The mission of this institution is to perform analyses and ensure the safety of the food supply. Other than this assigned service, scientists have 15-20% of their time free for doing research. They are developing interesting assays to test the safety of foods, but do not consider it worthwhile to interface with industry; though they are working on viral assays that could be used to develop detection kits, their view is that the market would be too small, and the ministry would simply reduce its appropriations if industrial funding were obtained. There seems to be no stimulus for innovation and no reward for excellence.

IV.F.6. General comments on SYKE, MTT, METLA and EELA

In contrast to the human health-related sector, the research effort on agriculture and forestry is less impressive. This discrepancy may be attributed to several factors. A generally conservative attitude may be initially responsible for the allocation of inadequate amounts of funds to biotechnology projects. This neglect may also be influenced by the prejudicial attitude of Europeans towards the use of biotechnology for food production (although this is a lesser issue in Finland than in many other parts of Europe, which equips Finland to grasp opportunity if and when public opinion across Europe changes). Geographical isolation of the agriculture and forestry institutes also has a negative effect. Whatever the reason, there is clearly a lack of critical mass in agriculture and forest biotechnology. The Panel's findings contrast with the importance attached by the Statistics Finland brochure "Biotechnology in Figures" (Section II.D.2) to institutes focusing on agricultural research.

It must be stressed that biotechnology methods do have important applications beyond the production of GMOs. Indeed, they are highly important tools for plant and animal breeding and for improving the productivity of agriculture and forestry. The Panel understands that only 1% of the public biotechnology funding has been granted through the Ministry of Agriculture and Forestry. This low funding level is particularly surprising as the Panel further understands that forestry contributes 20 – 30% of GDP and that 3 of the top 10 forestry companies in the world are located in Finland. Other countries with large forestry economies, *e.g.* Sweden, Canada and New Zealand are investing far greater amounts into forest biotechnology. The present neglect will leave Finland at a comparative disadvantage in an industry vital to its economy.

In addition to low funding, the Panel detected in several of these institutes a sense that the respective ministries are not interested in biotechnological innovation. There seem to be no incentives. Participation in EU programmes is quite limited. In MTT there is the potential for excellence and interest to improve the situation, but the odds seem overwhelming. The publication record could be improved significantly (in MTT it is better). The Panel believes that positive change is urgently needed, beginning at the governmental level.

IV.G. SUMMARY AND RECOMMENDATIONS

The Panel recommends:

- that ownership of IP/IPR should be clearly defined, and consistently vested with the employer of research scientists, *e.g.* Universities, research institutes, companies *etc.* TEKES might consider contributing to defray costs associated with patenting. The proposed change in ownership of IP/IPR should be accompanied by clear and binding obligations on the owner of the IP/IPR to include the inventing researchers in a significant share of revenues generated from the IP/IPR. The practice in many countries to share revenues between:

  – the inventors

  – their Department or Institute

  – the University

  has proved very effective.

- that a major initiative be undertaken to train a body of high quality individuals as Technology Transfer Professionals and to introduce a broader range of academic researchers into the nature and requirements of international patenting. The scale of funding needed to deliver these would be modest, with high returns, and an effective use of TEKES funds.

- that TEKES undertake to support the establishment and operation of major regional and national core facilities that are essential for the biotechnology system and can be broadly shared, by basic, applied and industry researchers.

- that a review of TEKES processes be undertaken to ensure that it is equipped to develop more effective commercialization of life sciences research through more open review, based on recognition of the specific opportunities and needs linked to commercialization of life sciences research.

- that the opportunities to utilise biotechnology for socially beneficial applications be recognised by the Ministry of Agriculture and Forestry and the Ministry of Environment, as they are by the Ministry of Education, the Ministry of Trade and Industry, and the Ministry of Social Affairs and Health.

V. THE ESTABLISHMENT AND MATURATION OF COMPANIES

V.A. COMMERCIAL BIOTECHNOLOGY AND ICT

Finland has a most enviable record in the successful creation of new companies, both large and small, in the ICT field. Current efforts to match this success in biotechnology have made good progress – whilst there remains substantial scope to become more effective. Major opportunities to increase the success of Finnish biotechnology companies should follow from recommendations proposed in earlier chapters on the research system, training of research scientists, enhanced attention to applied research in certain sectors, and improvements in the management of Intellectual Property. The present chapter focuses on the industrial sector and includes specific observations and recommendations of the Panel, following its interactions with the equity investment community and with a number of biotechnology SMEs.

As already indicated in the Introduction (Section II.C.), the Panel is concerned that several aspects of the Finnish innovation process do not adequately recognise the key differences between the successful commercialisation of ICT and of biotechnology. Biotech companies differ from companies in the ICT field, in several respects:

- biotechnology companies are highly dependent on ownership of clearly defined Intellectual Property rights.

- biotechnology companies can be highly diverse in their business models, ranging from service companies, strictly technology platform companies, diagnostics companies and finally companies involved in drug development. Whilst the latter offer the prospect for largest profit and ultimate commercial success, all business models can contribute to the economy and socially desirable goals (*e.g.* disease prevention, high quality employment) and should be encouraged.

- biotech companies are invariably characterised by an extended path to profitability, especially when dealing with drug development. Successful biotech companies frequently demand investment for up to 8 or 10 years after creation, and in some cases after they have become publicly listed companies. This reflects, in large part, the extended time required to bring a drug to the market. More rapid profit resulting from licensing deals is known to compromise eventual returns to the company from its own products.

- biotechnology companies carry high risk/uncertainty of success.

V.B. EVALUATION OF "SUCCESS"

It is notoriously difficult to evaluate the failure or success of a local biotech industry. We offer some suggestions on variables for consideration, aware of their limitations. Useful variables include:

- the number of *employees*, *i.e.* jobs created. The number can be underestimated when companies frequently outsource some of their work/needs; it can also be counterproductive unless based on a sound business model.

- the *quality* (rather than the number) *of valid patents*, albeit difficult to quantify.

- achieving specific, pre-defined *scientific and commercial milestones* (such as major commercial contracts, discovery of a drug candidate, or initiation of clinical trials).

- the *credibility of the investor base* of a company; sustained success in subsequent rounds of financing will require a solid and diversified, almost certainly international investor base.

- *quality of management*

Some commonly used variables can mislead assessment of progress. In particular:

- *counting companies*, (*i.e.* quantity, not quality) is notoriously misleading: too easy access to initial funding can, and will, result in poor selection, followed by very painful consequences, as failure becomes inevitable.

- *financial profit* in the early years, maybe as much as the first 10 years. Some business models, *e.g.* biotechnology services, lend themselves to early income, but for many of the long-term major successes, early profit is a very poor, possibly inverse, signal of success; "it costs money to do business".

V.C. SITRA AND THE INVESTOR BASE

SITRA, the national investment fund, is a highly creative concept, endowed at a time when many other nations were far more conservative, and was commendably allowed to behave in a business-like manner, including essential independence. A large amount of money, relative to the size of the country, has been invested as seed funding for companies, and there is clear evidence that this has been successful. SITRA has spread support constructively wider than TEKES, *e.g.* investing in technology transfer companies such as Licentia. As SITRA appears to work so well, the Panel considers it a major national asset. However, despite this evident success, a single dominant source of seed investment carries some risks. Finland might be well served by additional sources of early investment, and SITRA might benefit from healthy and constructive competition. The Panel was pleased to learn about BioFund Management Ltd, a SITRA spin-out that has become one of the significant private European venture capital management companies

investing solely in the life sciences industry. Its further development as an independent entity should be encouraged. The Panel has noted an initiative (Industry Investment Ltd., a government-owned company) that helps develop the local VC industry by investing in new local funds ("funding the funders"). This initiative is positive, provided that these new funds remain independent, and provided that they do not lead to neglecting the necessity of international VC investment.

An issue is the dominant, single Finnish investor base of most start-up biotech companies. A broader base of investors within Finland, coupled with the participation of international VC investors, will be essential to sustain growth in the stronger companies as they mature. Three approaches might be constructively pursued, as indicated in the Summary Recommendations (Section V.E.).

V.D. FURTHER COMMENTS

1. Whilst all biotechnology business models should be encouraged, there might be scope for more emphasis on *the field of drug discovery*. This will require greater integration of biology with *chemistry* (rational drug design, combinatorial chemistry, medicinal chemistry, *etc.*) than was evident to the Panel.

2. As many biotechnology products and services will find their primary use in healthcare delivery, the importance of *convergence between biology and medicine* needs greater attention, with better integration into all steps of education and research.

3. A major concern to the Panel is the plethora of very small companies with minimal/no investment and little management. Such companies will invariably prove too small to succeed, and this fragmentation constrains the development of successful companies. Fewer, more broadly based companies should be the objective as this approach will ultimately yield greater returns, whether measured in products and services developed, job creation or profitability. This current situation arises from a number of circumstances (including the confused ownership of IP/IPR commented in Chapter IV). Other factors include:

    - Facile *selection of candidate companies for seed investment*, with inadequate attention to the best chance of ultimate commercial success. This is difficult, and requires sophisticated and experienced experts, working in partnership with the scientific founders. A more selective attitude driven by the perceived quality and not quantity of companies is recommended; some projects should lead to licensing deals rather than to companies.

    - *Financing* of start up companies is usually local. Companies should be encouraged to be *more international*, and thus *more competitive as early as practical*. Thus far, few companies have been confronted by the need to meet international expectations. External validation by international Venture Capital will be a key test to measure success and will facilitate growth and

maturation. The Panel saw a good example of this in Fibrogen Europe Corp., and its links with the parent company headquarters in California.

- *Merger and acquisition between companies with obvious synergies* is highly desirable and requires encouragement. It is a positive way to build companies more likely to succeed, to recruit strong management, attain significant international investment and sustain job creation. Providing there is such synergy, merging should be viewed as a constructive step, and a credit to the management of the merging companies. The Panel saw a good example of this in the merger of BioTie Therapies Corp., Contral Pharma Corp., and its subsidiary Carbion Inc. In contrast, merger and acquisition as a last resort must be avoided; merger of two failing companies will generally result in failure.

4. The Panel saw clear evidence of collaboration between academic laboratories and local biotech companies; this is a strength of the Finnish biotechnology system. However, collaborations between academic laboratories and *international* pharmaceutical companies or large foreign biotech companies are uncommon. In addition to the funding that might be attained, such collaborations would introduce access to crucial know-how/experience and thereby indirectly contribute positively to the local biotech industry.

