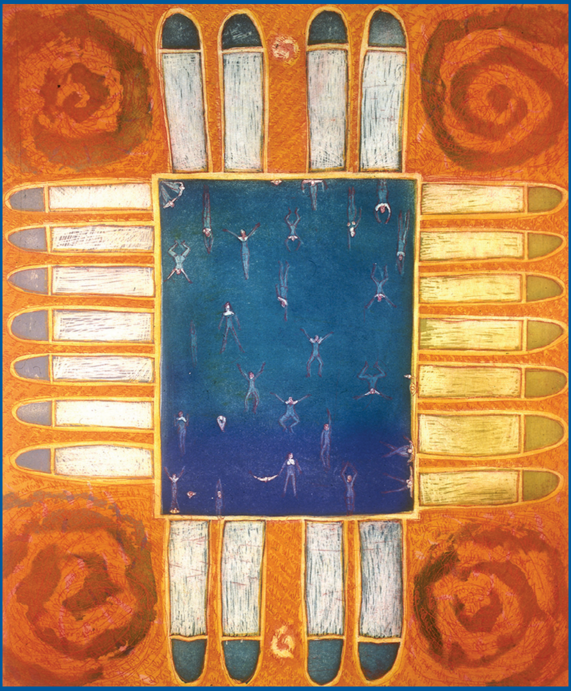
PUBLICATIONS OF THE ACADEMY OF FINLAND 10/03

SCIENTIFIC RESEARCH in Finland

A Review of Its Quality and Impact in the Early 2000s



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Editors: Timo Oksanen, Annamaija Lehvo & Anu Nuutinen

Reports by the Academy's Research Councils

Biosciences and Environmental Research
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Academy of Finland in brief

The Academy's mission is to finance high-quality scientific research, act as a science and science policy expert and strengthen the position of science and research. The Academy's operations cover all scientific disciplines.

The main focus of the Academy's development activities is on improving opportunities for professional careers in research, providing resources and facilities for high-profile research environments and making the best possible use of international opportunities in all fields of research, research funding, and science policy.

The Academy has a number of funding instruments for various purposes.

The Academy's annual research funding amounts to about 185 million euros, which represents some 13 per cent of the Finnish government's total R&D spending.

Each year Academy-funded projects account for some 3,000 researcher-years at universities and research institutes.

The wide range of high-level basic research funded by the Academy generates new knowledge. The Academy of Finland operates within the administrative sector of the Ministry of Education and is funded through the state budget.

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

Translation: David Kivinen

Layout: PixPoint ky

Cover illustration: Hanna Varis (1988): ”The World”

ISBN 951-715-466-6 (print)
ISBN 951-715-467-4 (pdf)

ISSN 0358-9153

Printed by Painotalo Miktor, Helsinki, Finland 2003

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Contents

GENERAL SECTION

SPECIAL THEMES

REPORTS BY THE ACADEMY'S RESEARCH COUNCILS

Contents

Foreword

The Academy of Finland carries out a review of the state and quality of scientific research in Finland once during the three-year term of its Research Councils. The assignment is based on Government decisions concerning the development of education and research as well as agreements on target outcomes signed between the Ministry of Education and the Academy of Finland. The previous reviews were published in 1997 and 2000.

The 2003 review is divided into **a general section; special themes that complement the general section; and reports by the Academy's four Research Councils**. The main theme that cuts across the whole review is the impact of scientific research, which is approached from different angles. Other issues that receive in-depth coverage include the challenges related to human resources in research.

The primary aim of the review is to serve the needs of national and international bodies and organisations responsible for science and technology policy as well as research funding. It also provides useful information for researchers and research organisations around the world.

Work to compile the review has been carried out under the supervision of a steering group appointed by the Board of the Academy of Finland. The group was chaired by Anneli Pauli, Vice President, Research (Academy of Finland). Its other members were the chairs of the Academy Research Councils: Professor Riitta Keiski (Research Council for Natural Sciences and Engineering), Professor Arto Mustajoki (Research Council for Culture and Society), Professor Terttu Vartiainen (Research Council for Biosciences and Environment) and Professor Eero Vuorio (Research Council for Health); and Markku Karlsson, Senior Vice President, Technology (Board of the Academy of Finland) and Director Sakari Karjalainen (Ministry of Education; Director Juhani Hakkarainen until 30 April 2002). Programme Manager Tarmo Lemola and Professor Reijo Miettinen have served as permanent expert members to the steering group. The steering group has defined the objectives for the review, endorsed the plan for compiling the review, taken part in revising drafts and given advice to the Research Councils on how to prepare their reports. Science Adviser Annamaija Lehvo, Project Officer Anu Nuutinen and Science Adviser Timo Oksanen (team leader) from the Academy of Finland have compiled and written the general section of the report and edited the review. Information Specialist Maija Miettinen has provided expert assistance for the bibliometric analyses. In addition, Project Officer Siru Oksa and university trainee Sari Purhonen have assisted in the preparation of the general section of the review. The review has been translated from Finnish into English by David Kivinen. Tuulikki Toivonen has assisted in proofreading.

Contents

1 Research infrastructure and environment

Researchers go about their job in an environment of great complexity. The Finnish research system comprises decision-makers and various advisory bodies (Parliament, the Government and its ministries, the Science and Technology Policy Council of Finland), funding bodies (such as the Academy of Finland, the National Technology Agency Tekes, the Finnish National Fund for Research and Development Sitra), and research organisations (universities, polytechnics, university hospitals, research institutes, business companies with R&D operations). Some of the work that research organisations and individual researchers do is steered by decision-makers and funding bodies, which in this narrow sense constitute the operating environment of research. That environment is further expanded when the research system is defined as part of the innovation system. In addition to decision-makers, funding bodies and researchers, the innovation system comprises business and industry as well as all the economic structures, political organisations and institutions that directly or indirectly exert an influence on research, which in turn reciprocates.

Since the bulk of all scientific research is done in public organisations, the research environment comprises not only the research system and the innovation system, but also the public sector and society at large. Within this operating environment there are both factors that facilitate and protect research, and factors that restrict and control research. In Finland the freedom of science is constitutionally guaranteed. There is also legislation aimed at securing the financial autonomy of universities (L 731/1999, 16 § and 123§; L 1052/1986, 1270/2001). Among the factors that restrict or control research are the priority definitions of science policy. Together, the factors that facilitate, protect, restrict and control research constitute the broader, societal operating environment of research. It is within this environment that economic globalisation, EU integration and Finland’s own internal development needs all come together. The effective management of the operating environments of research and the changes taking place within those environments require a concerted effort to support and develop the infrastructure, resources and other crucial preconditions for doing research.

Research as part of society

In the early 2000s funding from public sources accounted for more than one-quarter of total R&D expenditure in Finland. Basic research in particular relies heavily on support and funding from the public sector. It follows that public administration and the future course of its development will also have a direct as well as indirect bearing upon the future resources available to basic research. There is growing pressure in Finland to curb levels of national taxation, both as a result of economic globalisation and Finland’s membership of the EU. The goals adopted in the 1980s and 1990s for the development of public administration were mainly geared to improving efficiency and productivity (management by results, new public management). The new Government Programme also underlines the importance of further increasing the availability, quality, productivity and efficiency of public administration and its services.

At the same time as the research system is expected to accommodate to its public sector operating environment and to show greater efficiency, there are new or growing demands upon the social impacts of research. Overall there is a sense that society has become more immune to external intervention, yet government is expected to be able to provide a cure to a range of persistent problems such as structural unemployment, regional inequalities as well as the growing threats of marginalisation and poverty. Research is expected to provide a clearer picture of what exactly is happening in the ongoing processes of change; it is expected to provide new solutions to the increasingly diverse and complex problems and challenges in our society. Development projects have only just got off the ground so it is too early to say whether the management by results goals of productivity, efficiency, standardisation and harmonisation can be fitted together with the requirements of interactivity, communicativity, flexibility and long-term consistency that are necessary in the management of research.

During the 1990s more and more research at universities was funded from outside sources. At government research institutes, too, funding from non-budget sources has increased while core budget funding has decreased throughout the 1990s. More and more often now, universities and government research institutes are faced with private competition. In some situations the basic principles of transparency and democratic regulation that govern all operations in the public sector, complicate and hamper the transfer of knowledge and technology and the development of commercial applications. The number of knowledge and technology transfer and intermediary organisations has increased. At the same time there have been growing calls to give universities greater autonomy from the state as independent legal and economic entities.

In order that universities can provide the best possible service to society, it is crucially important that their responsibilities in education as well as in other service provision are fitted together with their research duties. If the elements of flexibility, transparency and predictability in universities' current management and funding mechanisms can be further improved and developed, then the core features of the state system may well prove to be a useful counterbalance. In this way it should be possible to protect basic research and its resources against short-sighted applications and impacts requirements. Government research institutes working under ministries have long since had to accommodate to such requirements, and that is one reason why their operating environment did not in the 1990s change to the same extent and as quickly as that of universities.

Research as part of the national and international research system

In 2001 universities accounted for 15 per cent of Finnish R&D expenditure, while the figure for government research institutes was around 10 per cent. Legal provisions concerning universities as well as key policy documents (L 1052/1986 with subsequent amendments, the Government Programme, the Science and Technology Policy Council's review of 2003) are committed to securing and developing budget allocations for universities in the near future. Closer cooperation between universities and government research institutes will pave the way to higher quality research and to increased operational efficiency, and by the same token help them meet future resource challenges.

Seen from the vantage-point of the research system, an important reference group for Finnish research is the international science community. Individual researchers are of course the main driving force behind the internationalisation of science and research, but the general framework for internationalisation is provided by science funding bodies and decision-makers. In the 1990s and early 2000s, researchers, funding bodies and decision-makers have all invested in the internationalisation of the Finnish research system. Finland is a member of several international science organisations. The international operating environment opens up new opportunities, throws up new challenges, presents incentives and needs for the further development of research: for raising the quality standards of research, for reducing unnecessary overlap in the production of new knowledge, for pooling resources and for other strategic allocation of resources. The challenge for Finland is to consolidate a position in which it can compete for talented researchers, projects and resources. A significant part of international funding instruments (e.g. EU programmes) provide support mainly for applications-oriented research.

Multidisciplinary and interdisciplinary research has increased. The direction and the focus of this work is determined not only by science's own internal diverse development logic, but also by new emerging challenges in society and by the tools of science policy (e.g. research and technology programmes). This has led among other things to the growth of new multidisciplinary fields of research, to the crisis and reform of the basic concepts, values and norms of research and often also to expanding social impacts of research. In this interpretation, the state of the Finnish research system and the operating environment of individual researchers have changed essentially during the 1980s and 1990s, even though the situation varies widely across different fields of research.

Research as part of the innovation system

Although the overall share of corporate funding for universities in Finland still remains relatively modest, the share of external funding as a whole increased markedly during the 1990s. The shifts and changes in university funding provide only a rather narrow perspective on the relative significance of different operating environments (public sector, research system, innovation system) in the day-to-day work of universities. For example, on the basis of the Science and Technology Policy Council's reviews the links of the research system with the public sector and with the innovation system have nonetheless been strengthened in the 1990s. Two main factors lie behind this change. Research is considered a major driving force of technological, economic and more generally social (e.g. regional) development. In addition, the ongoing processes of globalisation, which highlight the role of international competition, business and commerce based on high technology and the production and application of new knowledge, further underscore the role of research in an entirely new way.

Innovation system thinking looks upon basic research as an integral part of the broader socio-economic system and networks of dependency relations and in so doing directs and determines the needs and expectations attached to research. Innovation system thinking has increased interaction and cooperation among political actors. Through funding bodies, it has also promoted collaboration among universities, research institutes and business companies. Furthermore, cooperation among funding bodies has also increased, and innovation system thinking has been a major underlying influence in the development of so-called cluster programmes.

With the rise of innovation system thinking, the Science and Technology Policy Council of Finland has assumed a prominent role in the coordination of science and technology policy and at once in steering the operating environment of basic research in the direction of the innovation system. In the 1990s innovation system thinking began to place ever greater emphasis not only on national institutions, but also on regional innovation systems and on the other hand on the national innovation system's international contacts. The new millennium has seen social innovations brought to the fore, which among other things concern public services and practices in the workplace that have a direct bearing on people's welfare.

The operating environments of research (public sector, research system and innovation system) share both certain features in common and have distinctive features of their own. During the 1990s there has been growing convergence of these environments with the adoption of a more holistic approach to policy steering. In particular, the changes have been aimed at strengthening the technological and economic impacts of research. They narrow down the differences between different operating environments and may also blur important distinctive features of those environments. The research system is more and more often seen as an integral part of the innovation system. From this point of view some critical comments have been made both against the links of research with public administration and against the ambitions shown by universities for greater autonomy. If the different operating environments of research, their different underlying values and tendencies of change are not recognised, and if there is no effort to try to maintain those environments, then there is a real risk that the social and cultural impact of universities as well as of the research carried out at universities will be reduced.

2 Research funding

This chapter begins with an overview of trends in Finnish R&D expenditure and funding sources in different sectors of performance from the late 1990s through to the beginning of the 2000s.[1] In addition, the structure of R&D expenditure and funding in Finland is compared with international trends in development. The text covers the development of R&D funding from two Finnish funding bodies, namely the Academy of Finland and the National Technology Agency Tekes. Furthermore, there is an overview of R&D expenditure and sources of funding at universities, university hospitals (combined with university research) and polytechnics; here special attention is given to the ratio of core budget funding to external funding. Finally, the chapter discusses the funding of research at government research institutes.