5. More extensive *scientific and commercial collaboration* between local biotech companies and *international biotech companies*, alliances, *etc*. would also benefit Finland. This type of interaction, aiming at synergies, is especially important when exit strategies are no longer going to be limited to classical IPOs, but more often towards fusions, mergers and acquisitions ("trade sales").

6. As elsewhere in Europe, we identified a lack in competent and *experienced managers*, ideally including US-based experience. Finnish biotech companies are often run by scientists with little or no business experience and skills; despite a few notable exceptions, this approach rarely succeeds. Finland should train managers (CEO) in biotech, as well as business development specialists. Encouraging training and practice in the best international centres would be a critical element in the development of young biotech companies.

V.E. SUMMARY RECOMMENDATIONS

- SITRA should be encouraged to promote the development of a broader source of investments, and especially to co-invest with a small number of highly selected international biotech funds, specialised in early stage financing; this would build relationships that would facilitate follow-on investment, and would increase SITRA exposure to rapidly changing international practice in this specific field.

- SITRA should extend their commendable initiative to develop further relationships with non-Finnish investors to foster co-funding of companies within Finland as they mature.

- The Ministry of Finance should consider improvements in the tax law (or other incentives) to attract independent international Venture Capital funds into Finland. It is understood that the current taxation practice in VC funds established in Finland does not encourage international investors to participate in such funds, in contrast to the practice in many other countries.

VI. LOCAL INNOVATION ENVIRONMENTS

In general, Finland has a commendable regional development policy, and fosters development of all five of its major cities. Since the Regional Development Act of 1993, a series of programmes have created "Regional Centres of Expertise" and "Networks of Expertise." They are designed to be catalysts of the innovation pipeline, promoting science and research institutions, facilitating technology and knowledge transfer into companies (including spin-outs), and thus creating new jobs and tax revenues, and as a byproduct, improving the financing of science and research institutions. This Chapter briefly summarises and comments upon the biotechnology innovation environment in the cities visited by the Panel, in alphabetical order. For practical reasons, we discuss the University of Joensuu together with Kuopio, and the University of Jyväskylä together with Tampere, although of course they are in other nearby regions. The section integrates information about local Universities and research centres; the biotechnology and related industries; close collaboration between institutions (if any); integrative infrastructures (*e.g.* shared-use buildings and facilities, technology parks, technology transfer entities); and the degree of support by local government. The Panel's perception of strengths and weaknesses in the innovation environments is also presented. This section addresses the five regions as specific case-studies, and to avoid redundancy with earlier sections, no general recommendations are made.

VI.A. HELSINKI REGION

Helsinki is clearly the dominant city in terms of research, education, economy and population. Nearly one million people (20% of Finland's entire population of 5.2 million) live in the Helsinki region (Helsinki, Espoo, and Vantaa). As the capital, Helsinki is also the political and administrative centre. Together with Turku, Helsinki accounts for two thirds of the biotechnology industry of Finland, and the headquarters of the major funders: ministries, Academy of Finland, TEKES, SITRA (of these, TEKES has representatives in other cities). The University of Helsinki (UH) is the largest academic institution in Finland. The Helsinki region hosts four campuses relevant to biotechnology: the bioscience campus at Viikki, the biomedicine campus at Meilahti, the technology campus at Otaniemi, and the natural sciences campus at Kumpula. The first three campuses have major academic entities (Institute of Biotechnology, the Biomedicum, and the industrial biotechnology cluster (HUT, VTT, CSC Scientific Computing Ltd.), The companies are also found near these campuses, especially at Otaniemi's Science Park and software business centre (Innopoli), and Viikki's Helsinki Science Park. The Regional Centre of Expertise (Culminatum) appears to be proactive as a regional science and technology planning centre (it is a company, like the science centres). However, it should be noted that these campuses (and others devoted to art and design, business and humanities) are quite dispersed, forming a northwest to south arch, 10 km long across the city; Otaniemi is further west. In addition, a number of applied research institutes (SYKE, METLA, EELA, FIOH, KTL, VTT Biotechnology) are also found in the Helsinki area. The Helsinki area also includes the headquarters of Nokia (further west, at Espoo).

The Panel considers Helsinki as a strong environment for the development of biotechnology, for the following reasons:

- *Academic quality*. The academic leadership has vision. The research strength of UH is substantial, and the two Biocentres are exceptionally good. The KTL research branch housed in the Biomedicum is world-class. FIOH, the second institute belonging to the Ministry of Social Affairs and Health, is also good. Development of the bioinformatics centre is promising. The facilities that the Panel visited are well-developed. More than at any other place in Finland, the scientific community in Helsinki approaches critical mass. Together the Viikki and Meilahti campuses receive 43% (see Table IIb in Section II.D.) of the Academy of Finland's biotech money; 8 of the total 17 CoEs in biotech, as well as 5 of the total 20 graduate schools on biotech are found on these campuses. Both centres are very big, and include many core facilities such as proteomics, NMR, and transgenic mouse facilities. Efforts to integrate the working of the Biocentres with the University faculties, while maintaining autonomy, seem successful.

- the *co-location of basic research labs* of the Biocentrum *and clinical labs* of the Helsinki University medical school and the Institute of Public Health provides excellent opportunity for these researchers to interact and to collaborate. This is a *very good model* to integrate the biotech value chain *from basic research to clinical/translational research*.

- *Exciting research environments for doctoral students and postdoctoral fellows* in the Biocentres, because of critical mass under one roof, diversity of research areas availability of seminars on different topics in biosciences.

- *Commitment and coordinated action of regional authorities*. This includes a regional plan that is actively promoted. The Technology Transfer company, Licentia, is also headquartered here, and serves multiple institutions.

- *Strong and relevant industrial environment*.

- *Access to adequate human resources,* due to the city's population, the quality of academic training and the relative attractiveness to foreigners.

- *Strength in classical biotechnology*. Research relevant to industry is found both in VTT Biotechnology and in HUT, which is especially oriented toward the food industry, and has good competence in large-scale production of recombinant proteins.

On the other hand, weaknesses are also evident:

- *Dispersal of academic institutions*. It is easy to imagine that this dispersal might decrease commuting time and spread employment across the city. It comes at the cost of additional synergies. Although this is no longer feasible, the biotechnology and pharmaceutical industries would benefit from being located on or very near a single campus where molecular and cellular biology,

genomics, combinatorial chemistry, and clinical medicine strengths could be found.

- Persistence of outmoded University structures and curricula (a general problem in Finland)

- Unimpressive agriculture, forestry and environmental research activities.

Finnzymes, an example of a University spin-out

The Panel enjoyed meeting two senior employees of Finnzymes Oy – a company founded in 1986, and now thriving. Finnzymes represents an interesting and clearly successful business model, *i.e.* a service company, providing sophisticated laboratory materials, for life sciences researchers in Universities and companies. The model requires less initial investment than new drug discovery companies, with less risk to be carried over a short time, and lends itself to steady growth, much if not all of which can be financed through sales. This model can rarely, if ever, match the scale of financial return associated with a *successful* new drug discovery company – but is more likely to succeed in the long-term, generating steady profits and broadening its employment base. This approach represents one of many desirable approaches to commercialise life sciences knowledge and technology.

The technology origins of Finnzymes lie in the Helsinki University of Technology. New products developments are based on a number of academic interactions, with the Institute of Biotechnology (Helsinki University) being a particularly key, current partner. The Panel was informed of the constructive role played by matching company and TEKES funding, a mix of grants and loans, to finance some of these developments. Finnzymes has built important international partnerships allowing access to further products the company can market in Scandinavia, and to marketing its own products beyond Scandinavia.

The relationship between Finnzymes and a range of Universities represents a good example of how the innovation cycle can function effectively. To reinforce co-operation, which is one of the great strengths of the Finnish effort, the Panel advocates publicising this example of multiple academic relationships with Finnzymes to other companies and University-based researchers elsewhere in Finland.

VI.B. KUOPIO REGION

The lakefront city of Kuopio, estimated population of 85,000, is in the province of Eastern Finland. Principal industries in the city and the surrounding region include food processing, wood industry and machinery and textiles manufacturing. The city of Kuopio is highly supportive of biotechnology, and this has translated recently into buildings for start-up companies of the City's Technology Centre, Teknia Ltd. The first and second buildings, Mikroteknia 1 and 2 (the latter being the largest office building project in eastern Finland) have a total space of 80,000 m^2. The compact nature and

close proximity of the Mikroteknia buildings to the University, the Hospital and the A.I. Virtanen Institute for Molecular Sciences Biocentre (AIVI) has greatly facilitated interactions and the development of companies in the Kuopio Science Park.

Strength and weaknesses in biotechnology in the Kuopio Region

The Panel recognises excellent synergies between the academic centres. Together with Pohjois-Savo Polytechnic, the Kuopio Technology Centre, Teknia Ltd. and the City of Kuopio, a civic alliance is in place that promotes the development of the Kuopio Science Park. Scientists from the academic centres are actively participating in public promotion of biotechnology. Thus, the citizens are well informed and supportive of the biotechnology activities in the Kuopio Region, and its creation of new jobs. The academic centres encourage and actively promote technology transfer. The Biocentre (AIVI) has also promoted spin-offs by providing laboratory space and sharing of infrastructure and seminars with biotechnology companies founded by staff members. The Panel received a list of 15 biotechnology companies in this region. They focus on gene therapy, drug development, plant biotechnology, stroke prevention, laboratory diagnostics, and clinical trials, in addition to functional food and DNA diagnostics. Although not in the immediate vicinity of Kuopio, Joensuu University (130 km to the east) does good quality research and contributes positively to the region's potential.

On the side of weaknesses, there is concern about the product pipeline of the newly started biotechnology companies. A refocus on products that have a chance to reach the market in the nearer future appears to be necessary in order to guarantee a long-term effect for the region. A second weakness is that, despite internationally renowned and outstanding clinical research on, among others topics, diabetes type II, cardiovascular disease and neurodegenerative disorders, the potential of this research for biotechnological applications has not yet been fully explored. A third concerns human resources. The Kuopio region clearly does not have enough postdoctoral fellows and has not been able to compete for the best young researchers against Helsinki and Tampere; a special programme may be required.

VI.C. OULU REGION

The Panel saw clear evidence that the innovation environment is well developed and supportive in Oulu, and that further contributions to the local and national economy can be expected through the mechanisms established to support further knowledge-driven companies based on life sciences research. This city, the capital of Northern Finland, has contributed hugely to, and benefited from, the overall success of the ICT industry. A later starting, but parallel support structure is developing effectively for life sciences innovation. This field is defined very broadly to include wellness technology and environmental technology in addition to healthcare-oriented technology.