2.1 R&D expenditure and sources of funding in Finland

In 2002, R&D expenditure in Finland as a proportion of GDP, or the country's *R&D intensity* was estimated at 3.5 per cent.[2] The figure has grown throughout the 1990s (1991: 2.0%) and in the early 2000s. (Tutkimus- ja kehittämistoiminta... 2002, 2003b.) Finland's R&D intensity is one of the highest in the world (Figure 2.1). Since the mid-1990s, R&D expenditure has increased at an average annual rate of 13.5 per cent, which in an international comparison is an extremely high rate. In the EU, the average annual real growth of R&D expenditure during this same period has been no more than 3.4 per cent. (Third... 2003.) In 2002 the Barcelona European Council set the target that by the year 2010, all EU countries should be spending three per cent of their GDP on research and development and that two-thirds of all R&D investment should come from the private sector (More... 2002). In 2000 the EU's R&D intensity stood at 1.9 per cent, and the business enterprise sector accounted for 56 per cent of total R&D expenditure (Main… 2003). Finland has already met both these targets.

R&D investment by *business enterprises* has contributed significantly to the development of the Finnish research and innovation system.[3] In 2001 business enterprise R&D expenditure represented 2.4 per cent of GDP, the second highest figure in the OECD group after Sweden (3.3%). The corresponding figure for Japan was 2.3 per cent, for the United States 2.1 per cent and for the EU 1.2 per cent. (Main... 2003.) In Japan, Sweden and Finland business enterprises accounted for more than 70 per cent of R&D funding in 2001, more than the average for the OECD countries (64%) and well above the average for the EU countries (56%) (Figure 2.2). In the United States and Germany (66%) funding by business enterprises was also above the OECD average.

Since the mid-1990s, Europe has begun to fall behind the United States in terms of the development of R&D funding and expenditure. The reason why the US has continued

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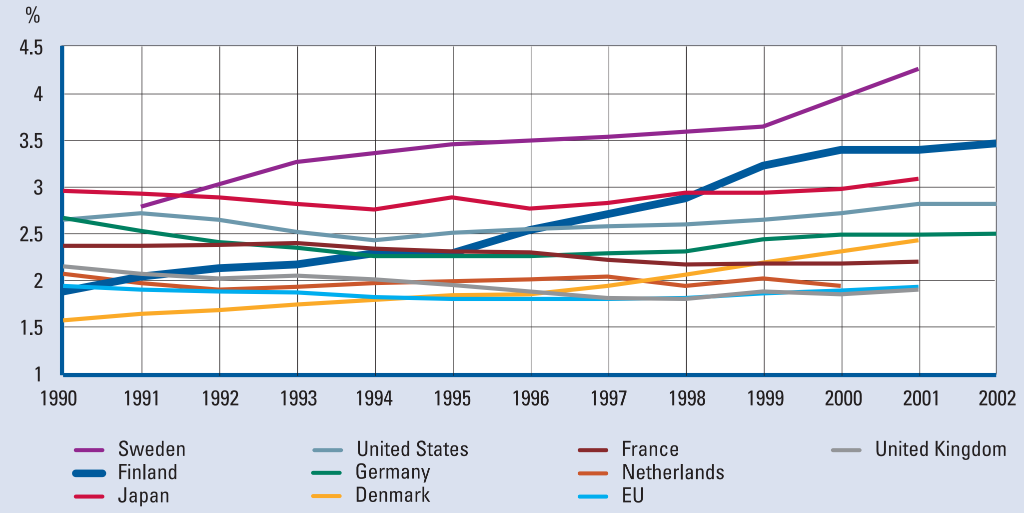
[1] The latest comprehensive Statistics Finland figures for R&D expenditure and funding were available for 2001.

[2] The GDP data used in calculating R&D intensity are based on Ministry of Finance forecasts.

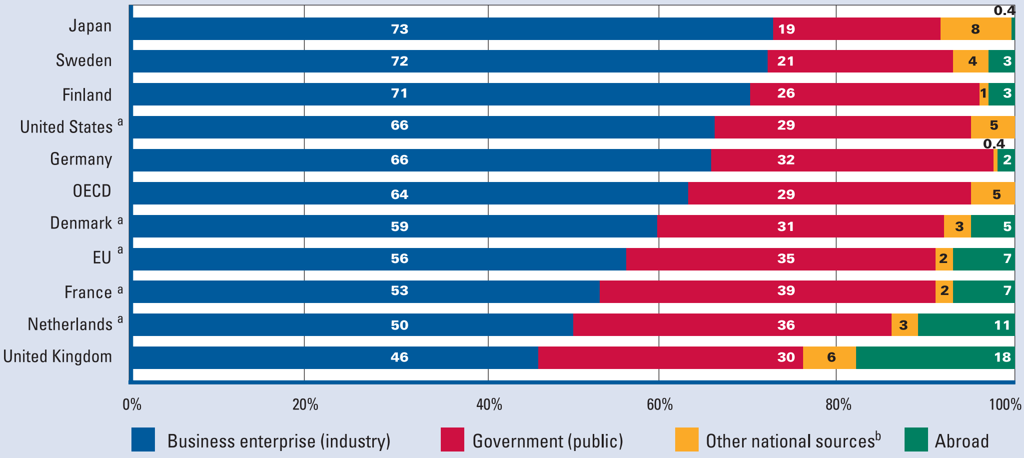
[3] In 2000 R&D expenditure as a proportion of Finland's GDP would have been not 3.4 but 2.4 per cent had it not been for Nokia's input. In 2001 Nokia accounted for about one-third of the country's total R&D expenditure, and for an estimated 47 per cent of the R&D investment in the business enterprise sector. (Ali-Yrkkö and Hermans 2002.)

■ Figure 2.1. R&D expenditure as a proportion of GDP (%) in selected OECD countries and the EU in 1990–2002.



Sources: Main Science and Technology Indicators 2002/2 & 2003/1, FoU-statistikk og indikatorer… 2003, Statistics Finland 2003b.

■ Figure 2.2. Funding from different sources as a percentage share of R&D expenditure in selected OECD countries and in the EU in 2001 (or latest year for which figures available). The countries are rank-ordered according to the share of business funding.



[a] Data on the US from 2002, Denmark from 1999 and the EU, France and the Netherlands from 2000.
[b] Other national sources refer to funding from the higher education sector and private non-profit institutions.

Source: Main Science and Technology Indicators 2003/1.

to increase its lead lies in the moderate growth of R&D in the major EU countries. Furthermore, business enterprise investment in R&D is at a comparatively low level in Europe, and government support for R&D has grown only slowly. (Third... 2003.)

In Finland, *government investment in R&D*[4] is one of the highest in the OECD countries: in 2002 budget funding for research and development represented around one per cent of GDP (see Main... 2003). In the 2003 budget a total of 1.4 billion euros is earmarked for purposes of supporting research and development, which represents some 4.4 per cent of total government expenditure excluding central government debt servicing. The Ministry of Education, the Ministry of Trade and Industry, the Ministry of Social Affairs and Health and the Ministry of Agriculture and Forestry together administer more than 90 per cent of central government R&D funding (Table 2.1). In 2003 more than one-quarter or 28 per cent of the monies will be allocated to the National Technology Agency Tekes and 13 per cent to the Academy of Finland. Universities will receive 27 per cent in core budget funding, government research institutes some 17 per cent and university hospitals three per cent of budget funds allocated to research and development. Other research funding, which includes non-earmarked ministry allocations for R&D, accounts for 12 per cent of government research funding.

Table 2.1. Government R&D funding by administrative branch in 1999, 2001 and 2003.

Administrative branch	1999[a]		2001[a]		2003[a]	
	€ million	%	€ million	%	€ million	%
Ministry of Education	494.4	39	554.8	41	592.0	42
Universities	323.3	25	349.8	26	386.7	27
Academy of Finland	155.5	12	187.1	14	185.1	13
Government research institutes	5.7	0.4	5.9	0.4	6.6	0.5
Other[b]	9.9	1	12.0	1	13.7	1
Ministry of Trade and Industry	490.5	38	494.0	37	487.9	34
National Technology Agency Tekes	411.2	32	400.1	30	399.3	28
Government research institutes	65.6	5	68.1	5	67.8	5
Other[b]	13.7	1	25.8	2	20.8	1
Ministry of Social Affairs and Health	114.4	9	116.2	9	111.9	8
University hospitals	60.5	5	56.7	4	48.7	3
Government research institutes	44.5	3	50.2	4	50.5	4
Other[b]	9.4	1	9.3	1	12.7	1
Ministry of Agriculture and Forestry	75.3	6	81.6	6	90.9	6
Government research institutes	67.4	5	70.8	5	82.0	6
Other[b]	7.9	1	10.8	1	8.9	1
Other ministries and Prime Minister's Office	101.0	8	104.6	8	134.1	9
Government research institutes	26.6	2	24.3	2	26.2	2
Other[b]	74.5	6	80.3	6	107.9	8
Total	1,275.6	100	1,351.2	100	1,416.7	100

[a] The data for 1999 include the budget proper plus supplementary budgets I and II, data for 2001 the budget proper plus supplementary budgets I–III. The data for 2003 are based on the budget proposal.

[b] Includes other core budget funding for R&D by ministries and by ministries to government agencies.

Sources: Kolu 2000 & 2002, Statistics Finland 2003a.

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[4] Government investment in R&D refers to the Total Government Budget Appropriations or Outlays for R&D (GBAORD).

The favourable trends in core budget funding for universities since the mid-1990s have begun to slow down in the new millennium. On the other hand, core funding for government research institutes has shown a more positive trend in the late 1990s and early 2000s than in the mid-1990s. In particular, core funding for research institutes under the Ministry of Agriculture and Forestry has increased in the new millennium. In real terms core funding for university hospitals has shown a tendency to decline from the late 1990s to the beginning of the 2000s.

Development of R&D expenditure

In 2002 the business enterprise sector accounted for 71 per cent of the country's total R&D expenditure of 4.6 billion euros (Table 2.2). Business investment in R&D showed strong growth in the latter half of the 1990s: R&D expenditure increased more than one and a half times over from 1997 to 2001, when business enterprise expenditure in research and development stood at 3.3 billion euros. In 2001 manufacturing accounted for 79 per cent of business enterprise R&D investment. On average business enterprise R&D expenditure has increased at an annual rate of 12 per cent from the late 1990s to the early 2000s.

Table 2.2. R&D expenditure, real growth of expenditure (%) and average annual real growth (%) in 1997–2001 by sector of performance.

Year	Business enterprise		Public sector[a]		Higher education[b]		Total	
	€ billion	%	€ billion	%	€ billion	%	€ billion	%
1997	1.9	66	0.4	14	0.6	20	2.9	100
2001	3.3	71	0.5	11	0.8	18	4.6	100
2002[c]	3.4	71	0.5	11	0.9	19	4.9	100
Real growth[d] in 1997–2001		56		11		31 (24[e])		44
Average annual real growth[d] in 1997–2001		12		3		7		10

[a] The public sector comprises government administrative branches, other public institutions and private non-profit institutions.
[b] The higher education sector comprises universities, university hospitals and polytechnics. The figures for 1997 do not include polytechnics' R&D expenditure, which in 2001 represented about five per cent (43.6 million euros) of the higher education sector's R&D expenditure.
[c] Statistics Finland's estimate based on survey responses and other calculations.
[d] Expenditure deflated by the GDP market price index (2000 = 100; see Kansantalouden… 2003).
[e] Real growth excluding polytechnics.

Source: Statistics Finland 1999 & 2003b.

The higher education sector[5] accounted for 18 per cent of Finnish R&D expenditure in 2001, the public sector for 11 per cent. R&D expenditure by the higher education sector increased from 0.6 billion euros in 1997 to 0.8 billion euros in 2001, marking a real increase of more than 30 per cent. In the higher education sector the average annual rate of real growth from 1997 to 2001 was seven per cent. Universities and university hospitals recorded a real increase of 24 per cent in their combined R&D expenditure

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[5] The higher education sector comprises universities, university hospitals and polytechnics: R&D expenditure for the latter are not included in the 1997 statistics.

during the period under review. The figures for the rest of the public sector have grown less rapidly: in real terms R&D investment increased by no more than 11 per cent from 0.4 to 0.5 billion euros. The average annual rate of real growth in 1997–2001 was three per cent.

Table 2.3 provides an overview of R&D expenditure by organisation. Although expenditure by universities and government administrative branches (which includes R&D expenditure by government research institutes) showed real growth from 1997 to 2001, their share of total R&D investment in Finland declined as a result of the growing contribution of business enterprises. In 2001 university hospitals accounted for two per cent of R&D expenditure. The figures for polytechnics, private non-profit institutions (such as the Finnish Cancer Registry and Folkhälsan) and other public institutions (such as the Bank of Finland and social security funds) were less than one per cent.

■ Table 2.3. R&D expenditure by organisation in 1997 and 2001.

Organisations	1997		2001	
	€ million	%	€ million	%
Business enterprises	1,916.7	66	3,284.0	71
Universities	515.0	18	715.7	15
Admin branches (incl. government research institutes)	375.2	13	451.6	10
University hospitals	65.0	2	74.9	2
Polytechnics	–	–	43.6	0.9
Private non-profit institutions	13.5	0.5	29.6	0.6
Other public institutions*	19.9	1	19.7	0.4
Total	2,905.4	100	4,619.0	100

* E.g. Bank of Finland, the Finnish National Fund for Research and Development, and social security funds.

Source: Statistics Finland 1999 & 2003b.