Oulu has a successful University, which has selected for special attention biotechnology, environment, IT and Northern issues. Biocentre Oulu was the first Biocentre to be created in Finland and is noted for its high quality. One of its

strengths is biotechnology of the extracellular matrix, which has served to establish a successful example of commercialisation of life sciences technology. Details on the Biocentre are presented elsewhere – but it is appropriate to acknowledge the exceptional quality, drive and commitment of the Biocentre leader and colleagues as important elements in building an attractive innovation environment. There is significant additional potential to expand this process further in Oulu.

Technopolis Ltd.

The first interviews of the Panel took place in the most impressive Technopolis Ltd. building, designed and managed to foster new companies in the City, and suitably located adjacent to the Hospital (although unfortunately at some distance from the main University campus). This building would attract the envy of entrepreneurs working to build successful companies anywhere in the world. The environment appears highly conducive to the support of new companies and "a pleasant place to work".

The Panel understands that Technopolis Ltd., now a quoted company, owns and manages "incubator" facilities both in the Oulu and in the Helsinki regions. This approach to the provision of "incubator" facilities represents a further example (alongside TEKES and SITRA) of the early, national recognition of the opportunity to build the economy on technology. There is close working and mutual dependence between Technopolis Ltd., TEKES and Finnvera plc. Finnvera is a specialised financing company offering services to promote the domestic operations of Finnish businesses and to further exports and internationalisation of enterprises; it is owned by the Finnish state and has 16 regional offices around Finland. Technopolis benefits through loan and grant support whilst the creation of this "incubator" facilitates TEKES objectives. In the same way that TEKES has financed the "incubator" infrastructure, it would contribute substantially to the Oulu and other innovation environments were it to support core technology facilities on which both academic researchers and life sciences companies depend for the success of the innovation cycle, as recommended in Chapter IV.

Fibrogen Europe Ltd.

The Panel heard a presentation from Fibrogen Europe Ltd. Scientists from Oulu had been key contributors to the creation of Fibrogen, a joint Finnish/USA venture which is based in California and is a quoted company. This link, in turn, has led to the creation of a subsidiary company, Fibrogen Europe in Oulu, which is currently small but has significant potential for success and for creating jobs locally. The company research in Oulu depends heavily on local expertise and knowledge within the Biocentre and the University. Although a subsidiary of the US-owned company, Fibrogen Europe creates high-value jobs in Oulu and benefits from needing to compete successfully against international standards. A generic theme arising from the work of the Panel is the need for greater internationalisation of the Finnish biosciences industries. Within the requirements of normal commercial confidentiality, the presence of Fibrogen Europe allows the Oulu community to gain first-hand knowledge of international working styles.

Oulu as an innovation environment

The Panel met a group of people from different communities and interests within Oulu, who reported on their co-ordinated work to build a supportive infrastructure for innovation. A local initiative to establish an international school (and thus help in recruiting internationally), and an invitation to VTT Biotechnology to establish a branch in Oulu (and thus bolster the next step towards large scale production methods for local biotech companies) are two examples that this group is working in a concrete, down-to-earth manner to further enhance the attractiveness of their community for the biotech industry.

A challenge arises directly from the past success. The enviable Technopolis building is now full, and new space for innovation will be essential if innovation is to accelerate, or even continue at its current rate. Part of the space problem arises from a generic issue within Finland, an excessive number of very small companies (many duplicating company infrastructure and the use of space, yet so small as to make many unlikely to succeed in the long term). Paradoxically, although a problem, lack of space might encourage the much needed merging and/or acquisition amongst very small companies in Finland (see Chapter V).

VI.D. TAMPERE REGION

Founded in 1779, the city of Tampere (pop. 190,000), is the third-largest city in Finland. Situated in the Finnish lakeland, Tampere is a centre of industry, culture, research and education. The city has two major universities, a university hospital, and numerous research centres and institutes of higher education, making the city an important centre for research and hi-tech industries.

Except for a long-standing Centre of Excellence in biomaterials at the Tampere University of Technology (TUT), excellent development of the life sciences is relatively recent in Tampere. To a great extent it is linked to the new Biocentre (Institute of Medical Technology, IMT). The history of this development is instructive.

The University of Tampere was founded in 1960 and its Medical School in 1972. The basic sciences, clinical research and public health are well developed. During the late 1980's, the existence of this Medical School was put in question in the context of budgetary constraints at the national level. This threat triggered the creation, in 1994, of IMT, a dynamic new structure that regroups some of the best basic science departments and laboratories of the Medical School. This is an interesting experience in terms of science policy: it illustrates the benefits of a new structure, with its relative independence from more conservative University practices and rules. There is a concomitant danger of inhibiting what is left behind, as the result of isolation and psychological cleavages. Fortunately, the personalities of the current Dean of the Medical School and the current head of IMT have tipped the balance of Tampere on the plus side.

The panel was also impressed by the innovativeness of certain University laboratories that are not within the IMT. This includes Urology, Virology and a very

dynamic Department of Cell and Tissue Engineering. The latter is actively involved in modern research on biomaterials (in collaboration with TUT) and has led to several spin-off companies.

The IMT impressed the Panel with its dynamic and ambitious spirit: the faculty, postdocs and students were enthusiastic about being in Tampere and proud to "score" internationally from there. IMT has 14 independent laboratories with an excellent publication record, a record of external funding, and its own graduate programme. IMT is aware of the need for better connection to medical (including clinical) research. This Biocentre probably deserves more than the current 3% of all Biocentre resources.

TUT has 10 000 students and 130 professors. In the life sciences, they are active in biomaterials, bioenvironment and biological signal processing (a computer-science-driven domain, ranging from bioinformatics to brain imaging). The biomaterials research is known internationally and has already lead to profitable technology transfer and industrial development.

An interesting commercial validation entity exists in Tampere called Finn-Medi. Although sponsored originally with public funds, it operates as an independent company, covering both Technology Transfer and the creation and incubation of new biotech companies. Finn-Medi is dedicated to the life sciences and has the necessary scientific competence; its business model and mode of operation could be an excellent example.

The most successful biotechnology company that the Panel encountered in Tampere is BionX, an international player in biological medical implants, at the forefront of research in biomaterials. In this competitive field, BionX enjoys solid IP protection on biopolymer technology. It is listed in the Nasdaq.

Although not in the immediate vicinity of Tampere (150 km to north), the University of Jyväskylä is worth noting. Its best biotechnology laboratories work on production of recombinant proteins. There is also a strong impetus on the nanosciences.

VI.E. TURKU REGION

The Turku region (population 289,000) is the old capital and one of the cultural centres of Finland. It is notable for a strong commitment to biotechnology, which dates back 15 years, involves all interested parties (Universities, industry, city government) and is said to be their top priority. Considerable thought, effort and investment have gone into an ambitious integrated programme for biotechnology development. Turku is not a major player in ICT (unlike Helsinki and Oulu), but hosts more than half of the pharmaceutical and half the diagnostics industry in Finland. The city features three Universities and a polytechnic. It has set as its aim to become an internationally recognised centre of biotechnology in Finland and Europe. The Panel saw substantial strengths that favour this aim:

- *Quality of the Universities*. Of the two multidisciplinary Universities, Turku University (TU) is strong in the biosciences, with immunology and receptor biology being especially good; Åbo Akademi has complementary strengths in biophysics, structural and computational biochemistry. The School of Economics and Business Administration, the TU Central Hospital and the polytechnic are also relevant. Altogether, the city has 35,000 students and 7 graduate schools with 300 students.

- *Commitment of the City Government*. The Deputy Mayor herself (an MD) came to describe this commitment, which includes direct support to research and education programmes; establishment of Turku BioValley Ltd. on 65 acres (14.5M €, to build infrastructure and own, manage and provide research or production facilities for biosciences); designation of prime land as the Turku Science Park (including the academic institutions and 750 enterprises); establishment of an international school to facilitate recruitment of scientists with families (Autumn 2003).

- *Strong presence of pharmaceutical and diagnostics industry*.

- *Strong collaborative spirit*. The Universities coordinate their activities, pool resources, and share the Turku Biocity building. This houses research groups from both, as well as the Centre for Biotechnology, a set of core facilities that absorb all the earmarked biotechnology funds.

- *Compact campus* in Turku Science Park. This permits sharing of facilities and encourages interchange and collaboration.

- *Openness to multiculturalism*, partly reflecting the Swedish legacy and the city's location on the Stockholm-St. Petersburg axis.

On the other hand, through the presentations and interviews, the Panel also identified some weaknesses:

- Conservative University structures. Although the Panel has not repeated this for every city, this is a general problem in Finland. In Turku it is in striking contrast to the inventiveness and cooperativity of the community. The main problems are the absence of a tenure-track system, resulting in very few young group leaders; the near-absence of postdoctoral fellows and therefore the limited daily guidance of the graduate students; and the 4-paper rule for the PhD degree which deters students from tackling difficult projects ("no room for failure").

- Sense of lack of resources which, together with transient appointments of the directors of the core facilities, undermine the effectiveness of the earmarked funds; complaints that too low a fraction of these funds is assigned to Turku (and some grumblings that the University retains 20% for Biocity).

- Sense that, despite its ambitions, the community is not able to compete for the best researchers against Helsinki and Stockholm.

CONTENTS

VII. RESPONSES TO THE STEERING COMMITTEE'S QUESTIONS

VII.A. The Impact of National Biotechnology Funding Programmes

1. To what extent and how does the status and quality of research and innovation environments reflect the impact of the previous public biotechnology funding programmes?

The Panel has concluded that the national effort in biotechnology has made impressive progress. The question becomes, to what extent and how this progress can be credited to the public funding programmes.

- The progress in the research sphere has been particularly impressive, relative to 15 years ago. Internationally known foci of excellence now exist in most major cities.

- The Biocentres, funded by an earmarked programme of the Ministry of Education, have been central to these developments. Their funding has been relatively modest (16.6 M€ in 2001), but has had important direct and indirect effects. Biocentres have supported directly high quality research and/or essential research infrastructure. Indirectly, they have fostered a shift in the scientific landscape towards recognition of excellence as the paramount value, assembly of critical mass as a necessity, and cooperation as an effective mode of operation. Most have instituted periodic international reviews leading to significant turnover; in sum, they have fostered excellence, promoted accountability and enhanced both ambition and a collaborative spirit in the community.