Sources of R&D funding

Domestic business companies funded about 70 per cent of Finland's total R&D expenditure in 2001 (Figure 2.3). The share of public funding[6] was less than 30 per cent (1.26 billion euros). Table 2.4 describes the sources of R&D funding in Finland by different sectors of performance in 2001. Public funding was primarily channelled to the higher education sector (705.3 million euros) and to other organisations in the public sector (369.4 million euros). The bulk of funding for business sector R&D came from business companies' own sources. The share of public funding (181.7 million euros) was no more than six per cent of total business enterprise R&D expenditure. A comparison of OECD countries shows that in 2001, government funding for business sector R&D was markedly lower in Finland (3%[7]) than in OECD countries (8%) and EU countries (8% in 2000) (Main... 2003).

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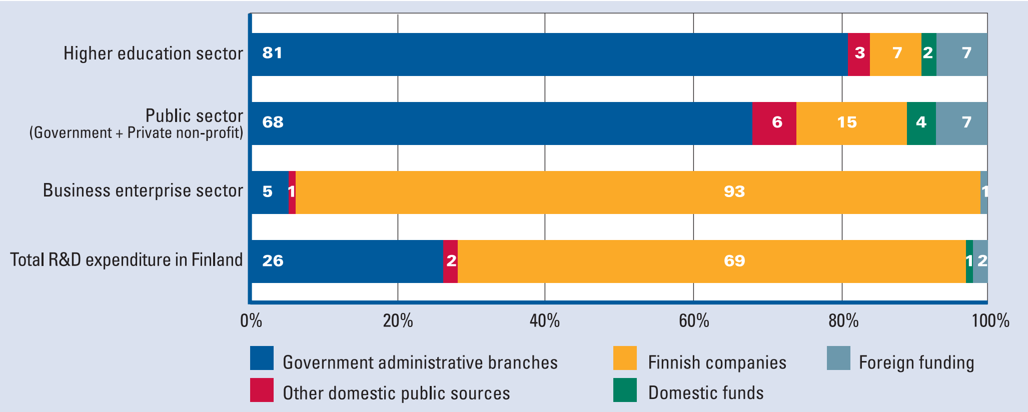
[6] Public funding comprises monies allocated to research from the State Budget as well as other public sources of domestic funding (e.g. local governments, the Finnish National Fund for Research and Development, the Finnish Work Environment Fund, Finnvera, and the Social Insurance Institution).

[7] In the OECD comparison public loans are not counted as government funding, which is why in Figure 2.3 and Table 2.4 the percentage indicated for government administrative branches is greater than the figure given in the OECD comparison.

Figure 2.3. Funding from different sources as a percentage share of R&D expenditure in Finland by sector of performance in 2001.



Source: Statistics Finland 2003b.

Table 2.4. R&D expenditure by source of funding in different sectors of performance in 2001.

			Sources of funding										
	Expenditure total		Government admin branches[b]		Other domestic public sources[c]		Finnish companies		Domestic funds[d]		Foreign funding[e]		Shares total
Sectors of performance	€ million	%	€ million	%	€ million	%	€ million	%	€ million	%	€ million	%	%
Business enterprise	3,284.0	71	164.6	5	17.1	1	3,069.5	93	9.8	0.3	23.0	1	100
Public sector[a]	500.9	11	341.8	68	27.6	6	74.4	15	20.6	4	36.5	7	100
Higher education	834.1	18	677.3	81	28.0	3	55.9	7	17.6	2	55.4	7	100
Total	4,619.0	100	1,183.6	26	72.7	2	3,199.8	69	47.9	1	115.0	2	100

[a] Includes private non-profit institutions.
[b] Includes the Academy of Finland and the National Technology Agency Tekes.
[c] E.g. local governments, the Finnish National Fund for Research and Development, the Finnish Work Environment Fund, Finnvera, and the Social Insurance Institution. The euro figures for the higher education sector also include universities' own funds.
[d] The euro figures for the public sector also include private non-profit institutions' own funding.
[e] EU funding from framework programmes and structural funds, foreign companies and funding, for example, from foreign universities, central agencies and international organisations.

Source: Statistics Finland 2003b.

As well as doing their own research and development, domestic business companies gave 74.4 million euros to support public sector research and development in 2001 (representing 15% of total public sector R&D expenditure) and 55.9 million euros to support research and development in the higher education sector (representing 7% of the sector's R&D expenditure). Half of all foreign funding (55.4 million euros) went to the higher education sector, with 65 per cent of these monies coming from EU sources. In all, EU funding accounted for 1.5 per cent of Finnish R&D expenditure in 2001.

2.2 Funding organisations

During the 1990s, government R&D funding in Finland was increasingly channelled through dedicated funding organisations, the thinking being that competitive funding has a positive impact on the quality of research. Funding administered by the National Technology Agency Tekes and the Academy of Finland increased sharply in the late 1990s as a result of the government's additional funding programme. Since that programme in 1997–1999, government budget funding through the National Technology Agency has decreased in real terms. Budget funding through the Academy of Finland has also declined in real terms in 2002 and 2003.

2.2.1 Academy of Finland research funding

The Academy of Finland is an expert organisation dedicated to promoting scientific research by means of long-term research funding based on quality criteria. The Academy grants research funding most particularly to fields of research that are internationally competitive and to fields that with the extra injection can be expected to make an international breakthrough, or that have a key role to play in building up national knowledge resources. The Academy can also take special measures to support fields of research that have national importance but that are still in the process of developing their own research culture or that are lagging behind international development. In order to guarantee sustained funding over longer periods of time, the Academy is phasing in a cycle of mainly four-year funding decisions. At the same time Academy funding for research programmes and centres of excellence in research programmes will be so spread out that annual fluctuations especially in amounts of non-earmarked funding can be ironed out. As from the beginning of 2001, all Academy funding decisions for research projects and research posts have included a 12.5 per cent overheads share.

In Table 2.5 Academy research funding is divided into five main categories. In 1998–2002, funding for research projects has represented the biggest single category of Academy funding. In 2002 the Academy's total research funding amounted to 176.5 million euros: 30 per cent of that went to research projects, eight per cent to cover the research costs of Academy Professors and Academy Research Fellows and one per cent to cover the research costs of Senior Scientists. Other funding accounted for two per cent. Research programmes and the centres of excellence programme together represented 29 per cent. Programme funding is one example of the increased cooperation between the Academy of Finland, the National Technology Agency and other funding bodies, both nationally and internationally (see also chapter 4.2.).

In 2002 researcher training accounted for 13 per cent of the value of Academy funding decisions, research posts (Academy Research Fellows and Academy Professors) for nine per cent. The annual fluctuations in the figures for research posts are explained by the corresponding fluctuation in the number of research posts. Funding that comes under the general heading of international cooperation (researcher exchange to Finland, researcher exchange to foreign countries, foreign researchers working in Finland and membership fees to international research organisations) accounted for eight per cent. In addition, the Academy of Finland supports international cooperation through its

Table 2.5. Academy of Finland research funding decisions by type of funding in 1998, 2000 and 2002.

Type of funding	1998		2000		2002	
	€ million[a]	%	€ million[a]	%	€ million[a]	%
Research projects and other support	56.7	41	68.0	43	70.6	41
Programmes	29.5	21	30.8	20	52.1	29
Research programmes	26.5	19	30.8	20	21.8	12
Centre of excellence programmes[b]	3.0	2	–	–	30.3	17
Researcher training	16.5	12	16.8	11	23.7	13
Research posts	19.6	14	23.7	15	15.8	9
International cooperation[c]	16.6	12	17.0	11	14.3	8
Total	138.9	100	156.4	100	176.5	100

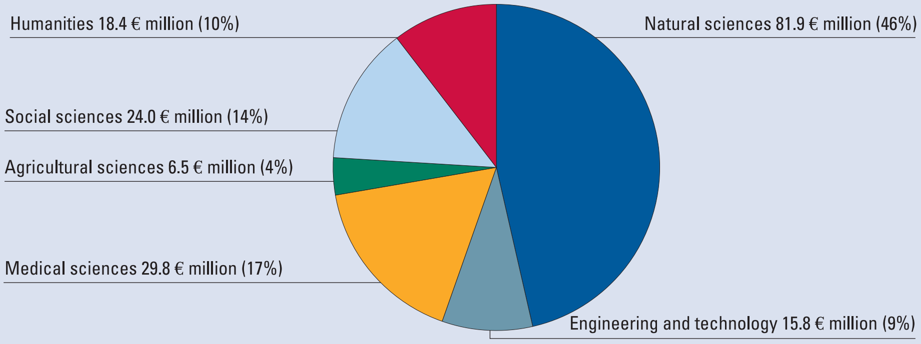
[a] The euro figures indicated for each year are annual funding authorities the cost effects of which extend beyond the year when the original funding decision was made.
[b] Funding decisions for centres of excellence in research are not made every year.
[c] Includes membership fees to international research organisations.

Source: Academy of Finland Annual Operating Review 2002.

project and programme funding (see also chapter 4.3.1). The Academy's international strategy (2002) underlines the agency's commitment to further developing its funding instruments that will support active international cooperation and networking among researchers.

In 2002 the Academy used the bulk of its research funding (46%) to support research in the natural sciences[8] (Figure 2.4). The natural sciences have accounted for a growing proportion of the total value of Academy research funding since the late 1990s. In 1999, research in the natural sciences accounted for 37 per cent of total Academy research funding. At the same time the amount of funding allocated to

Figure 2.4. Breakdown of Academy of Finland research funding decisions by major fields of science (million euros and %) in 2002.



Source: Academy of Finland Annual Operating Review 2002.

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[8] This examination is based on the six major fields of science used by the OECD. The category of natural sciences comprises the exact natural sciences, biosciences and environmental sciences: therefore research in the natural sciences (as defined by the OECD) gets support from more than one of the Academy's Research Councils.

engineering and technology has dropped from 18 per cent in 1999 to nine per cent in 2002. This trend is explained among other things by the development of disciplines supporting the information industry: the emphasis in funding has shifted from electronics to computer science, which is classified under the category of natural sciences. Funding decisions for research programmes also go some way towards explaining the changes in the relative shares of different fields of science. Funding for research in medical sciences has been in the region of 16–19 per cent, for research in the social sciences 13–16 per cent and for research in the humanities 10–12 per cent in 1998–2002. Research in agricultural sciences has accounted for 2–4 per cent of the Academy's research funding decisions.

2.2.2 Technology funding from the National Technology Agency

Technology funding from the National Technology Agency Tekes is aimed at encouraging business companies, universities and research institutes to step up their research and development effort and to take manageable risks. Public technology funding is crucial to the development and application of new knowledge and new technology. In addition, the availability of public technology funding helps to raise the ambition level and quality of research projects, support their implementation and cooperation, and spread out the technological, business and funding risks involved. The National Technology Agency allocates part of its funding on a demand basis to all technology and industry branches. Part of the funding goes to technologies that are most crucial to the national economy and society. (The Tekes Strategy… 2003.)

In 2002 the Agency's technology funding amounted to 381 million euros. One-third of the total or 32 per cent (122 million euros) went to ICT projects; 27 per cent to biotechnology and chemical technology; 19 per cent to product and production technology; and 18 per cent to energy, environmental and construction technology projects. Space activities accounted for four per cent. The only category that has increased its share since the turn of the millennium is information and communication technology: the amount of funding granted to ICT projects increased in nominal terms by 21 million euros from 2000 to 2002. Funding for energy, environmental and construction technology declined most in nominal terms, by a total of seven million euros during the same period. (Tekes Annual… 2001, Tekes funding… 2003a, 2003b.)

Technology funding from the National Technology Agency is provided in the form of research and product development funding for business companies (62% in 2002) and funding for public research at universities, polytechnics and research institutes (38%). The shares of these two categories of funding have remained effectively unchanged in 1998–2002 (Table 2.6). The Agency's technology funding is an important tool of networking that helps to bring together business companies and public research organisations: business cooperation has a key role to play in public research projects funded by the National Technology Agency. In addition, businesses that are awarded Tekes funding commission research from universities, polytechnics and research institutes.

Tekes funding for *business companies* (237 million euros in 2002) includes industrial R&D grants, industrial R&D loans and capital loans for R&D to companies. In

Table 2.6. Tekes technology funding decisions in 1998, 2000 and 2002.

Tekes funding	1998		2000		2002	
	€ million*	%	€ million*	%	€ million*	%
Industrial R&D grants for companies	146	40	154	41	157	41
Research funding for universities, polytechnics and research institutes	140	39	140	38	144	38
Industrial R&D loans for companies	45	13	45	12	46	12
Capital loans for R&D to companies	30	8	34	9	34	9
Total	361	100	373	100	381	100

* Volume of funding decisions indicated in the value of the respective year.

Source: Tekes Annual Review 2002.

1998–2002, about 40 per cent of Tekes technology funding has been awarded as industrial R&D grants. In volume terms, industrial R&D grants represent the biggest category of Tekes funding. Industrial R&D loans and capital loans have together accounted for around 20 per cent of the Agency's technology funding during the period under review. Tekes is particularly keen to support research and product development in small and medium-sized enterprises. In 1998, 45 per cent of Tekes business funding went to SMEs, in 2002 the figure was 50 per cent. When monies channelled to SMEs through Tekes-supported major corporations are included, the figure for 2002 is 56 per cent. Tekes also seeks to encourage new businesses to get involved in research and product development. In 1998–2002, new customers have accounted for 36–42 per cent of the total number of businesses being awarded Tekes support. In a regional analysis 42 per cent of Tekes business funding went to the southernmost province of Uusimaa in 2002.

In 2002 Tekes awarded 144 million euros (38% of its technology funding) to support *public research* at universities, polytechnics and research institutes. In 1998–2002, 21–25 per cent of Tekes technology funding went to universities and polytechnics (for research institutes, see chapter 2.4). The Helsinki University of Technology, the Tampere University of Technology, the University of Helsinki and the University of Oulu have been among the main recipients of funding from the National Technology Agency.