- The special programme identifying biotechnology as a national priority has had important amplification effects and mobilised host University funding of biotechnology. In 2001, these Universities reportedly spent, from their own budgets, 152% of the Ministry of Education funding of the Biocentres.

- Amplification also occurred at the level of city authorities. Some provided modest direct support to the biotechnology research sector. Invariably, they helped assemble civic alliances to promote infrastructure projects in support of the biotechnology innovation environments (science parks, industrial parks, dual-use buildings *etc.*).

- The Academy of Finland has stimulated excellence in biotechnology research, mostly through stringent evaluation procedures and partly through targeted Research Programmes. Without pre-allocating a fixed share of its resources, in 2001 it provided competitively ca. 39 M€ or 21% of its resources to biotechnology (234% of the Ministry of Education's earmarked funds). Based on the

questionnaire responses, much of this funding went to Universities and Biocentres (in the proportion of 49% and 51%, respectively), while additional funds went to research institutes and individual scientists.

- The Ministry of Trade and Industry's agency, TEKES, also contributed 19.8 M€ to biotechnology research with an applied orientation: 39% to Biocentre-based and 61% to University-based projects. This amount was only 5.1% of TEKES' total funds (which have a wider mission), but still exceeded the level of earmarked funds from the Ministry of Education.

- The Ministry of Social Affairs and Health has also wisely promoted biotechnology research in its own centres, especially KTL, thus reinforcing important strengths in the biomedical sciences of Finland. The involvement of other relevant Ministries has been minimal.

- In conclusion, the earmarked programme of the Ministry of Education was a pioneering initiative, and had a major impact on the status and quality of biotechnology research in Finland, both directly and by stimulating investments from other sources.

2. What other impact have public biotechnology funding programmes had?

- The establishment of Graduate Schools by the Ministry of Education, with quality-control assured by the Academy of Finland, had a major impact on advanced training. In combination with the Biocentres, the Graduate Schools are rapidly modernising graduate education in biotechnology.

- TEKES has provided significant support for industrial R&D in biotechnology (20.1 M€ in 2001).

- The upgrading of biotechnology research and training, together with the stimulation of industrial R&D and local infrastructure, have greatly improved the biotechnology innovation environment and fostered a significant start of bioindustries in Finland.

3. What has been the added value of the national development programmes running since 1988?

- The answers to Questions 1 and 2 make clear that the added value of these programmes has been quite remarkable.

4. How sustainable is the Finnish research system in biotechnology taking into account the size of the Finnish population, national economy and other relevant attributes?

- The continuing improvements in graduate education and in the research system bode well. However, bold action is needed to build on these successes and make them sustainable, as summarised below. Additional structural reform, investment and internationalisation are needed.

- The most fundamental reform will be to introduce a tenure-track system for University appointments. Without it, Finland cannot adequately retain, repatriate or attract the necessary top-quality young scientists, and will lose their talent and energy from the national effort.

- A complementary further need is to modernise University organisational structures (faculties, departments) and curricula, so as to achieve greater flexibility, integration of the life sciences, interdisciplinary interfaces, and close links between biology and medicine.

- Scarcity of postdoctoral fellows is a striking gap in most Universities, which needs to be addressed by coordinated actions: increasing the capacity of graduate education to enhance the supply, recruiting foreign postdoctoral fellows, and making University and researcher careers more attractive, as suggested above.

- The research system can be strengthened further by establishing independent research institutes (ideally adjacent to, and collaborating with, the Universities) for fields of special interest, in particular those where Finland has a comparative advantage. KTL is an excellent model.

- Internationalisation is strongly recommended for the entire biotechnology system. In the research sector it will sharpen performance with a more demanding frame of reference, close gaps in expertise, and address future demographic problems.

- Sustainability requires continuity or even increases in funding the instruments that have proven so positive to date, while undertaking the additional tasks that are recommended.

- There is a major gap in resources for funding and sustaining the core facilities that are now essential for biotechnology. At least the major core facilities can be shared with industry. Funding by TEKES is recommended, and funding by the Ministry of Education or the Academy of Finland and a national competition for large equipment (as was done in the UK recently) are additional options.

5. How competitive is the Finnish innovation system in biotechnology as a whole and the local biotechnology centres in international comparison? What are their strengths and weaknesses? What opportunities and threats do they have?

The competitiveness of the research and training sector was addressed under Question 4. The translation process, from basic to applied research and then to commercialisation, clearly has captured the interest of Finnish scientists and is benefiting from investments at several levels; however, to enhance success some significant improvements are needed.

- The two most important (and related) requirements are to rationalise the ownership of IPR and to professionalise technology transfer. Ownership of the

IPR needs to be vested in the institutions, including the Universities, with guarantees that the inventors will share sufficiently in the proceeds. A professional technology transfer infrastructure is vitally important, to optimise the protection and utilisation of IPR, and to help establish viable companies when appropriate. Supporting the training of technology transfer professionals and setting up effective technology transfer structures are suitable opportunities for TEKES.

- The local/regional centres for promoting biotechnology are a strong feature in Finland. They tend to engage all the necessary actors from the public and private sectors. Their effectiveness would be enhanced by the recommended professionalisation of technology transfer activities and by the recommended establishment of well-funded major research infrastructures. Recruitment of foreign scientists requires some specific measures (*e.g.* foreign-language schools). "Inter-regional" programmes may enhance the value of isolated nuclei of excellence in outlying areas, but would also build more critical mass in the smaller biotechnology centres.

6. What is the current status of Finnish bioindustries and how does their future look? What kinds of local, regional and/or national initiatives have contributed to its growth and development? What has been the role of dedicated technology transfer activities in the nearest environment?

- Many biotechnology companies are now being established in Finland but most are too small for success. Furthermore, they tend to have a too narrow and often exclusively local investor base. Fewer and more broadly based companies should be the objective, and would ultimately yield greater returns.

- The rarity or even absence of dedicated technology transfer professionals and the confused ownership of IPR are major causes of the current difficulties. Too facile selection of candidate companies for seed investment does not favour ultimate commercial success. Early competitiveness and exposure to international norms should be encouraged by the participation of international VC investors. Mergers and acquisitions between companies with obvious synergies should be encouraged.

- Competent and experienced managers are in short supply; a national effort to train managers and business development specialists for biotech would be very beneficial.

- SITRA, the national albeit independent investment fund, is a great asset for the development of hi-tech industries in Finland; it has been involved in the establishment of most of the biotechnology companies. The SITRA staff are highly professional, and have already initiated steps in the direction that the Panel recommends. They are encouraged to accelerate their partnering with highly selected international biotech funds specialised in early stage financing, and to develop further relationships with non-Finnish investors to promote co-funding of companies within Finland as they mature.

- Private VC funds in Finland may also be too small and numerous, requiring consolidation and internationalisation. Financial incentives to attract independent international VC funds into Finland may be considered.

VII.B. Evaluation of Future Visions and Strategies

7. How promising and ambitious are the visions of the organisations and how adequate and appropriate are their strategies taking into account the available resources?

- As noted in the report, the Panel encountered several impressive leaders, both in Universities and in Biocentres. They reflect (and we suspect have helped shape) appropriate and ambitious visions in their organisations, and are due credit for the organisations' success.

- As concerns the University sector (Universities and Biocentres), the Panel admired the clear, strong visions for the future prevalent at the two Biocentres and the University of Helsinki, and at Biocentre Oulu. We were also gratified by the ambition coupled with high standards and internal cohesion encountered in the small academic community of Tampere, and found the Turku environment highly attractive. Turku is notable for its strong focus on the biosciences, the high degree of integration and the collaborativeness of both Universities, the interactions with pharmaceutical and diagnostic companies, and the evident support of the local authorities; its academic sector has a high level of overall performance and a number of foci of excellence. The choice to devote the Biotechnology funds to core facilities is understandable in light of lack of alternative funding sources, but has the downside of missing opportunities to increase recruitment, catalyse new research directions, and create critical mass in areas of present excellence. The Kuopio community has some unusual research strengths for such a small city, and actively promotes biotechnology; development of an integrated strategy to take advantage of all the strengths and address the weaknesses would be helpful.

- Amongst other Universities, TUT is notable for its multidisciplinary approach, including integration of engineering with biochemistry and biotechnology, and has impressive strength in specific niches. HUT has an appropriate strategy for its speciality of classical biotechnology and fermentation technology. The Universities of Joensuu and Jyväskylä have strong determination, coupled with specific strengths, but require help to address the problems of subcritical mass and isolation, possibly through a "trans-regio" research networking programme.

- Amongst the research institutes, KTL is a leading light; it has excellent vision and prospects. CSC Scientific Computing is a new and highly promising entity, with an excellent strategy. VTT has a strategy appropriate for its focus on industrial biotechnology. The impression from FIOH is satisfactory. MTT researchers are forward looking but need encouragement and resources. In the other three institutes that the Panel interviewed, encouragement to utilise

biotechnology for socially beneficial applications is needed at the governmental level.

- As concerns the vision and strategy of the major funding organisations (Ministries, Academy of Finland, TEKES, SITRA), overall the Panel is very impressed. Finland has become one of the leaders amongst the smaller countries of Europe in developing biotechnology, from a starting point far behind countries like Sweden or Switzerland. Comments on the strategies of all of these organisations have been made in the appropriate sections, but the Panel wishes to recognise here the special contributions of the Ministry of Education and the Academy of Finland in this national effort.

8. How well is the Finnish biotechnology sector prepared for the challenges of the 6th Framework Programme of the EU, the European Commission's communication " Life Sciences and Biotechnology – A Strategy for Europe", the ERA initiative and the accelerating globalisation of research and biotechnology business?

- The Finnish biotechnology sector has participated intensely in the Framework Programmes of the EU. The only puzzling non-participation is that of HUT; low participation by institutes in the agriculture, forestry and environment sectors is understandable given their minimal involvement in the national biotechnology effort. FP6 has a much stronger focus on research, in particular on health-related biotechnology, and places more emphasis on large integrated projects and networks of excellence. Finland is well positioned to take advantage of these new opportunities and other cooperative initiatives supported by the Commission. The main hurdle is that internationalisation of the research system and the new industrial sector is still limited. The Panel has stressed repeatedly the imperative of internationalisation, because it remains one of the few systemic weaknesses in the national biotechnology effort.

9. Is the magnitude and quality of cooperation at local, national and international level adequate? How should it be improved?

- Cooperation is one of the great strengths of the Finnish effort. With very few exceptions, the Panel encountered this strength throughout the site visits and interviews. International links need to be strengthened significantly (*e.g.* they do not approach the level of Switzerland or Sweden, not to mention the UK or Germany).

10. What else does the Panel recommend to funding organisations, Universities and research institutes, enterprises and other organisations involved to improve the competitiveness of the Finnish research system and biotechnology sector?

- Rather than repeat or summarise the recommendations given throughout this report, the Panel points especially to the Summary Recommendations of Chapters III, IV and V, and the answers to other Questions.

11. What should be the overall structure and priorities of the next national development programme for 2004-2006?

The Panel has felt free to speak its collective mind throughout this evaluation, and has offered summary recommendations at the end of Chapters III-V. The answers to previous questions and the observations and conclusions in the main text may also be useful for planning purposes. Here we will bring together and recapitulate the major recommendations. Some of them have implications beyond the biotechnology system (e.g. broad internationalisation, tenure-track system in the Universities). We hope that such reforms can be introduced (at least on a pilot basis) in the biotechnology sector, which is both well defined and sufficiently large for adequate testing.

General

- The current overall planning for biotechnology is of high quality, and its broad directions should be maintained. The important innovative instruments that are already in place (*e.g.* Graduate Schools, Biocentres, civic alliances to promote regional innovation environments), should be preserved and strengthened further.

- TEKES and SITRA are potentially great assets; some improvements have been suggested to optimise the benefits.

- Given the long-term horizon of biotechnology, it is essential that support be sustained, to develop this sector as a long-term investment.

- Research as well as teaching need to be recognised in the funding of Universities.

- Some recommended reforms have significant cost, and therefore the total funding should increase if possible.

- The entire biotechnology system would be strengthened by increased internationalisation (from postdoctoral recruiting to VC investing).

- Expert reviewing is recognised as important; it should be extended where it is missing.

Academic sector (fundamental research and training)

- Institute a tenure-track system in the Universities, to ensure that the academic system can benefit from the energy and talent of the best young people.

- As an immediate action, fund a specific programme to retain/repatriate/ internationally recruit exceptional postdoctoral fellows and young group leaders in the Universities Biocentres and research institutes.

- Invest into core facilities as the recent scientific developments require (both capital equipment and personnel to run them).

- Adjust the funding of individual Biocentres periodically, based on international peer reviews.

- However, also place more trust on the best scientists (cf. the special 7-year Merit Award grants of the NIH in the USA).

- Enhance the role of the Graduate Schools: entrust them with the responsibility for a greater fraction of fellowships for the PhD, and encourage admission of candidates by a committee rather than individual supervisors, opportunities for rotations in different laboratories, and emphasis on quality rather than quantitative norms for acceptance of the dissertation.

- Expand and restructure the biosciences to encourage modernisation, integration and interdisciplinarity in research and training.

- Promote bioinformatics and strengthen the interfaces between biosciences, medicine and chemistry.

- Emphasise the fields in which Finland has comparative advantages (*e.g.* human genetics and epidemiology).

Research & Development

- Institute peer review of applied research in TEKES.

- Shift the ownership of IPR to the institutions, with adequate sharing of the benefits with inventors.

- Train technology transfer professionals and establish technology transfer entities of high competence.

- Make available high quality instrumentation infrastructure (with support from TEKES, to encourage sharing between the academic and commercial sectors).

- Utilise technology transfer professionals not only for effective IP protection but also for selecting the appropriate follow-up (applied research, licensing or company formation).

Industry

- Encourage mergers and acquisitions, utilising synergies to build strength.

- Encourage rigorous evaluation already at the seed stage, avoiding fragmentation of IP and ensuring the formation of companies with significant growth potential.

- Attract international VC, both for seed funding and for sustaining growth in the stronger companies as they mature.

APPENDIX VIII. A.

TERMS OF REFERENCE

THE EVALUATION OF BIOTECHNOLOGY IN FINLAND – THE IMPACT OF PUBLIC RESEARCH FUNDING AND THE STRATEGIES FOR FUTURE

BACKGROUND AND PURPOSE

1. The impact of public research funding on biotechnology and related life sciences in Finland will be evaluated in 2002 as a joint effort of the Ministry of Education, the Ministry of Trade and Industry, the Ministry of Agriculture and Forestry, the Ministry of Social Affairs and Health, the Ministry of the Environment, the Academy of Finland, the National Technology Agency Tekes, Sitra and the Finnish Bioindustries. The evaluation will be done by a panel of international experts. The purpose of the evaluation is two-fold: first, to evaluate the impact of public research funding, and, second, to advise funding organisations, universities, research institutes and industry how to develop and focus biotechnology and life sciences research in Finland. The mission of this exercise is to improve the competitive ability of Finnish innovation system in biotechnology.

2. According to the report of the Working Group released in December 2000: *"The preparations for the biotechnology evaluation shall be started in early 2001 in a joint effort by different ministries, the Academy of Finland, the National Technology Agency and Sitra. The evaluation shall apply not only to the public funding of biotechnology research and its impacts and productivity as a whole, but also its impacts on the innovation system as a whole, including the impacts of earmarked funding on the economy and society. The next national development programme for 2004-2006 shall be drafted on the basis of the recommendations of this evaluation."*

3. The Ministry of Education appointed on 24 July 2001 a Steering Committee, chaired by Director General Arvo Jäppinen, to plan and support the execution of the evaluation. The Steering Committee members represent the Ministries of Education, Environment, Trade and Industry, Agriculture and Forestry, and Social Affairs and Health; and the Academy of Finland, the National Technology Agency Tekes, universities and Finnish Bioindustries FIB. The Steering Committee has also two permanent experts representing Statistics Finland and CSC – Scientific Computing Ltd. The Steering Committee is due to complete its assignment by 31 December 2002.

MEMBERS OF THE EVALUATION PANEL

4. The evaluation will be carried out as an external evaluation by an international Panel of six independent high-level experts. The Steering Committee has invited Professor **Fotis C. Kafatos**, Director General of the European Molecular Biology Laboratory, to act as the Chair of the Panel. The other members of the panel are **Konrad Beyreuther**, University of Heidelberg (D); **Nam-Hai Chua**, Rockefeller University, New York (US); **Bernard Mach**, University of Geneva (emeritus), Geneva (CH); **David Owen**, MRC Technology Transfer, London (UK); and **Joan Steitz**, Yale University, New Haven (US).

OBJECTIVES AND SCOPE OF THE REVIEW

5. The external evaluation has two main objectives. The first objective is to find out what has been the scientific and socio-economic impact of the public funding on biotechnology research in Finland. The second objective is to assess whether the strategies of public funding organisations, universities, research institutes and other actors influencing technology transfer are appropriate and adequate in achieving scientific excellency and socio-economic impact in the field of biotechnology in Finland.

6. The results of the evaluation – conclusions and recommendations – are used by the public funding organisations to develop their individual and joint strategies to promote biotechnology research and the application of it in Finland. As proposed by the Working Group "Biotechnology 2000", the next national development programme for biotechnology for 2004-2006 will be drafted on the basis of the recommendations of this evaluation. The feedback from the Evaluation Panel will also help universities, research institutes and other similar organisations to develop their own strategies.

7. In this evaluation, biotechnology is understood to cover all life sciences research that uses the methods of modern biology and the applications of this research. The OECD Working Party on Biotechnology and the OECD Working Party of National Experts on Science and Technology Indicators have provisionally adopted the following definition of biotechnology: *"The application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."* This definition is supposed to help to decide whether a certain kind of research activity or certain kinds of products or services can be classified as biotechnology.

8. The scope of this evaluation is somewhat different from a traditional evaluation of a scientific research field. The quality of the research is not evaluated at the level of individual research groups, and accordingly, the recommendations are not supposed to be targeted to research groups but to research institutes, universities and funding organisations as a whole.

KEY ISSUES TO BE ADDRESSED

The impact of national biotechnology funding programmes

9. The External Evaluation panel is supposed to answer the following questions:

- To what extent and how does the status and quality of research and innovation environments reflect the impact of the previous public biotechnology funding programmes?

- What other impact have public biotechnology funding programmes had?

- What has been the added value of the national development programmes running since 1988?

- How sustainable is the Finnish research system in biotechnology taking into account the size of the Finnish population, national economy and other relevant attributes?

- How competitive is the Finnish innovation system in biotechnology as a whole and the local biotechnology centres in international comparison? What are their strengths and weaknesses? What opportunities and threats do they have?

- What is the current status of Finnish bioindustries and how does their future look? What kinds of local, regional and/or national initiatives have contributed to its growth and development? What has been the role of dedicated technology transfer activities in the nearest environment?

Evaluation of the future visions and strategies

1. The External Evaluation panel is supposed to answer the following questions:

- How promising and ambitious are the visions of the organisations and how adequate and appropriate are their strategies taking into account the available resources?

- How well is the Finnish biotechnology sector prepared for the challenges of the 6th Framework Programme of the EU, the European Commission's communication " Life Sciences and Biotechnology – A Strategy for Europe", the ERA initiative and the accelerating globalisation of research and biotechnology business?

- Is the magnitude and quality of co-operation at local, national and international level adequate? How should it be improved?

- What else does the Panel recommend to funding organisations, universities and research institutes, enterprises and other organisations involved to improve the competitiveness of the Finnish research system and biotechnology sector?

- What should be the overall structure and priorities of the next national development programme for 2004-2006?

TASKS, RESPONSIBILITIES AND WORKING ARRANGEMENTS OF THE PANEL

1. In conducting the expert evaluation the panel members will base their examination on:

- *Desk research* to examine all relevant documentation as provided by the Steering Committee such as description of the Finnish innovation system, public documents, previous scientific evaluations of universities, institutes or research

fields, lists of publications and answers to a questionnaire prepared for this evaluation.

- *Interviews with government officials and other similar experts* who have been or are currently involved in planning and implementing public biotechnology funding

- *Interviews with market actors* such as representatives of biotech industry, regional technology centres and technology transfer companies

- *Interviews with rectors of universities, directors of researcher institutes and other key players in biotechnology research*

- *Interviews with a sample of researchers* representing various phases of the researcher career

2. The Panel will provide the Steering Committee with the draft report including the main conclusions and recommendations by 31 October 2002. The correctness of facts will then be checked by the Steering Committee by 8 November 2002. The Chairman of the Panel confirms and signs the final report by 15 November 2002.