2.2.3 Other funding bodies

The Finnish National Fund for Research and Development (Sitra) provides funding for applied research that is concerned with the future challenges presented to society from a business and industry perspective (Social... 2003). In 2002 Sitra granted a total of 2.5 million euros to support research, representing around five per cent of the total volume of its funding decisions (48 million euros) (Sitra… 2003).

Grants from foundations are an important source of funding for doctoral students, for instance. In 2002, the 51 major foundations and associations represented by the Finnish Cultural Foundation's Advisory Board awarded grants worth a total of some 85.5 million euros to support scientific research and the arts in Finland (Säätiöiden… 2003).

2.3 Higher education sector

2.3.1 Universities and university hospitals

In real terms the total combined research expenditure of universities and university hospitals (hereinafter "university research") increased by almost one-quarter from 1997 to 2001, when the figure stood at 790.6 million euros. Almost 80 per cent of this increase was attributable to research expenditure covered from outside sources[9]. In 2001 over half (55%) of university research expenditure was funded from outside sources. In 1997 the share of external funding was one-half of total university research expenditure.[10]

External R&D funding by sources of funding

The most significant source of external funding for university research in 2001 was the *Academy of Finland*, which accounted for about 26 per cent of the total (Table 2.7). *The National Technology Agency Tekes* accounted for about 18 per cent. Measured in terms of funding volume, university research expenditure funded by Tekes and the Academy of Finland increased in real terms by almost the same amount from 1997 to 2001 (Tekes 35.2 million euros, Academy 34.6 million euros). Compared to the 1997 level, however, R&D expenditure funded by Tekes increased in real terms by about 82 per cent, while the corresponding increase for the Academy was 47 per cent. In other words, R&D expenditure funded by Tekes increased in relative terms more rapidly than expenditure covered from Academy sources, strengthening Tekes' role as a source of funding for university research.

In 2001 *ministries* (excluding the Academy of Finland and Tekes) covered 24 per cent of the research expenditure funded from outside sources (107.1 million euros); in 1997 the figure was 32 per cent. In 2001 about half of the support from ministries consisted of so-called EVO grants from the Ministry of Social Affairs and Health, which are paid out to university hospitals by way of compensation for the research done by university hospital staff. *Other public funding* for university research showed strong real growth from 1997 to 2001, although it accounted for no more than four per cent of the research expenditure covered from outside sources in 2001.

In 2001 *business companies* spent 61.6 million euros in support of university research, which represented about eight per cent of the total research expenditure by universities and university hospitals. Private business accounted for 14 per cent of the total volume of external funding made available to university research. Most of the corporate funding came from domestic companies, whose funding for university research increased in real terms by 17.3 million euros from 1997 to 2001. The real increase in domestic and foreign corporate funding was about 55 per cent. In relative terms funding from foreign companies increased more than funding from domestic companies.

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[9] University research expenditure covered from core budget sources refers to those categories of research expenditure that are funded from university appropriations in the State Budget; external research funding refers to all other sources of funding. Although funding granted to universities by administrative branches (including funding from the Academy of Finland and the National Technology Agency) is part of the government's budget resources, it is considered as a form of external funding. (For more on the definition of external university funding, see Ulkopuolinen... 2002. For further details on the principles applied by Statistics Finland in compiling R&D statistics and on the definitions of concepts, see Tutkimus- ja kehittämistoiminta... 2003b.)

[10] In 2001 outside sources accounted for 51 per cent of the universities' research expenditure, in 1991 for 31 per cent (including investments in buildings).

Table 2.7. External funding for research by universities and university hospitals and real growth of external funding (%) from 1997 to 2001 by source of funding.

Sources of funding	1997		2001		Real growth[a] %
	€ million	%	€ million	%	1997–2001
Academy of Finland	69.2	24	112.0	26	47
Ministries[b]	91.1	32	107.1	24	7
National Technology Agency Tekes	40.4	14	81.0	18	82
Finnish companies	30.3	10	51.3	12	54
EU funding[c]	20.9	7	26.5	6	15
Domestic funds[d]	7.3	3	17.0	4	110
Local governments and other public funding[e]	8.6	3	16.0	4	70
Foreign companies	5.9	2	10.3	2	58
Other foreign funding[f]	6.9	2	8.8	2	16
Universities' own funds[g]	8.3	3	7.8	2	–15
External funding total	289.0	100	437.8	100	38
Core budget funding	291.0		352.7		10
Research expenditure total	580.0		790.6		24

[a] Deflated by the GDP market price index (2000 = 100).
[b] Excluding the Academy of Finland and the National Technology Agency Tekes.
[c] EU funding from framework programmes and structural funds.
[d] Including foundations, organisations, associations and private citizens.
[e] E.g. the Finnish National Fund for Research and Development, the Finnish Work Environment Fund, Finnvera, and the Social Insurance Institution.
[f] E.g. foreign universities, central agencies and international organisations.
[g] Including funding from universities' own foundations.

Source: Statistics Finland 1999 & 2003c.

Financing for university research from *domestic funds* more than doubled from 1997 to 2001, when it accounted for about four per cent of total external funding.[11]

In 2001, one-tenth of the external funding made available to university research came from *foreign sources*. Funding from EU sources represented 58 per cent of all foreign funding. The volume of EU funding increased in real terms by around 15 per cent or 3.4 million euros from 1997 to 2001.

University research expenditure by major fields of science

Table 2.8 describes the breakdown of total university research expenditure by major field of science as well as the allocation of core budget funding and external funding to different disciplines in 2001. In Finland most support went to research in the natural sciences, medical sciences, engineering and technology, and the social sciences. Core funding was more evenly distributed between different fields of science than external funding. The bulk of external funding was channelled into research in medical sciences as well as in the natural sciences: both categories represented around 30 per cent of the total volume of external funding to universities and university hospitals.

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[11] R&D statistics do not cover all grants and allocations from funds and foundations, but only those that are paid through university books of account.

Table 2.8. Total research expenditure, core budget funding and external funding for research at universities and university hospitals by major field of science in 2001.

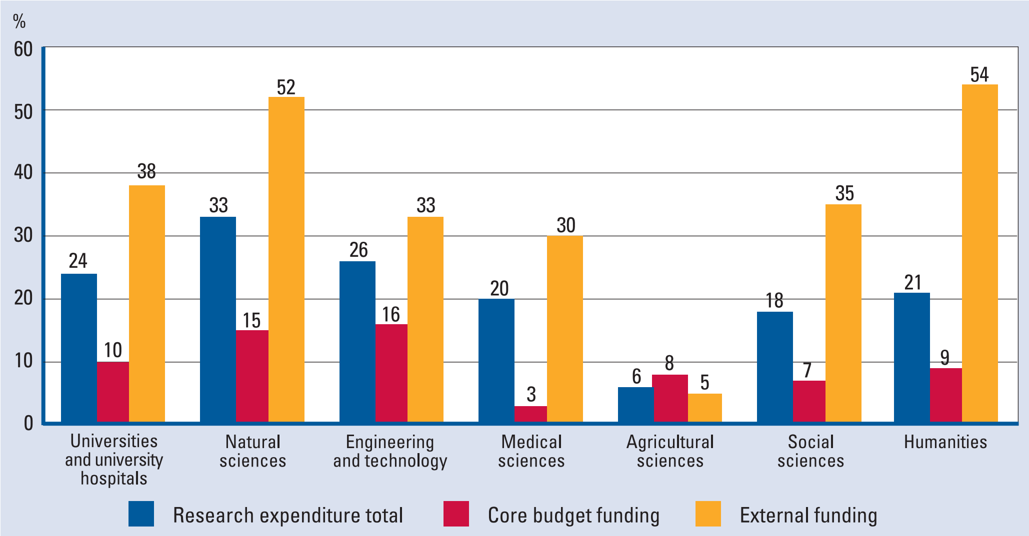
Major field of science	Research expenditure		Core budget funding		External funding	
	€ million	%	€ million	%	€ million	%
Natural sciences	226.9	29	100.0	28	126.9	29
Engineering and technology	147.1	19	56.9	16	90.2	21
Medical sciences	196.8	25	66.1	19	130.7	30
Agricultural sciences	14.2	2	6.2	2	8.1	2
Social sciences	137.0	17	78.4	22	58.6	13
Humanities	68.4	9	45.1	13	23.4	5
Total	790.6	100	352.7	100	437.8	100

Source: Statistics Finland 2003c.

With the exception of the social sciences (43%) and the humanities (34%), well over half of all research expenditure was covered from outside sources in all major fields of science in 2001. The share of external funding was greatest (66%) for research in medical sciences.

Figure 2.5 describes the relative development of research expenditure and the research funding structure from 1997 to 2001 in different fields of science. In real terms both total research expenditure and research funding from core budget sources increased most in the natural sciences and engineering and technology. With the exception of agricultural sciences, the real change in external funding was far greater than the real change in core budget funding in all fields of science. In relative terms external funding increased most in the humanities and natural sciences, where in real terms funding from outside sources increased more than a one and a half times over.

Figure 2.5. Real growth (%) of total research expenditure, core budget funding and external funding for research at universities and university hospitals from 1997 to 2001 by major field of science.



Source: Statistics Finland 1999 & 2003c.

2.3.2 Polytechnics

The applied research and development effort at Finnish polytechnics is geared to supporting teaching at polytechnics, the needs of working life and regional development. In 2001, R&D expenditure by polytechnics represented about five per cent (43.6 million euros) of the higher education sector's total R&D expenditure. The figures have shown relatively strong real growth in recent years. Total research expenditure by polytechnics increased almost one and a half times over from 1999[12] to 2001, while the real growth recorded for university research at the same time was no more than 0.6 per cent. By major fields of science, engineering and technology and the social sciences clearly stand apart from other fields, accounting for about 80 per cent of total R&D expenditure by polytechnics. In 2001, engineering and technology accounted for 46 per cent of core budget funding, and for 51 per cent of external funding. The corresponding figures for the social sciences were 34 and 27 per cent.

External funding for R&D at polytechnics showed a real increase of 51 per cent and core budget funding an increase of 44 per cent from 1999 to 2001. In 2001, external funding for R&D at polytechnics amounted to 32.4 million euros (74%). The share of funding from outside sources was markedly higher than in university research (i.e. universities and university hospitals), where 55 per cent of total research expenditure in 2001 was covered from outside sources. Excluding the contributions of the National Technology Agency Tekes and the Academy of Finland, public sources accounted for 44 per cent of the external funding of R&D at polytechnics. Tekes covered around ten per cent of the all R&D expenditure covered from outside sources, domestic companies 14 per cent. The share of EU funding was 30 per cent.

2.4 Government research institutes

Total research spending by government research institutes increased in real terms by about eight per cent from 1998 to 2002, when the figure stood at 447.3 million euros[13]. Government research institutes, too, have seen an increase in the proportion of external funding. Core budget funding for research[14] decreased in real terms by one per cent, while external funding increased in real terms by 20 per cent from 1998 to 2002. In 1998, 43 per cent of the government research institutes' R&D expenditure was covered from outside sources, while the corresponding figure in 2002 was 48 per cent. In 2002, government research institutes expected to receive 33 million euros or 16 per cent of their external research funding from the European Union. The estimate for EU funding in 2003 is 41 million euros: that would mean the amount of EU monies available for research institutes has more than doubled since 2000.

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[12] Statistics Finland's R&D statistics have covered R&D expenditure by polytechnics since 1999. Calculations of real growth deflated by the GDP market price index (2000 = 100).

[13] The analysis of research expenditure and the funding of research expenditure in the higher education sector (chapter 2.3) is based upon Statistics Finland R&D statistics. Funding for research at government research institutes is described on the basis of figures published in reports compiled based upon the State Budget. The R&D statistics and the figures from these budget analyses are not directly comparable. Figures for the volume of external funding for individual government research institutes are target estimates.

[14] Core funding for 1998 includes Ministry of Finance real estate investments. Calculations of real growth deflated by the GDP market price index (2000 = 100).

Government research institutes' structure of R&D funding varies widely case by case. The Technical Research Centre of Finland VTT continues to account for a significant proportion of the combined external funding for government research institutes, even though its share has declined from 79 per cent in 1998 to 70 per cent in 2003. External research funding has also increased at other research institutes. In 2003 more than 70 per cent of R&D at VTT is funded from outside sources (Table 2.9). Likewise, over half of the R&D funding at the Finnish Environment Institute comes from outside sources. At the Research Institute for the Languages of Finland, the share of external funding is no more than seven per cent.

■ Table 2.9. Total R&D funding for government research institutes and percentage share of external funding in 2003. The institutes are rank-ordered according to the share of external funding.

Government Research Institutes[a]	Funding total € million	Percentage share of external funding[j]
Technical Research Centre of Finland VTT[b]	216.1	73
Finnish Environment Institute[c]	18.5	51
Regional Environment Centres[c]	5.7	45
National Public Health Institute[d]	27.3	38
Finnish Institute of Occupational Health[d]	21.4	36
Agrifood Research Finland[e]	46.4	35
Consumer Research Centre[b]	2.6	33
Finnish Meteorological Institute[f]	9.8	32
National Research and Development Centre for Welfare and Health[d]	17.9	24
Finnish Game and Fisheries Research Institute[e]	11.9	23
Government Institute for Economic Research[g]	4.7	21
Finnish Geodetic Institute[e]	3.8	21
National Board of Antiquities[h]	2.5	17
Finnish Institute of Marine Research[f]	4.2	16
National Research Institute of Legal Policy[i]	1.2	14
Geological Survey of Finland[b]	8.5	14
Veterinary Medicine and Food Standards Research Institute[e]	4.7	14
Radiation and Nuclear Safety Authority[d]	6.8	11
Finnish Forest Research Institute[e]	39.7	10
Research Institute for the Languages of Finland[i]	4.9	7
Total	458.5	49

[a] Host ministry indicated by superscript as follows:
[b] Ministry of Trade and Industry
[c] Ministry of the Environment
[d] Ministry of Social Affairs and Health
[e] Ministry of Agriculture and Forestry
[f] Ministry of Transport and Communications
[g] Ministry of Finance
[h] Ministry of Education
[i] Ministry of Justice.
[j] Target estimate including expenditure of budgeted projects as well as projected other external funding.