3. The Panel will have a Secretary recruited by the Chair of the Panel. The Steering Committee will provide the Chair and the Panel with all necessary secretarial and other support for preparing and accomplishing meetings and site visits.

4. The Panel Member and the Secretary undertake not to make use of and not to divulge to third parties any non-public facts, information, knowledge, documents or other matters communicated to him/her or brought to his/her attention in the performance of the evaluation.

PROVISIONAL TIMETABLE

5. The evaluation will proceed according to the following timetable:

- December 2001: The Steering Committee meets the Panel Chair and discusses the composition of the Panel and the Terms of Reference.

- January 2002: The Steering Committee confirms the Terms of Reference including the Membership of the Panel.

- February-May 2002: The Steering Committee and its Secretariat collect, compile and prepare the background documents for the Panel and survey the visions and strategies of the involved organisations.

- June 2002: The Panel meets for the first time, gets its background documents and meets the representatives of the public funding system.

- June-August 2002: The Panel studies the material it has been provided with.

- September 2002: The Panel makes the planned site visits and has its second meeting.

- October 2002: The Panel prepares its conclusions and recommendations and submits its report to the Steering Committee by 31 October 2002.

- November 2002: After checking the correctness of the facts the Chair of the Panel confirms and signs the final report, which will then be printed.

- December 2002: The final report will be delivered to the Ministry of Education and presented to the public by the Chair of the Panel.

APPENDIX VIII. B.

BIOTECH 2002 EVALUATION IN FINLAND

LIST OF ORGANISATIONS INTERVIEWED:

I QUESTIONNAIRES + INTERVIEWS:

Funding organisations

1 Academy of Finland
2 Tekes – the National Technology Agency
3 Sitra - Finnish National Fund for Research and Development

Biocentres

4 A.I. Virtanen Institute for Molecular Sciences (AIVI), University of Kuopio
5 Biocenter Oulu, University of Oulu
6 Biocentrum Helsinki, University of Helsinki
7 BioCity Turku, University of Turku
8 Institute of Biotechnology, University of Helsinki
9 Institute of Medical Technology (IMT), University of Tampere

Universities (Form A: universities with a biocentre)

10 University of Helsinki
11 University of Kuopio
12 University of Oulu
13 University of Tampere
14 University of Turku
15 Åbo Akademi University

Universities (Form B)

16 Helsinki University of Technology (HUT)
17 Tampere University of Technology (TUT)
18 University of Joensuu
19 University of Jyväskylä

Ministries

20 Ministry of Agriculture and Forestry
21 Ministry of Education
22 Ministry of Environment
23 Ministry of Social Affairs and Health
24 Ministry of Trade and Industry

Research Institutes

25 Agrifood Research Finland (MTT)
26 Finnish Environment Institute (SYKE)
27 Finnish Forest Research Institute (METLA)
28 Finnish Institute of Occupational Health (FIOH)
29 National Public Health Institute (KTL)
30 National Veterinary and Food Research Institute (EELA)
31 VTT Biotechnology (Technical Research Centre of Finland)

II Interviews only

Research Institutes

32 CSC Scientific Computing LTD
33 The Research Institute of the Finnish Economy (ETLA)

Companies

34 Ark Therapeutics Oy
35 Oy Jurilab Ltd
36 Fibrogen Europe Ltd
37 Finnzymes Oy
38 Bionx Implants
39 Fit Biotech Plc
40 BioTie Therapies Corp.
41 Hormos Medical Corp.
42 Carbion Inc.
43 Licentia Ltd

APPENDIX VIII. C.

BIOTECH 2002 EVALUATION IN FINLAND

CONTENTS OF THE EVALUATION DOCUMENTS

1. Finnish research and innovation environment

   Academy of Finland (2000). *The State and Quality of Scientific Research in Finland. A Review of Scientific Research and Its Environment in the Late 1990s.* Helsinki: Academy of Finland.
   Science and Techonology Policy Council of Finland (2000). *Review 2000: The Challenge of Knowledge and Know-How.* Helsinki: Science and Technology Policy Council.
   Research in Finland (2001). Helsinki: Ministry of Education.
   Statistics Finland. *Science and Technology in Finland 2000 (2001).* Science, Technology and Research 2001:2. Helsinki: Statistics Finland.
   Kuusi, Hannele (2001): *Finland a European Leader in Biotechnology.* Kemia-Kemi 28 (6), 431-436.

   Appendix: Biotechnology in figures

2. Development of biotechnology research in Finland

   2.1 EMBO evaluation report, 1996
   2.2 "Biotechnology 2000 Working Group"
   Appendix: Biotechnology 2000, Report from Finland, Ministry of education, 2000:31
   2.3 Cooperation between Finnish biocentres

3. Questionnaires
   Contents of questionnaires *(material separately in plastic folders)*

4. Biotechnology industry and its development; Venture capital financing
   4.1 Overview of the biotechnology industry in Finland
   4.2 Research and development funding enterprises by Tekes
   4.3 Supporting measures for new business activities
   4.4 Venture capital financing markets
   Finnish venture capital industry in 2001
   Venture capital investments by industry sector
   Public venture capital financing
   Private venture capital financing

Appendices:
Preliminary findings of the ETLA and Etlatieto Oy study on Finnish biotechnology firms
Index of Biotechnology Companies, Organisations and Science Centres in Finland
BioTech Finland

5. Article: *Finnish biotechnology – built on solid foundations*
   by Riku Lähteenmäki, Nature Biotechnology, 20:437-440 (2002).

6. The Finnish intellectual property system
   - 6.1 Effective Commercialisation of University Inventions, University Inventions Working Group, June 2002.
   - 6.2 The Finnish intellectual property system
   - 6.3 Finnish biotechnology and pharmaceutical patents obtained in Finland, EPO patents and in the United States, 1989-1998

7. Science and society
   - 7.1 Ethical evaluation of research in Finland
   - 7.2 Finnish Science Barometer 2001

APPENDIX VIII. D.

BIOTECH 2002 EVALUATION IN FINLAND

BACKGROUND SURVEY

INSTRUCTIONS TO RESPONDENTS OF QUESTIONNAIRES

The purpose of the document is three-fold. First, the Biotechnology 2002 evaluation is described in terms of its purpose, scope, utilisation and data collection. In addition, biotechnology is defined as understood in the evaluation. Second, general instructions for the survey and other requested background material are presented in Finnish. Lastly, a detailed explanation of each question at the survey is also included in Finnish.

About the Evaluation

The impact of public research funding on biotechnology and related life sciences will be evaluated in Finland in 2002 as a joint effort of the Ministry of Education, the Ministry of Trade and Industry, the Ministry of Agriculture and Forestry, the Ministry of Social Affairs and Health, the Ministry of the Environment, the Academy of Finland, the National Technology Agency (Tekes), Sitra and the Finnish Bioindustries. **The purpose of the evaluation** is two-fold: first, to evaluate the impact of public research funding and second, to advise funding organisations, universities, research institutes and industry how to develop and focus biotechnology and life sciences research in Finland. The mission of this exercise is to improve the competitive ability of the Finnish innovation system in biotechnology.

In the evaluation, **biotechnology** is understood to cover **all life sciences research that uses the methods of modern biology and the applications of this research**. The OECD Working Party on Biotechnology and the OECD Working Party of National Experts on Science and Technology Indicators have provisionally adopted the following definition of biotechnology: *"The application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."* This definition is supposed to help decide whether a certain kind of research activity can be classified as biotechnology.

The scope of the evaluation is somewhat different from a traditional evaluation of a scientific research field. The quality of research is not evaluated at the level of individual research groups, and accordingly, the recommendations are not supposed to be targeted to research groups but to research institutes, universities and funding organisations as a whole.

The results of the evaluation – conclusions and recommendations – will be used by the public funding organisations to develop their individual and joint strategies to promote biotechnology research and the application of it in Finland. As proposed by the Working Group 'Biotechnology 2000', the next national development programme for biotechnology for 2004-2006 will be drafted on the basis of the recommendations of this evaluation. The feedback from the Evaluation Panel will also help universities, research institutes and other similar organisations develop their own strategies.

About the Survey

The purpose of the survey is to provide the international panel with a clear picture of the Finnish innovation system in biotechnology and the roles and strategies of various actors. The data describing your organisation's current mission, research activities and results are supposed to help the panel assess the impact of public biotechnology funding in Finland. The visions, strategies and SWOT analysis (strengths, weaknesses, opportunities, threats) you are requested to present, are supposed to help the panel evaluate the future prospects and ground their recommendations for the future.

Your organisation's answers will be forwarded to the panel members as such. Only the layout may be edited, if necessary, to help the panel members read the documents.

APPENDIX VIII. E.

(add here the name of your organisation in English)

BIOTECH 2002 EVALUATION – QUESTIONS TO BIOCENTRES

PART A. ORGANISATION, STRATEGY AND RESOURCES

1. Mission, organisation and administration of the Biocentre

a) Describe the mission, organisation and financial structure of the Biocentre and its decision-making process on research strategies. Inclusion of a chart describing the operation of the organisation is recommended. Max. length 1.5 pages.

b) Use Table 1 to indicate the percentage distribution of the Biocentre's biotechnology-related research activities by research field in 2001.

Table 1. The percentage distribution of the Biocentre's biotechnology-related research activities by research field in 2001.

Research field	(%)
Applied biotechnology	
Cell and molecular biology of animal cells	
Molecular genetics	
Molecular microbiology and microbial genetics	
Plant biotechnology	
Protein chemistry and macromolecular structure	
Other biotechnology, please specify:	
Other than biotechnology	
Total	**100**

2. Research strategy of the Biocentre

Describe the present research strategy of the Biocentre: its focus, objectives, organisation and priorities. Max. length 1.5 pages.

3. Research funding for biotechnology in 1996-2001

Use Table 2 to indicate the amount of funding the Biocentre has received for biotechnology research from different sources in 1996–2001.

Table 2. The funding **(in thousand EUR)** the Biocentre has received for biotechnology research from different sources in 1996–2001.

Source		**Budget year**						
		1996	**1997**	**1998**	**1999**	**2000**	**2001**	**Total**
Budget funding	**Earmarked funding**							
	Graduate schools							
	Other							
External funding	**Academy of Finland**							
	Tekes							
	Ministries							
	Other public sources							
	Industry							
	Private foundations							
	EU							
	Other foreign organisations							

Notes (if applicable)

4. The use and impact of earmarked biotechnology funding from the Ministry of Education

a) Report in detail how the earmarked biotechnology funding from the Ministry of Education was used in 2001. Max. length one page.

b) Describe how the Biocentre has implemented the development plans set up in the Working Group Report 'Biotekniikka 2000' of the Ministry of Education. Max. length 0.5 page.

c) Evaluate from the Biocentre's point of view the impact of the earmarked biotechnology funding from the Ministry of Education. Max. length 0.5 page.