Source: Statistics Finland 2003a.

In 1998–2002 research institutes have received from six to eight per cent of Academy of Finland research funding. In 2002 the Academy granted to research institutes a total of 10.7 million euros in research funding. In the 2000s especially the National Public Health Institute, the Finnish Forest Research Institute, the Finnish Meteorological Institute and the Technical Research Centre of Finland VTT have fared well in the competition for funding. In 1998–2002 Tekes has awarded 10–12 per cent of its technology funding to projects at research institutes. The majority of Tekes funding to research institutes (87% or 34 million euros in 2002) has been awarded to VTT.

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3 The human resources of research

This chapter provides an overview of personnel engaged in research and development (R&D) in Finland as well as their placement, employment and mobility, with special reference to the research career and the researcher's profession[1].

3.1 Research personnel

3.1.1 International comparison

Finland and Sweden are among the EU's most active member states in terms of investment in human resources in R&D and research funding (Human resources... 2002). A recent comparison by the EC shows that in 1995–1999, the total number of research-years increased most in Greece (53%) and in Finland (51%) (Third... 2003). The average increase for all EU Member States was 12 per cent. Finland recorded the highest number of research-years[2] as a proportion of the total employed population. In 1999 the number of research-years per 1,000 employed persons in Finland was 9.6; in Sweden the figure was 9.1, while the average for all EU countries was 5.4. The figure for Japan was 9.7 and for the United States 8.7. It is noteworthy that although the number of research-years in Finland has been high, it has still continued to show strong growth.

In 1999 the private business sector accounted for half of all research-years worked in the EU countries. The university sector accounted for one-third, the rest of the public sector for less than 15 per cent. In Finland, the business sector accounted for 42 per cent, the university sector for 41 per cent and the rest of the public sector for 16 per cent of all research-years. In 1999 the number of research-years as a proportion of all person-years worked by R&D personnel[3] in the Finnish business sector was 38 per cent, in the university sector 70 per cent and in the rest of the public sector 55 per cent. The average for EU countries in the university sector was 65 per cent and in the rest of the public sector and in private companies about one-half. (Third... 2003.)

According to OECD statistics the level of education in OECD countries is continuing to rise even though investment in higher education increased more slowly than GDP in the latter half of the 1990s. The sharp rise in the educational level has coincided with an increase in the number of researchers in virtually all OECD countries, particularly in the private sector. In 2000, the number of new graduates with a researcher training (science and engineering) per one thousand population aged 25–34 in Sweden was 1.2 and in Finland 1.0, with the EU average standing at 0.6 (Third... 2003).

OECD comparisons suggest that Finland's main strengths lie in the country's high level of education, its strong education system and positive public opinion towards education. The main challenges for the future, in the assessment of the Science and

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[1] See also chapter 9 (Hannele Kurki: Gender in the research system).

[2] Includes categories ISCO-2: Research Professionals and ISCO-1237: R&D Department Managers (Frascati Manual. Proposed standard practice for surveys on research and experimental development 2002. OECD).

[3] Includes categories ISCO-2: Research Professionals, ISCO-1237: R&D Department Managers and ISCO-3: Technicians and Associate Professionals (Frascati manual... 2002).

Technology Policy Council of Finland (Knowledge, Innovation... 2003), include raising the level of education and preventing exclusion by encouraging age cohorts in their entirety to complete a secondary level degree. It is at this level that young people make the most critical choices with regard to their further studies and professional career.

3.1.2 Placement in different sectors[4]

Around two per cent of the active workforce (person-years) in Finland are engaged in research and development; this is more than anywhere else in the OECD. In 2001, almost 70,000 people worked in research and development, with the number of person-years totalling more than 50,000 (Table 3.1). From 1997 through to 2001, the number of personnel increased by 26 per cent and the number of person-years by 30 per cent. Women have accounted for just over 30 per cent of R&D personnel. In 2001, 31 per cent of the research personnel were engaged in the higher education sector, 15 per cent in public sector positions and 54 per cent in the business enterprise sector.

Table 3.1. R&D personnel and person-years by sector in 1997, 1999 and 2001.

	1997	%	1999	%	2001	%	% change 1997–2001	% change 1999–2001
Higher education sector								
Number of personnel	16,685	30	20,036	30	21,517	31	29	7
Person-years	11,762		14,840		15,596		33	5
Public sector*								
Number of personnel	9,666	17	10,523	16	10,300	15	7	–2
Person-years	7,099		7,946		7,738		9	–3
Business enterprise sector								
Number of personnel	29,139	53	36,406	54	37,971	54	30	4
Person-years	22,302		27,818		30,090		35	8
Total								
Number of personnel	55,490	100	66,965	100	69,788	100	26	4
Person-years	41,163		50,604		53,424		30	6

* incl. private non-profit institutions.

Source: Statistics Finland 1999, 2000 & 2003.

In 2001 about half of the R&D personnel had a university degree, marking an increase of 23 per cent on the figure for 1997. The number of PhDs as a proportion of research personnel has remained more or less unchanged at just over 10 per cent. In 2001 less than one-third or 30 per cent of PhDs were women (Figure 3.1). More than two-thirds or 68 per cent of PhDs were engaged in the higher education sector, primarily in universities. Less than one-fifth, 18 per cent were engaged in other public sector jobs. Only 14 per cent of PhDs worked in the private sector.

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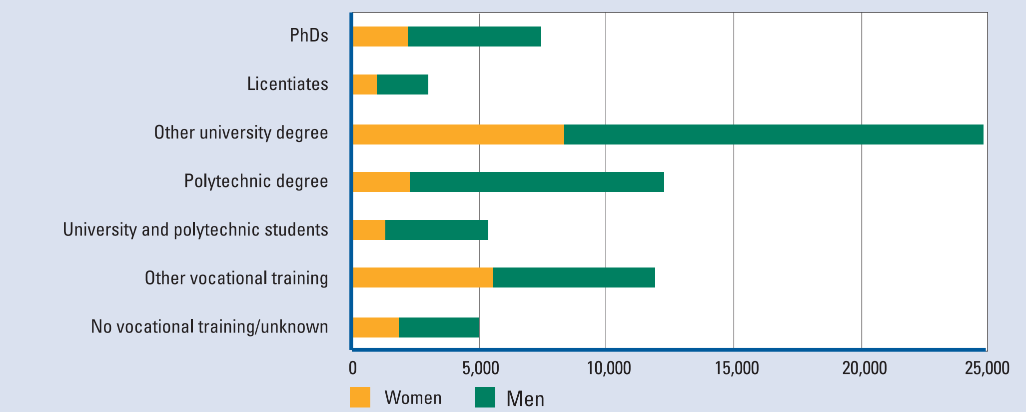
[4] 1) Higher education sector: universities, university hospitals, and polytechnics (since 1999); 2) Public sector: government administrative branches, other public institutions, private non-profit institutions; 3) Business enterprise sector: industrial manufacturing and other industries.

Figure 3.1. R&D personnel by education and gender in 2001.



Source: Statistics Finland 2003.

In the *higher education sector* the number of research personnel has increased from 1997 to 2001 by 29 per cent. PhDs accounted for 23 per cent of research personnel, Licentiates for eight per cent, while 36 per cent had some other university degree in 2001. Natural sciences accounted for the largest number of research-years in 2001, representing 30 per cent of the total; within this category biology and environmental sciences accounted for one-third of the total (Table 3.2). Electrical engineering accounted for one-third of the 22 per cent share of engineering and technological sciences. Medical sciences accounted for 19 per cent of all research-years, social sciences for 18 per cent and the humanities for eight per cent. Agricultural sciences represented no more than two per cent of the total number of research-years. The number of research-years funded from outside sources showed the strongest growth in the humanities, social sciences and in agricultural sciences.

Table 3.2. Breakdown of person-years in the university sector by major fields of science in 1997 and 2001.

Major field of science	1997 Person-years	Share of external funding	2001 Person-years	Share of external funding	% change in person-years	% change in external funding
Natural sciences	3,352	2,001	4,731	3,088	41	60 → 65
of which biology and environmental sciences	1,151	662	1,543	1,008	34	58 → 65
Engineering and technology	2,288	1,636	3,503	2,559	53	72 → 73
of which electrical engineering	617	434	1,108	820	80	70 → 74
Medical sciences	2,573	1,613	3,009	1,938	17	63 → 64
Agricultural sciences	274	187	342	256	25	68 → 75
Social sciences	2,244	1,239	2,829	1,765	26	55 → 62
Humanities	1,031	459	1,182	643	15	45 → 54
Higher education sector total	11,762	7,135	15,596	10,249	33	61 → 66

Source: Statistics Finland 1999 & 2003.

In 2001 the number of research personnel in the *public sector* was 10,300, marking an increase of seven per cent on 1997. The proportion of PhDs was 13 per cent, Licentiates accounted for six per cent and those with some other university degree 37 per cent. The administrative branches with the largest number of research personnel were those under the Ministry of Trade and Industry, the Ministry of Agriculture and Forestry and the Ministry of Social Affairs and Health. These are all branches that have major government research institutes. In relative terms the proportion of PhDs was highest, at one-fifth of research personnel, in the administrative branches under the Ministry of Education and the Ministry of Transport and Communications.

In the *business enterprise sector* the number of research personnel in 2001 stood at 37,971 (Table 3.3), of whom more than 22 per cent were women. The number of research personnel has increased by 30 per cent since 1997, with hardly any change in the proportion of women. In 2001 the proportion of PhDs was close on three per cent, that of Licentiates two per cent and that of personnel with some other university degree 35 per cent. In 1997 the number of business enterprise sector research personnel engaged in industry stood at 22,094 (women 20%) and in 2001 at 27,592 (women 23%).

Table 3.3. Business enterprise sector R&D personnel by industry in 1997 and 2001.

Industry	1997	2001	% change
Manufacturing total	22,094	27,592	25
Food industry	765	858	12
Textile, clothing, leather and footwear industries	219	216	–1
Wood processing industry	1,222	1,217	0
Chemical industry	3,176	3,430	8
Metal and mechanical industry	4,581	5,104	11
Electronics industry	11,455	16,073	40
Other manufacturing	677	694	3
Electricity, gas and water supply	539	306	–43
Construction	445	648	46
Wholesale and retail trade	596	743	25
Transport, storage and communication	1,120	1,563	40
Computer and related activities	1,147	3,790	230
Research and development	1,256	1,239	–1
Other business activities	1,445	1,842	27
Other industries	405	247	–39
Business enterprises total	29,139	37,971	30

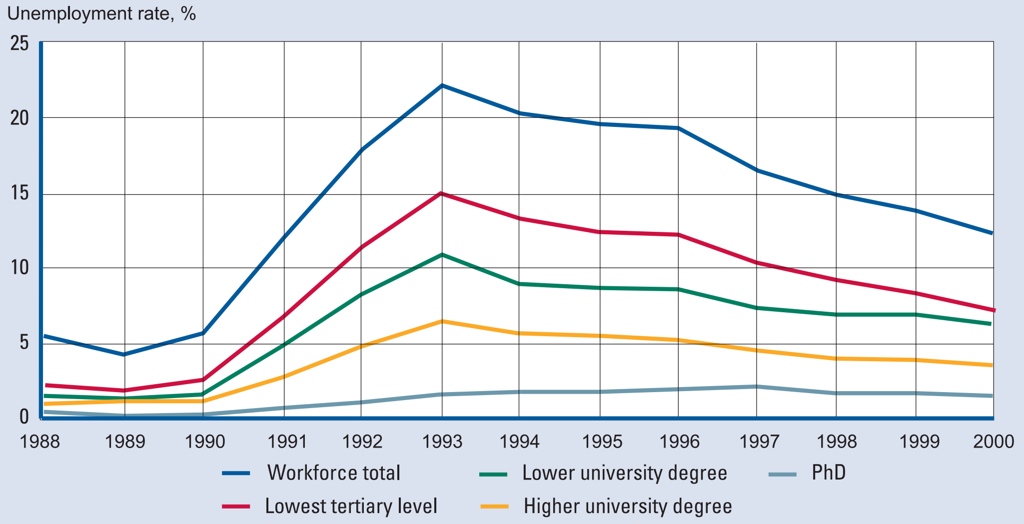
Source: Statistics Finland 1999 & 2003.

In 2001 the electrotechnics industry had a research staff of 16,073, representing 42 per cent of the total business enterprise sector research staff and 58 per cent of the research staff in industrial manufacturing companies. The personnel number in the electrotechnics industry increased by 40 per cent from 1997 to 2001. The second highest personnel number was recorded for computer and related activities, where research staff numbers increased by as much as 230 per cent from 1997 to 2001. Research staff (3,790 in 2001) accounted for 10 per cent of all business sector research personnel.

3.1.3 Employment

With the jobless rate persistently at around the 10 per cent mark, unemployment remains a major obstacle to socio-economic development in Finland. However people with a higher university degree have had little difficulty finding employment. In 2000, the unemployment rate in this category was no more than 3.6 per cent (Figure 3.2). Among PhDs, the unemployment rate in 2000 was 1.5 per cent. In engineering and technology as well as in medical sciences, the unemployment rate among PhDs was just 0.6 per cent. In the humanities, 3.7 per cent of PhDs were out of work in 2000. (Husso 2002.)

Figure 3.2. Unemployment rate (%) by level of education in 1988–2000.



Source: Husso 2002.

According to an inquiry[5] conducted at year-end 2002 among more than one thousand public sector organisations and private corporations, PhD graduates were in demand most particularly in ministries, in the public administration sector, in government agencies and in the administration of university cities. Half of the respondents representing these organisations said they would be needing to recruit one or more PhDs. At government research institutes one in three would have hired PhDs, at research and product development units in major corporations one in four. Half of the major corporations (total 100) included in the survey did not have a single PhD in research and product development positions. It was expected that the demand for PhDs would be increased in five years' time. Most of the PhDs would be recruited into research and development jobs.

The number of R&D personnel has increased steadily throughout the 1990s, particularly in the higher education and business enterprise sector. The numbers have grown

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[5] The survey is based on 1,140 interviews with the following target groups: 1) large, medium-sized and small enterprises, 2) major corporations with their own R&D operations, 3) ministries, the administrative sector, government agencies and university and other cities, and 4) government research institutes (PhDs in Finland...2003).

most in engineering fields. The Finnish industrial structure has become increasingly knowledge-intensive within a short space of time, and at the same time qualification requirements have continued to rise. The Science and Technology Policy Council of Finland (Knowledge, Innovation… 2003) expects to see the same trend continue in the future, with new jobs more and more often being created in fields that require high levels of knowledge and expertise. However, for reasons that have to do with the population's age structure, the recruitment base is set to become much reduced in the very near future.

The trends and patterns of change in the volume of research are not the same across different industries. In Finland the information industry is a more significant source of employment than in any other OECD country, but the sector's employment potential is very much dependent on cyclical effects. According to the Science and Technology Policy Council of Finland (Knowledge, Innovation… 2003) the outlook for the next few years is still good, in spite of the current recession. It is expected that the bulk of economic growth and new jobs will be created in and by the service industries. In Finland knowledge-intensive services, such as research and development, have increased very rapidly. The development of service innovations ties in closely with the skills and know-how of individual staff members. In some service branches the public sector has a major role either as a provider, regulator or buyer of services. Business know-how is more and more in demand in several different branches. In their assessment of the government's additional funding programme for science and research, Prihti et al. (2000) concluded that in the near future we may well be seeing a shortage of competent people in the cultural sector.

In the public sector large numbers of R&D personnel work at government research institutes, which have seen some cutbacks in their core budget funding during the 1990s. Staff numbers have increased mainly through fixed-term project funding from outside sources. In the higher education sector there was no change during the 1990s in the number of university teaching staff paid from core budget funds, so newly recruited research staff are mainly engaged in fixed-term projects with external funding. Some research laboratories have a shortage of competent staff, and technical personnel are more and more often in need of additional training. Future employment prospects will largely depend upon the development of university funding, changes in the system of teaching and research posts and the retirement of babyboomers. Research and development at polytechnics is gathering momentum all the time, and in this sector there will be a growing need for competent staff to further strengthen that input. The Science and Technology Policy Council of Finland suggested in 2003 that in developing their basic training programmes, universities should pay close attention to forecasts of the future labour demand and to changing regional needs.

3.1.4 Mobility

Labour mobility[6] increases with level of education: the higher the level of education, the higher the level of mobility (Figure 3.3). People with a higher university degree have

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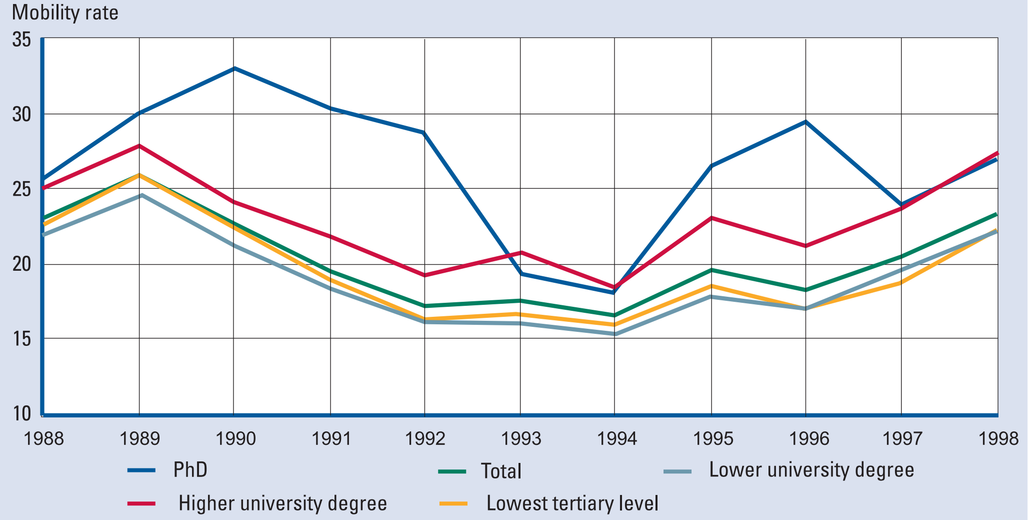
[6] Mobility in these data occurs between organisations or between organisations operative units. Operative unit refers here to an administrative unit or area of responsibility within an organisation (Husso 2002).

had a higher rate of mobility than people with a lower level of education. Among PhDs, no less than one-quarter change jobs each year. The labour markets for PhDs are not as closely dependent on business cycles as they are for the rest of the labour force. This is explained, among other things, by the fact that the majority of PhDs are engaged in the public sector. In 1999, PhD mobility at operative unit level in universities was 18 per cent, in government research institutes 10 per cent and in the business sector 33 per cent (Husso 2002).

Figure 3.3. Mobility rate* by level of education (job-to-job inflow, operative unit level) in 1988–1998.



*Mobility rate = number of employed persons who have changed operative units since previous year / total number of employed persons. Operative unit refers here to an administrative unit or area of responsibility within an organisation. Mobility may occur between or within organisations.

Source: Husso 2002.

Comparatively few PhDs have moved permanently[7] to Finland from other countries. For instance, in 1998 a total of 52 PhDs moved permanently to Finland, but only 15 of them were foreign nationals. The majority or 37 of them were Finnish citizens, 27 of them returning from EU countries. In the same year 102 PhDs moved permanently out of Finland, 92 of them were Finnish citizens. Sixty Finnish PhDs moved to EU countries, 22 of them to Sweden, 15 went to the United States. (Husso 2002.)

In 2000 the number of foreign nationals as a proportion of Finland's R&D personnel[8] (1.3%) was the fourth lowest in the European Union (Figure 3.4). The average for the EU countries was 4.1 per cent. In 1998 the Finnish figure was no more than 0.6 per cent. Most foreigners moving to Finland were from non-EU European countries (Third... 2003).

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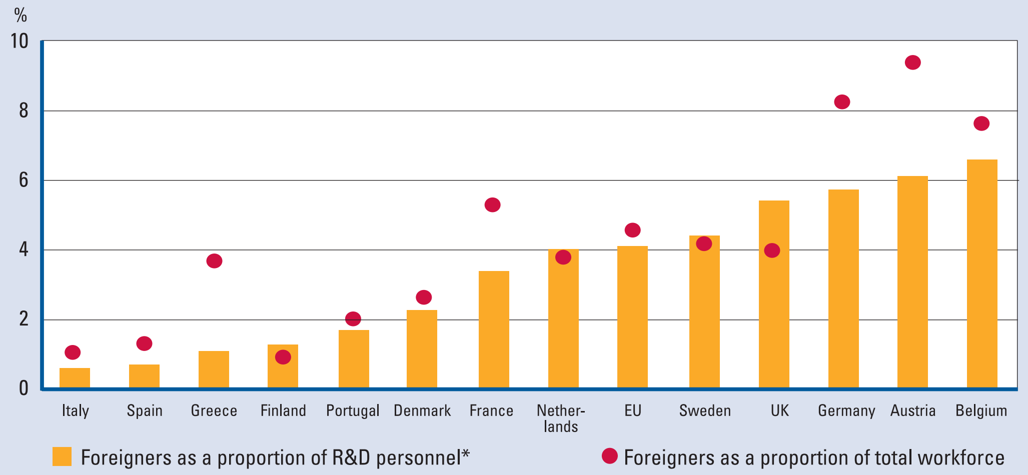
[7] Based on immigration authorities' information on the number of people moving permanently into or out of Finland.

[8] Includes categories ISCO-2: Research Professionals and ISCO-3: Technicians and Associate Professionals (Frascati manual... 2002).

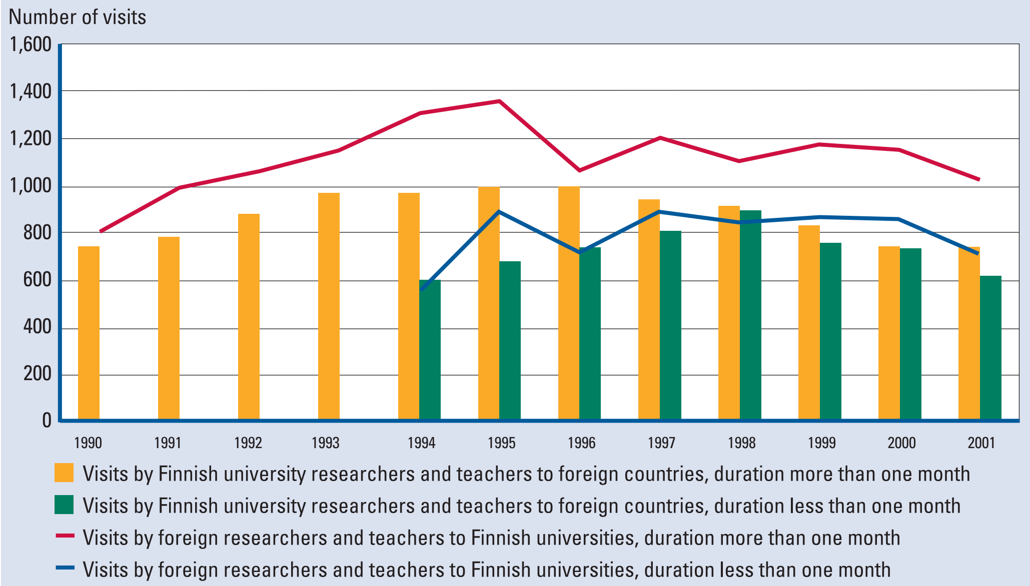
Figure 3.4. Number of foreign nationals as a proportion of R&D personnel and active workforce in EU Member States in 2000.



* R&D personnel includes research professionals, and technicians and associate professionals (ISCO 2 & 3; Frascati manual... 2002).

Source: Third European Report on S&T Indicators 2003.

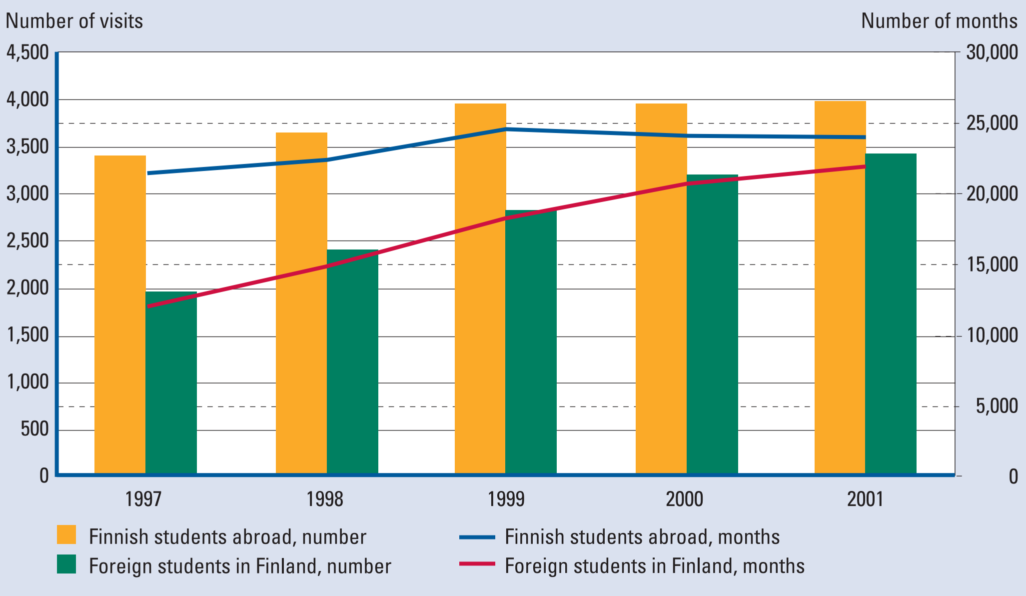
Figure 3.5. Visits by teaching and research staff from Finnish universities to foreign countries and visits by foreign researchers to Finnish universities in 1990–2001.



Source: KOTA database, Ministry of Education

The number of visits by teaching and research staff from Finnish universities to foreign countries is smaller than the number of visits made to Finnish universities from abroad (Figure 3.5). The number of visits by foreign students to Finnish universities has rapidly increased, but the number of visits by Finnish students has remained more or less unchanged (Figure 3.6).

■ Figure 3.6. Visits lasting more than three months by Finnish university students to foreign countries and foreign students' visits lasting more than three months to Finnish universities in 1997–2001.