5. Research personnel in 1996 and 2001

Use Tables 3a and 3b to indicate the number of research personnel and person-years of all personnel in 1996 and 2001, respectively, by personnel category.

Table 3a. The number of all personnel and foreign citizens in the staff, and the person-years of all personnel **in 1996**.

Personnel category	Number of personnel		Person-years of all personnel
	All staff	Foreign citizens	
Principal investigators			
Senior researchers			
Post-doctoral researchers			
Graduate students			
Other trainees			
Technical personnel			
Total			

Table 3b. The number of all personnel and foreign citizens in the staff, and the person-years of all personnel **in 2001**.

Personnel category	Number of personnel		Person-years of all personnel
	All staff	Foreign citizens	
Principal investigators			
Senior researchers			
Post-doctoral researchers			
Graduate students			
Other trainees			
Technical personnel			

Total			

6. Core facilities

a) Describe the core facilities available at the Biocentre. Max. length 0.5 page.

b) Evaluate the role and importance of **the national core facilities** (e.g. CSC – Scientific Computing Ltd, Finnish DNA Microarray Centre and Finnish Genome Centre) for the biotechnology research of the Biocentre. Max. length 0.5 page.

PART B. RESEARCH AND ITS IMPACT

7. Major projects in the field of biotechnology and its applications in 1996-2001

Describe 5–10 major projects (e.g. R&D projects, infrastructure development) that highlight the Biocentre's mission in the field of biotechnology and that have significantly contributed to biotechnology research locally, nationally and internationally. Each project (max. length 0.5 page) should be described by name and goals of the project, the name(s) of the principal investigator(s), if applicable, collaborators in Finland and abroad, main lines of research, if applicable, and major achievements.

8. Scientific impact in terms of biotechnology publications in 1996-2001

a) Use Table 4 to indicate the number of biotechnology publications by year of publication.

Table 4. The number of biotechnology publications in international peer-reviewed journals in 1996–2001 by year of publication.

	Year of publication						
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**TOTAL**
Publications in international peer-reviewed journals							

b) List **30 publications** (published in 1996–2001) that **profile the Biocentre** in biotechnology research.

9. Research collaboration in terms of joint publications in 1996-2001

List **30 publications** (published in 1996–2001) that **profile the research collaboration** of the Biocentre in the field of biotechnology. Break up the list into three categories according to the type of collaboration:

a. collaborations within the University

b. collaborations with other institutions in Finland

c. collaborations with foreign institutions.

Specify also the collaborators (organisations).

a. collaborations within the University

b. collaborations with other institutions in Finland

c. collaborations with foreign institutions

10. Research collaboration in terms of EU projects in 1996-2001

List separately all the research projects funded by the EU in which the Biocentre has acted (a) as a co-ordinator or (b) as a partner in 1996–2001.

Of each project, indicate the name of the project, the name of the co-ordinator (principal investigator and organisation), a list of participating countries, the year of signing the funding contract and the name of the respective EU research programme.

a. as a co-ordinator

b. as a partner

11. Researcher training in 1996-2001

a) Use Table 5 to indicate the number of doctoral degrees achieved in the research groups of the Biocentre in 1996-2001.

Table 5. The number of doctoral degrees completed in 1996-2001.

Field of degree	Year of completion of doctoral degree						
	1996	1997	1998	1999	2000	2001	TOTAL
Science							
Medical sciences							
Agriculture and forestry							
Technical sciences and engineering							
Other							
TOTAL							

b) Describe how researcher training is organised at the centre. Max. length one page.

12. Mobility of researchers

Use Table 6 to indicate the present location of doctoral and postdoctoral fellows who have left the Biocentre by year of departure.

Table 6. The number of doctoral and postdoctoral fellows who have left the Biocentre by present location and by year of departure in 1996–2001.

Present location	Year of departure						
	1996	1997	1998	1999	2000	2001	1996–2001
Other organisation within the same University							
Other University in Finland							
Industry in Finland							
Other organisation in Finland							
University or research institute abroad							
Other organisation abroad							
TOTAL							

13. Technology transfer

Describe the organisational structures and practices enhancing technology transfer at the Biocentre. Max. length one page.

14. Socio-economic impact in terms of patents, licensing and spin-off companies

Describe briefly, if applicable, how the Biocentre is involved in practice in patenting, licensing and spin-off companies in the field of biotechnology. Max. length one page.

15. Other socio-economic impacts

Describe other socio-economic impacts of the Biocentre's biotechnology research since 1996. Max. length one page.

16. The Biocentre as part of the local innovation system

Describe the local innovation system which the Biocentre is part of. Which are the other players and what is the Biocentre's relationship to them? What kind of financial or other support the Biocentre has received from others and what the Biocentre has given to them, reciprocally? Max. length 0.5 page.

PART C. SWOT ANALYSIS AND FUTURE VISIONS

17. Self-evaluation using the method of SWOT-analyses

a) Describe the **s**trengths, **w**eaknesses, **o**pportunities and **t**hreats of the Biocentre **in biotechnology research**. Max. length one page.

b) Describe the **s**trengths, **w**eaknesses, **o**pportunities and **t**hreats of the Biocentre as part of the biotechnology innovation system **in relation to other players**. Max. length one page.

18. Visions of biotechnology-related activities by 2007

a) In what kinds of activities will the Biocentre be involved in the field of biotechnology R&D by 2007? What kind of role will the Biocentre play in the biotechnology innovation system? What will be the international status of the Biocentre in the field of biotechnology in 2007? Max. length one page for a and b together.

b) What will be the major means of carrying out the biotechnology visions of the Biocentre?

19. The future of biotechnology funding

Describe the Biocentre's expectations and proposals concerning the future of biotechnology funding in Finland. Max. length one page.

APPENDIX VIII. F.

BIOTECH 2002 EVALUATION IN FINLAND

LIST OF ADDITIONAL QUESTIONS FROM PANEL

ISSUES TO BE ADDRESSED BY UNIVERSITIES AND BIOCENTERS

UNIVERSITIES:

(includes interviews for Research Institutes and Innovation Environments)

To be present: Rector
IP/Technology Transfer representative
Key researchers (3-6)

Issues:

(Questions 9 a-c and 10 e in Terms of Reference)

- To what extent and how does the status and quality of research and innovation environments reflect the impact of the previous public biotechnology funding programmes?
- What other impact have public biotechnology funding programmes had?
- What has been the added value of the national development programmes running since 1988?
- What should be the overall structure and priorities of the next national development programme for 2004-2006?

Local biotech strengths and weaknesses (Research and Training)

Local biotech strengths and weaknesses (Technology Transfer)

Local biotech strengths and weaknesses (Local, National and International cooperation)

How is excellence rewarded?

Mechanisms used in technology transfer

Visions, ambition and strategy for future

Future resource requirements

Recommended structure and priorities of future national development programmes

Biocenters:

To be present: Director
Key researchers (4-10)
Graduate Programme Chair
Fellows (30 min. closed meetings)

Issues:

(Questions 9 a-c and 10 e in Terms of Reference)

- To what extent and how does the status and quality of research and innovation environments reflect the impact of the previous public biotechnology funding programmes?

- What other impact have public biotechnology funding programmes had?

- What has been the added value of the national development programmes running since 1988?

- What should be the overall structure and priorities of the next national development programme for 2004-2006?

Local biotech strengths and weaknesses (Research and Training)

Local biotech strengths and weaknesses (Technology Transfer)

Local biotech strengths and weaknesses (Local, National and International cooperation)

How is excellence rewarded?

Mechanisms used in technology transfer

Visions, ambition and strategy for future

Future resource requirements

Recommended structure and priorities of future national development programmes

and

Quality assessment mechanisms in research and training programmes

Decision-making: leadership vs. consensus

APPENDIX VIII. G.
BIOTECH 2002 -EVALUATION IN FINLAND

SCHEDULE OF THE EVALUATION PANEL ON 12 JUNE, 2002

Meeting venue: Academy of Finland, Vilhonvuorenkatu 6, Helsinki

Evaluation Panel:

Professor Fotis Kafatos, Director General, European Molecular Biology Laboratory (D)
Professor Konrad Beyreuther, University of Heidelberg (D)
Professor Nam-Hai Chua, Rockefeller University, New York (US)
Professor (emeritus) Bernard Mach, University of Geneva, Geneva (CH)
Dr David Owen, MRC Technology Transfer, London (UK)
Professor Joan Steitz, Yale University, New Haven (US)

Secretary of the panel:

Ms Sarah Sherwood, Administrative Officer, EMBL (D)

Present from the Steering Committee:

Mr. Arvo Jäppinen, Ministry of Education (Steering Committee Chairman)
Dr. Leena Hömmö, Ministry of Trade and Industry
Dr. Jari Järvinen, Scientific Computing Ltd, CSC
Dr. Sakari Karjalainen, Ministry of Education
Dr. Markus Koskenlinna, National Technology Agency, Tekes
Ms Hannele Kuusi, Picea Tech Ltd/Finnish Bioindustries
Professor Ossi Lindqvist, University of Kuopio
Dr. Markku Mattila, Ministry of Education
Ms Elina Nikkola, Ministry of Agriculture and Forestry
Ms Paula Nybergh, Ministry of Trade and Industry
Dr. Anneli Pauli, Academy of Finland
Professor Matti Sarvas, National Public Health Institute
Dr. Tuija Talsi, Ministry of Environment
Professor Eero Vuorio, University of Turku

Coordination:

Dr. Katri Haila, Academy of Finland
Ms Anu Nuutinen, Academy of Finland

Chairman: *Mr. Arvo Jäppinen*

8.00-8.45
ORIENTATION

– **Goals of the Evaluation; discussion with Steering Committee members**
Mr Arvo Jäppinen and Steering Committee members

Chairman: *Professor Fotis Kafatos*

8.45-09.30
GENERAL BACKGROUND

– **Characteristics of the Finnish science and technology policy and the research system**
Mr Esko-Olavi Seppälä, Chief Planning Officer, Science and Technology Policy Council (Ministry of Education)
Present also:
Mr Kimmo Halme, Chief Planning Officer, Science and Technology Policy Council (Ministry of Trade and Industry)