Source: KOTA database, Ministry of Education.

In 2002 the Academy of Finland had bilateral researcher exchange agreements with 37 organisations and 25 countries. Almost all of the Academy's funding instruments can also be used for purposes of supporting researcher mobility. In 2002 the number of researchers working in foreign countries with international exchange grants from the Academy stood at 412, while the number of foreign researchers in Finland was 236. A total of 136 persons (125 person-years) worked abroad in 2002 with funding for researcher training and work abroad.

In Finland the Centre for International Mobility (CIMO) coordinates and implements scholarship and staff exchange programmes and has responsibility for the national execution of almost all EU training, culture and youth programmes. Grants for postgraduate students and researchers are awarded primarily to Russia and neighbouring regions. In 2001 a total of 389 scholars travelled from Finland to 35 different countries, while Finland received 785 fellows from 60 countries. Scholars from Russia accounted for 27 per cent, those from the Baltic States and countries of Central Eastern Europe for 38 per cent. In 2000–2001, the number of students arriving in Finland through the Erasmus programme (3,554) exceeded the numbers leaving Finland (3,286) for the first time. (CIMOn vuosi... 2002.)

The Fifth EU Framework Programme in 1998–2002 included 31 projects that had researcher exchange with Finland. Sixteen of these consisted of grants to individual researchers travelling to Finland, fifteen provided funding for the Finnish host organisation. Twenty-nine researchers left Finland for Europe with a Marie Curie grant. In addition, some Finnish researchers joined European research infrastructures. The most popular destination for Finnish researchers was Great Britain, followed by the Netherlands, France, Greece, Poland and Germany.

3.2 The researcher's profession

3.2.1 Science policy lines and objectives

The Science and Technology Policy Council of Finland has stressed the importance of raising the overall level of education in the country and at once of upgrading the competencies of R&D staff within the Finnish research and innovation system (Finland... 1996, Review... 2000). One of the three main development challenges identified in the Council's most recent review is presented by training, the development of research careers and the expansion of broadly-based research knowledge (Knowledge, Innovation... 2003).

A working group appointed by the *Ministry of Education* to explore different avenues for the development of the research career (Tutkijanuran... 1997) recommended that a postdoctoral system be created and that young researchers be supported in the initial stages of setting up research teams. Research environments should be so developed that posts for teacher-researchers would be for fixed terms only. That would promote mobility. Universities should also work more closely with business and industry, sectoral research and the school system. The Ministry of Education's Education and research development plan adopted by the Council of State for 1999–2004 (Education... 2000) included plans to further expand and strengthen the graduate school system, which was to become a key avenue to the PhD: the target was set at around 1,400 new degrees annually. Graduate schools were to be appointed on a fixed term basis through open competition. Furthermore, the aim was to encourage and promote collaboration between individual schools; to establish a network of graduate schools with nationwide coverage; to allocate training places according to the need for PhDs in different branches; and to remove obstacles to women's careers in research.

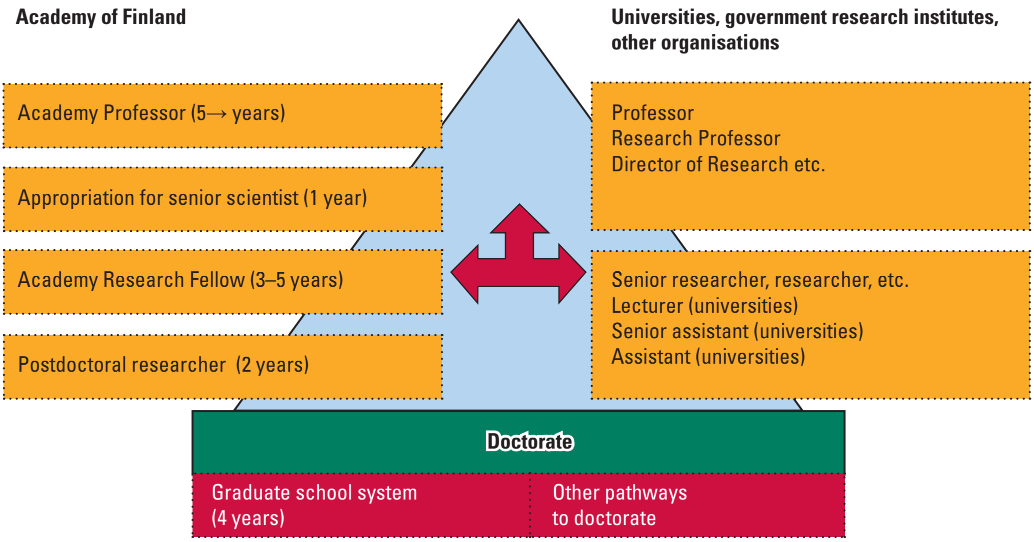
In 2002 the Ministry of Education appointed a working group charged with the promotion and development of researcher training during 2002–2005. Specifically, the working group is concerned with developing researcher training and research careers; securing a sufficient supply of competent professional researchers; securing a broad and diverse knowledge base as well as its regeneration and renewal; and developing creative research and training environments.

The agreement on target outcomes between the Ministry of Education and the *Academy of Finland* for 2001–2003 includes the targets of promoting high-quality and effective researcher training and offering professional researchers competitive career prospects. In addition, the Academy of Finland has compiled the following strategies: Competition and Cooperation (1998), Academy of Finland's Forward Look 2000 (2000), the Academy's Equality Plan for 2001–2003 (2001) and the Academy's International Strategy (2002). It is emphasised in all these documents that professional researchers shall be given the opportunity to an internationally competitive, interesting and financially rewarding career. Steps shall also be taken to secure an adequate supply of professional researchers. The aim is to have one-fifth of all PhD graduates proceed to the postdoctoral system, with the Academy proposing to increase the number of postdoc vacancies to 500. At graduate schools the PhD shall be completed before age 30. Researcher exchange, mobility as well as women's careers in research shall be supported. The skills and competencies needed by researchers in international cooperation shall be improved and upgraded. The discussion below will also consider the attainment of these objectives.

3.2.2 The professional research career: stages and avenues

The research career proper (Figure 3.7) begins with PhD training. However, the foundation is provided by the school system as a whole, which ideally inspires young people at school to consider the option of a career in research.

Figure 3.7. The professional research career: from researcher training to professor.



In spring 2003, Finland's regular (daytime) upper secondary schools had a total of 115,000 pupils. International comparisons have shown that learning results in Finland are of a very high standard. For instance, the OECD's PISA survey, youth literacy in Finland is at a higher level than anywhere else in the world (Knowledge and skills... 2001). Educational equality is also reasonably well secured, both in regional terms and between individual schools and genders. There are not very many drop-outs or top performers in Finland. In maths and the natural sciences, Finnish schoolchildren rank in the top one-quarter. Nonetheless, it is estimated that 10–20 per cent of each age cohort have gaps in their knowledge in these subjects that will adversely affect their future success and performance even in upper secondary school (Knowledge and skills… 2001). In Europe the main focus in the development of secondary education is on strengthening the interest of young people in the natural sciences, which in many countries has been showing signs of dwindling. Coordinated by the Ministry of Education, the national LUMA development programme in 1996–2002 was aimed at improving skills and competencies in mathematics and the natural sciences (physics, chemistry, biology and natural geography), but the final evaluation of the programme still identified areas that called for further development.

In 2002 Finnish universities had a total of 169,970 degree students. The number of new students was 20,563, 56 per cent of whom were women. From 1997 to 2002, the total number of degree students has increased by 19 per cent. About one-half of all matriculating upper secondary school students seek admission to university, but no more than one-fifth gain entry at their first attempt. In 2003 the Ministry of Education and the universities agreed that as from the beginning of 2005, newly matriculated students will have a 50 per cent quota among new university entrants. Gap years after the matriculation examination are another typical feature of Finland. In 2000–2001, four per cent of all university students dropped out.

Researcher training

Launched by the Ministry of Education in 1995, the graduate school system in Finland is built around a network of schools that are nominated for a fixed period of time. Students are enrolled on a full-time basis, and they are expected to complete their doctoral degree within four years. The selection of both graduate schools and students is based on open competition. The graduate school system was set up with a view to providing better supervision for doctoral students, supporting more systematic researcher training and raising its quality standards, lowering the average age of PhD graduation, promoting the professionalisation of the research career and increasing international cooperation in the field of research and researcher training. The scientific standard of applications for graduate schools and the quality of researcher training provided are evaluated by the Academy of Finland. The Board of the Academy submits to the Ministry of Education a shortlist of graduate school candidates and the number of student places at each school. The final decision rests with the Ministry of Education.

At the beginning of 2003 there were a total of 114 graduate schools in Finland. Operating in connection with universities, they offered 1,426 graduate school places funded by the Ministry of Education. Graduate schools are often multidisciplinary, but they can be roughly categorised as follows. There were 45 graduate schools in the field of natural sciences and engineering, with a total of 618 student places (43%); 40 graduate schools in the fields of culture and society, with 346 places (24%); 16 graduate schools and 245 places in medicine and health sciences (17%); and 13 graduate schools with 217 student places in the field of biosciences and environmental research (15%). Some 320 graduate school places were allocated to information industry branches, and roughly the same amount to biotechnology. Out of the country's 20 universities 19 have cooperation through the graduate school network, and 17 out of 19 government research institutes are involved. In addition, graduate schools have an estimated 2,500 places that are financed from other than Ministry of Education funds.

Graduate schools have varied widely in terms of their funding structure, academic orientation and research and training traditions. Most graduate schools work closely with centres of excellence in research, biocentres or research teams under Academy Professors.

The number of postgraduate students enrolled at universities has increased by 21 per cent from 1997 to 2002, when the figure stood at 21,937. Universities are also responsible for the provision and development of researcher training in those fields that are not covered by the graduate schools. Many universities have adopted the graduate school model for purposes of developing their researcher training. For instance, at the University of Jyväskylä Rector's graduate school places and grants are awarded to such fields of research where there are no graduate schools; on the other hand university funds are also made available to support graduate schools. University assistants have traditionally researched their PhD thesis as part of their teaching and other duties at the department, in the process gaining the qualifications of researcher. However, with the changes that are now being made to the system of teaching and research posts, the number of vacancies available for doctoral students is declining. Some government research institutes have taken part in developing researcher training mechanisms within their own branches through their involvement in graduate schools, and several docents provide teaching and supervision as well.

The Academy of Finland has worked consistently to develop and promote an efficient researcher training system among other things by providing funding for researcher training in the context of research projects, research programmes and centres of excellence in research. According to the Academy's Annual Operating Review (Suomen... 2003) some 5,300 persons received Academy research funding in 2002. Around 70–75 per cent of them were doctoral students. In 2002 the Academy awarded close on 2.7 million euros to support other graduate school activities.

One of the main criteria on which the Ministry of Education has allocated core budget funding to universities is the number of doctoral degrees completed. The total number of PhDs has shown rapid growth in all fields of study during the 1990s, rising from less than 500 in 1990 to more than 1,200 in 2002. Women accounted for 36 per cent of all PhDs in 1995, in 2002 the figure was 46 per cent. By major fields of science, the largest number of PhDs in 1997–2001 was completed in medical sciences, the social sciences and natural sciences, which together accounted for almost 70 per cent of all doctoral degrees. The sharpest increase in the number of PhDs from 1997 to 2001 is seen in the social sciences (30%), engineering and technology (25%) and medical sciences (20%). In the humanities and natural sciences the number of degrees went up by around 13 per cent. (KOTA database.)

In 1999 over half of all research work towards the PhD[9] was done in the employ of universities and the rest in other workplaces, such as local government (including university hospitals), business enterprises and government research institutes (Figure 3.8). By major fields of science, the number of PhDs completed at universities and research institutes is the highest in the natural sciences, in the municipal sector in medical sciences, in the central government sector in the social sciences and in the business sector in engineering and technology (Husso 2002).

Almost 70 per cent of those who took their PhD in 2000 had had a scholarship at some stage of their studies: public funds and private foundations therefore had a major role

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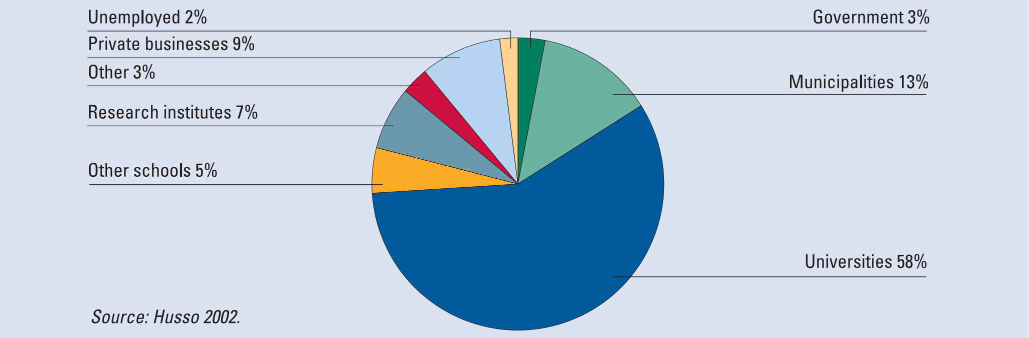
[9] Sector in which 1999 PhD graduates were employed two years before graduation.

Figure 3.8. Placement of PhDs graduating in 1999 two years before graduation.



Source: Husso 2002.

in financing doctoral degrees. The proportion who had held a university post or position was 41 per cent, 23 per cent had been funded by a government research institute and 21 per cent had had Academy project funding. Industry had supported 10 per cent of all graduating PhDs and almost 10 per cent had worked under an international exchange agreement or with EU funding. Three-quarters of PhDs had also received funding from some other sources than those mentioned above. (PhDs in Finland... 2003.)