09.30–10.00
PUBLIC BIOTECHNOLOGY FUNDING, PART I

– **Ministry of Education**
Mr Arvo Jäppinen Director General, Department of Education and Science Policy
Dr Sakari Karjalainen, Director, Science Policy Division

10.00-10.15
BREAK

10.15–11.05
PUBLIC BIOTECHNOLOGY FUNDING, PART II

10.15 **Ministry of Social Affairs and Health**
Research professor (emerita) P. Helena Mäkelä, National Public Health Institute, Chairperson of the Board for Gene Technology
Present also:
Professor Matti Sarvas, National Public Health Institute

10.35 **Ministry of Agriculture and Forestry**
Ms Elina Nikkola, Senior Research Officer

10.50 **Ministry of Environment**
Dr. Tuija Talsi, Special Adviser

11.05–11.45
PUBLIC BIOTECHNOLOGY FUNDING, PART III

– **Academy of Finland**
Professor Eero Vuorio, Chair, Research Council for Health

Present also:
Professor Reijo Vihko, President and Director General
Dr Anneli Pauli, Executive Vice President (research)
Dr Arja Kallio, Secretary General, Bioscience and Environment Research Unit

11.45-12.30
LUNCH

12.30–13.30
PUBLIC BIOTECHNOLOGY FUNDING, PART IV

12.30 **Ministry of Trade and Industry**
Ms Paula Nybergh, Deputy Director General, Technology Department
Present also:
Dr. Leena Hömmö, Chief Counsellor

National Technology Agency, Tekes
Dr Markus Koskenlinna, Executive Director, Impact Analysis

13.30–16.30
THE CORE OF PUBLIC BIOTECH RESEARCH IN FINLAND

Presentation of the six Biocentres

13.30 A.I. Virtanen Institute, Kuopio
Prof. Juhani Jänne

14.00 Biocenter Oulu
Prof. Taina Pihlajaniemi

14.30 BioCity Turku
Prof. Kalervo Väänänen

15.00 Biocentrum Helsinki
Prof. Olli A. Jänne

15.30 Institute of Biotechnology, Helsinki
Prof. Mart Saarma

16.00 Institute of Medical Technology, Tampere
Prof. Olli Silvennoinen

16.30–17.00

Business and funding structures of the biotechnology industry in Finland

Dr Terttu Luukkonen, Etla, The Research Institute of the Finnish Economy

17.00-18.00

CLOSED SESSION OF THE PANEL

APPENDIX VIII. H.

BIOTECH 2002 EVALUATION IN FINLAND SITE VISITS

Time	**Wed (A) 25.9. KUOPIO *(Beyreuther, Mach, & Sherwood, Oksa)***	**Wed (B) 25.9. OULU (Kafatos, Steitz, Owen, & Haila)**	**Thu (A) 26.9. TAMPERE (Beyreuther, Chua, Mach & Sherwood, Oksa)**
8–12	→ 6.45 taxi to airport Flight to Kuopio 07.40-08.45 → A.I.Virtanen Institute (Bioteknia 1, 2. krs kokoushuone, Neulaniementie 2)	→ 6.30 taxi to airport Flight to Oulu 07:25-08:30 → Medipolis Center, (Kiviharjuntie 11, Merkurius-kabinetti, 3.krs)	→ 6.45 walk to the railway station Train to Tampere 07.04–08.52 → FinnMedi (Tiimi-Kabinetti, Lenkkeilijänkatu 6)
12–13	09.30–10.30 University of Kuopio 10.30–10.45 Coffee10.45–12.45 A.I Virtanen Institute	09.00–9.45 Fibrogen Europe Ltd 9.45–10.00 Coffee 10.00–10.45 Oulu as an innovation environment	09.15–10.15 University of Tampere 10.15–10.30 Coffee 10.30–12.30 IMT and FinnMedi
	12.45–13.30 Lunch at A.I.Virtanen Institute	10.45–11.40 Lunch (at Medipolis) 11.40-12.00 Taxi to Linnanmaa	12.30–13.15 Lunch at FinnMedi
13.00–15.30	13.30–14.30 University of Joensuu 14.30–15.15 Kuopio as an innovation environment 15.15–15.30 Coffee 15.30–16.00 Ark Therapeutics Oy 16.00–16.30 Oy Jurilab Ltd	12.00–14.00 Biocenter Oulu 14.00-14.10 Coffee 14.10–15.10 University of Oulu	13.15–14.15 University of Jyväskylä 14.15–15.15 Tampere University of Technology 15.15–15.30 Coffee15.30–16.00 Bionx Implants 16.00–16.30 FIT Biotech Plc.
15.30–19.00	→16.30–17.00 taxi Flight to Helsinki 17:20–18.20	→ 15.15–15.35 taxi Flight to Helsinki 16:00-17.00	→ 16.30–16.45 taxi Train to Helsinki 17.07–18.56
19.00-		18.35 Hotel lobby → Ratakatu 3 Finnzymes Oy (18.45-19.15)	
	19.30–21.30 (Ministry of Trade and Industry, Ratakatu 3) Working dinner – SITRA, Venture Capital for biotechnology in Finland – Tekes		*20.00-22.00 Closed Dinner (Panel, Secretary, Coordinator) Hotel Radisson SAS Plaza Helsinki (Mikonkatu 23)*

Note! Tue 24 September 18.30 Evaluation: Helsinki region as an innovation environment (Hotelli Torni, Näköalakabinetti, Yrjönkatu 6)
Tue 24 September 20.00-22.00 Welcoming Dinner hosted by the Academy of Finland (Hotelli Torni, Näköalakabinetti, Yrjönkatu 6)

AND PANEL MEETING 24-28 SEPTEMBER 2002

Thu (B) 26.9. **TURKU** **(Kafatos, Steitz, Owen& Haila)**	**Fri (A) 27.9.** **HELSINKI** **(Kafatos, Beyreuther, Steitz & Haila)**	**Fri (B) 27.9.** **HELSINKI** **(Chua, Mach, Owen & Sherwood, Oksa)**	**Sat 28.9.** **HELSINKI** **(Kafatos, Beyreuther, Chua, Mach, Steitz & Sherwood, Haila, Oksa)**
→ 7.20 walk to the railway station Train to Kupittaa 07.38–09.19 → Pharmacity 5 min walk (PharmaCity, huone 3)	7.00-7.30 /OwenLicentia (breakfast in the hotel) → 7.30 taxi to Viikki 08.00-09.00 University of Helsinki 09.00-09.15 Coffee 09.15–11.15 Institute of Biotechnology and Viikki Biocenter	→ 7.30 taxi to Meilahti (Biomedicum, Faculty Club) 08.00–10.00 Biocentrum Helsinki, and Biomedicum 10.00–10.15 Coffee 10.15–11.00 KTL National Public Health Institute 11.00-11.30 Finnish Institute of Occupational Health and Safety	→ 8.45 taxi to the Academy 09.00–12.30 (room 216) Closed Panel Meeting (Panel, Secretary, Coordinator) Report preparation
09.45–10.45 University of Turku 10.45-11.00 Coffee 11.00–13.00 BioCity Turku	11.15–11.45 Carbion Inc, Viikki → 11.45-12.00 taxi to the Academy (Vilhonvuorenkatu 6)	→ 11.30-12.00 taxi to the Academy (Vilhonvuorenkatu 6)	
13.00-13.45 Lunch at Pharmacity	12.00–14.30 (room 216) Closed Panel Meeting & Lunch (Panel, Secretary, Coordinator)		12.30–13.30 (room 216)CSC Scientific Computing Ltd Lunch
13.45–14.45 Åbo Akademi 14.45-15.30 Turku as an innovation environment 15. 30-16.00 BioTie Therapies Corp. 16.00–16.30 Hormos Medical Corp.	room 240 (Chua, Kafatos, Steitz) 15.00–15.45 MTT Agrifood Research Finland 16.00-16.30 Finnish Forest Research Institute 16.30-17.00 Finnish Environment Institute 17.00-17.30 National Veterinary and Food Research Institute	room 216 (Beyreuther, Mach, Owen)15.00-16.00Helsinki University of Technology 16.00-17.00VTT Biotech(Beyreuther, Mach, Owen/Chua)	13.30-16.00 (room 216)Closed Panel Meeting (Panel, Secretary, Coordinator)Report preparation
→ 16.30–16.45 walk to Kupittaa Train to Helsinki 17.06–18.57	→ Hotel Radisson SAS Plaza	→ Hotel Radisson SAS Plaza	Departures
	19.20 Hotel lobby →SITRA		
	19.30-22.00 Meeting and Dinner with the Steering Committee *Informal Buffet* (SITRA, Itämerentori 2)		

APPENDIX VIII. I

Selected References

- Biotechnology in Figures (brochure), Statistics Finland
- Molecular biology and biotechnology research in Finland: EMBO Evaluation Report 1996
- Hermans, R. & Luukkonen, T. (2002) Findings of the ETLA Survey on Finnish Biotechnology Firms (Discussion Papers, No. 819)
- IMD World Competitiveness Yearbook 2002
- Review 2000: The Challenge of Knowledge and Know-how (2000) Science and Technology Policy Council of Finland, Helsinki
- Science and Technology in Finland 2000, (2001) Statistics Finland, Helsinki
- The biotechnology industry and its development; Venture capital financing (manuscript by Hannele Kuusi, Piceatech Ltd/Finnish Bioindustries, as part of the evaluation documents)
- The State and Quality of Scientific Research in Finland (2000) Husso, K., Karjalainen, S. & Parkkari, T. (eds), Academy of Finland, Helsinki
- World Economic Forum's Global Competitiveness Report 2001-2002

The present Panel's report evaluates the current status of the Finnish biotechnology innovation system, and proposes improvements as appropriate. The evaluation combined an external assessment by an international Evaluation Panel with an internal self-assessment exercise. The evaluation has been commissioned to serve as a basis for drafting the next national biotechnology development programme 2004-2006.

The Panel concludes that Finland has made an admirable start and has a very real chance to become one of the most successful small countries in the world in biotechnology. Cooperation is one of the great strengths of the Finnish effort. The progress in the research sphere has been particularly impressive, relative to 15 years ago. The translation process has captured the interest of Finnish scientists and is benefiting from investments at several levels; however, to enhance success some significant improvements are needed.

The Panel sets out a number of recommendations directed to academic sector (fundamental research and training), research & development, and industry.

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