Almost 60 per cent of PhDs graduating in 2000 had completed their degree in less than four years of full-time study, 20 per cent had taken 4–5 years and 20 per cent more than five years. When both full-time and part-time work is included in this analysis, only 12 per cent completed their degree in less than four years, almost 17 per cent took less than five years and 70 per cent more than five years. (PhDs in Finland... 2003.)

On average people who work outside universities are older upon PhD graduation than those who work at universities. In 1999, the average age of PhDs graduating at universities was 35.5 years, while the figure for those working in local government, research institutes and private business was over 39 years. PhD graduates were the youngest in the natural sciences and engineering and technology, aged 35–36. In the social sciences and the humanities they were over 40 (Husso 2002). The mean age of PhD graduates who studied at graduate schools in 1995–1999 was about 32 years (The Graduate... 2000). According to Määttä et al. (2002) those completing their PhD at graduate schools in 1996–2000 were younger in all fields than those completing their PhD elsewhere. However, the median age of PhD graduation at graduate schools will rise when the figures for those graduating later are included in the analysis.

The graduate school system has brought major changes to researcher training in Finland. Most of the goals set for the system have been reached. The quality of postgraduate training has improved, work has become more systematic, supervision more focused and teaching more diversified, and there has been better cooperation and networking among research teams (Aittola & Määttä 1998, The Graduate... 2000). Students at graduate schools have also had active cooperation with colleagues abroad (The Graduate...2000).

The directors of graduate schools were unanimous in their opinion that the system had many important advantages. They said they had seen improved cooperation among research teams and more international contacts. Postgraduate training was more systematic now, and the standard of teaching had improved. It was easier for doctoral students to concentrate full-time on their research. Another advantage of the system was that it had lowered the average age at PhD graduation and encouraged growing numbers to proceed to take the doctorate. On the reverse side of the coin, it was pointed out that pay levels were too low to allow the school to recruit the most talented students, who often had to rely on several different sources of funding. Some referred to the problems of excessive bureaucracy and the lack of coordinators, others still to the inequality between graduate school students and other postgraduate students. Some voiced the criticism that the university was unable to provide supplementary funding to graduate schools and in this way to secure adequate resources. In addition it was felt that steps were needed to clarify the division of tasks between graduate schools, university administration, faculties and individual departments. (The Graduate... 2000.)

Graduate school students generally had a very positive assessment of the system: 10 per cent described it as excellent, 45 per cent as good and 25 per cent as reasonably good. Students were particularly pleased with the continuity that the system provided, the opportunity to work full-time on research, the security of funding and the contacts with researchers at home and abroad. More than 40 per cent felt the atmosphere at graduate schools was creative and inspiring. The main sources of dissatisfaction were the poor pay and the resulting difficulties in making ends meet, which in turn was reflected in the amount of time taken to complete the degree. Graduate school students often had to take on teaching or other jobs to earn extra. About 40 per cent took the view that the funding they received was not enough, but levels of satisfaction varied between different disciplines. In the humanities and social sciences, the pay level was regarded as wholly inadequate. In these fields it is rarely possible to pay the researcher more than the sum granted by the Ministry of Education. (The Graduate... 2000.)

According to Määttä (2001) the graduate school system has met the main targets it has been set: those concerning the number of new PhD graduates, the organisation of researcher training, raising the quality standards of training and the allocation of training places to fields with the greatest national significance. He considered particularly important that all universities across the country offer doctoral degrees and that university studies are free of charge. Another significant advantage is that there are two separate avenues to completing the PhD, either through graduate schools or outside that system.

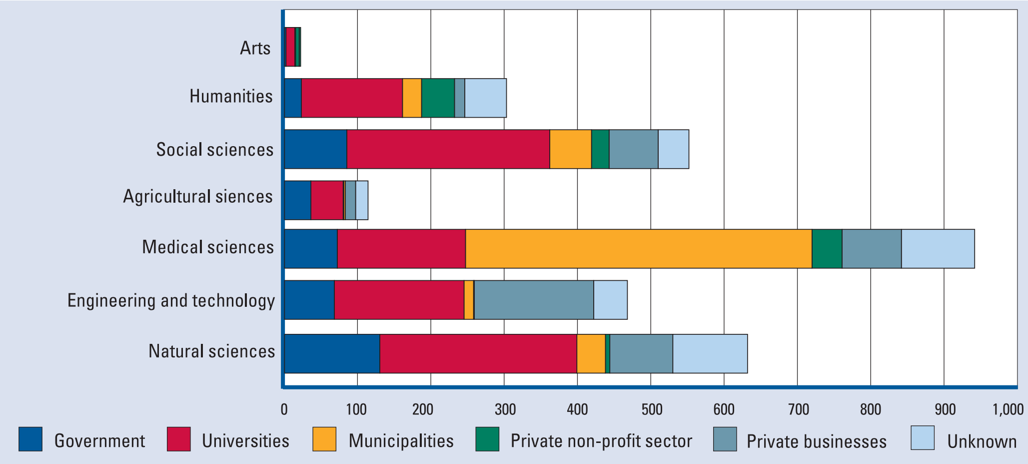
There remain a number of challenges for graduate schools that they will need to tackle in order to further improve the quality of researcher training (The Graduate... 2000). First of all, steps are needed to further develop and improve research and innovation environments in order that graduate schools can remain an attractive option. It is also important to avoid overlap between graduate schools, to encourage closer cooperation between graduate schools and to support their efforts at further specialisation in their areas of expertise. In addition, it has been suggested that steps are needed to make a professional career in research a more viable option by strengthening the support structures available after PhD graduation, especially for women. It is also considered important that adequate resources are made available to graduate schools.

One of the main challenges for researcher training today is to stem the outflow of the most talented students. It is also crucial to make sure that adequate support is made available for fields of research and for PhD students that are not covered by the graduate school system. In research and researcher training environments, a further potential problem is the lack of support and supervision from senior researchers. The research equipment is not always up-to-date, nor is professional maintenance always available. In most cases the financial rewards for the time spent in training do not provide sufficient incentive to the young researcher. Doing quality research is a time consuming business, and it may be hard to fit together the intensive years of researcher training with family life, for instance.

The research career after the PhD

A significant fraction of PhDs continue with their research at least for some while after graduation. In 2002, almost 70 per cent of PhDs who graduated in 2000 were still engaged as postdoctoral researchers (PhDs in Finland... 2003). About 40 per cent of those who had graduated in 1997–1999 were still in university jobs in 1999 (Figure 3.9). According to a questionnaire carried out among graduate school students in 1995, around 40 per cent of them were aiming for a university career, a further 40 per cent had career plans outside of research (Aittola & Määttä 1998).

■ Figure 3.9. Placement in 1999 of PhDs who graduated in 1997–1999.

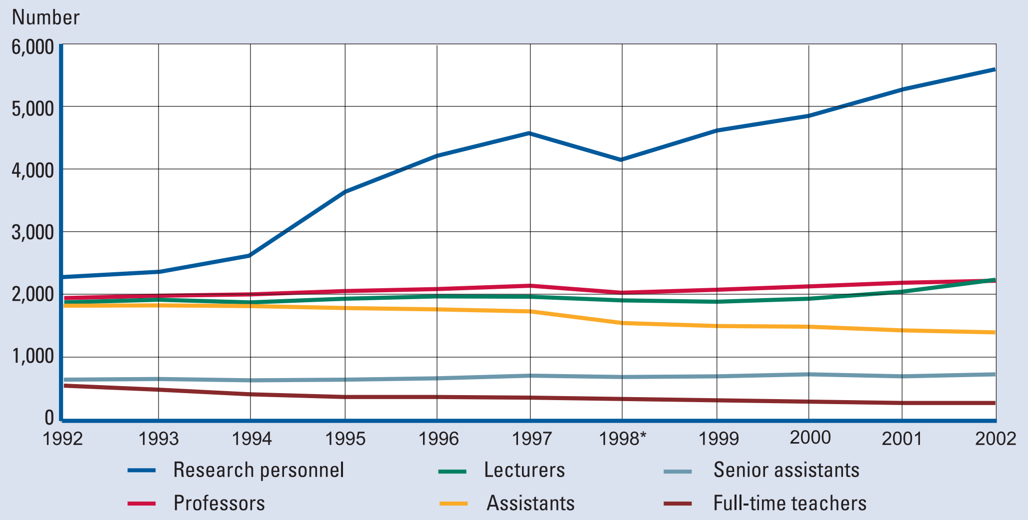


Source: Husso 2002.

The sharp increase in the amount of external funding in the 1990s meant that universities were able to step up their research effort and hire more research staff in fixed-term projects. The number of teaching staff in universities has remained more or less unchanged during the 1990s (Figure 3.10), whereas the number of students has grown by 140 per cent over the past 10 years. At the same time the number of researchers and doctoral students hired on external funding has increased by 150 per cent.

University posts of assistants are more and more often held by researchers with a PhD. The universities of Helsinki and Turku have recently streamlined their system

Figure 3.10. University teaching staff (professors, senior assistants, assistants, lecturers and full-time teachers) and research personnel in 1992–2002.*



*As from 1998 calculations based on number of person-years instead of number of posts.

Source: KOTA database, Ministry of Education.

of teaching and research posts so that positions previously intended for doctoral students and financed from core budget sources will be reallocated to PhDs; many other universities will soon be following suit. At the University of Helsinki, many departments have adopted a policy whereby two assistantships have been discontinued for every new post opened for a researcher-lecturer. PhDs have also been hired with external funding.

Almost 30 per cent of universities' teaching staff are professors. Large numbers of professors of the babyboomer generation are set to retire towards the end of this decade, and over the next 15 years some one hundred professors will be pensioned off each year. How the number of teaching staff relative to the number of university students will develop over the next few years, is mainly dependent upon the funding made available to universities.

The Academy of Finland has developed its system of research posts by clearly demarcating different stages in the research career and by opening vacancies for postdoctoral researchers and Academy Research Fellows. In 2002 the total number of research posts, excluding those for Academy Professor, stood at 588, 51 per cent up on the figure for 1997. Posts for postdoctoral researchers numbered 350, and those for Academy Research Fellows 230. Both types of posts have been primarily tailored to relatively young researchers oriented to a professional career in research, and the Academy has awarded incentive monies to the most promising Academy Research Fellows. Universities and business companies have been encouraged to apply for postdoc positions for joint research projects in companies, but not many applications have been received.

In 2002 one-third or 33 per cent of Academy Research Fellows and 56 per cent of postdoctoral researchers were women. The Academy has consistently sought to promote gender equality and women's prospects for career advancement, and in 1997–2002 the number of women appointed to research posts has been higher than their share among the applicants to those posts.

In 2000–2002, a total of 5,200–5,400 persons received Academy research funding, with PhDs accounting for an estimated 25–30 per cent of that number (Suomen... 2002, 2003). The majority of the PhDs hired were postdoctoral researchers.

The position of Academy Professor is one of the most fiercely contested in the Finnish research system. In 2002 there were 38 such posts in the country, marking an increase of 52 per cent on the figure for 1997. Less than one-third or 29 per cent of all Academy Professors in 2002 were women. In addition, 75 person-years have been awarded each year to professors and other senior scientists, usually in the form of 12-month fellowship contracts. This has given incumbents an opportunity to concentrate full-time on their research, away from their departmental duties.

Many Academy researchers have had extremely prominent careers. Unpublished materials from the Academy of Finland history I-III project indicate that in 2000, there were in Finnish universities a total of 1,837 professors (compared to 1,480 in 1990), of whom 38 per cent (29% in 1990) had at some stage of their career held an Academy research post. Among them 42 per cent had occupied the position of Senior Research Fellow (now renamed as Academy Research Fellow). At the University of Helsinki 50 per cent and at the universities of Turku, Jyväskylä, Kuopio and Joensuu more than 40 per cent of all professors had at some stage of their career held an Academy post. In 2000 the number of professors working at government research institutes stood at 151 (compared to 126 in 1990), 19 per cent of whom had held an Academy post (13% in 1990).

Grants awarded by public funds and private foundations are an important source of research funding. In 2001, for instance, 300 of the 6,000 members of the Finnish Union of University Researchers and Teachers worked on a grant. Over half of the union membership had at some stage of their career conducted research with funding from a grant (Puhakka & Rautopuro 2001). Researchers working on grants do not have the unemployment, pension and social security benefits that come with regular wage employment. They may also feel excluded from the workplace community and have difficulty arranging the tools and other facilities they need.

Finland has invested heavily in the development of its researcher training and postdoctoral system, but for graduated PhDs the career options available are still very constrained – there is no system in place that opens up any meaningful prospects through success in research career. Most crucially, the individual researcher at this stage needs to have the opportunity to gain the experience and qualifications needed for top research positions. At universities the teacher-researcher career offers the options of a position as senior assistant or university lecturer, and from there further to the position of professor. However, the teaching duties of university lecturers may be so demanding that it is virtually impossible in that position to engage in serious research. The posts of assistant and senior assistant are usually for fixed terms, as are some professorships. Finnish universities have no tenure track system for these posts and positions.

Universities also have large numbers of project researchers as well as researchers working on grants. Fixed-term contracts have also increased at government research institutes with the growth of external funding. However, for researchers a position at a research institute has the important advantage that it involves no teaching duties. That said, many researchers working at research institutes also hold docentships and thus teach at universities. However, involvement in other duties, projects and activities at the research institute may prove an unnecessary distraction from one's own research work.

3.2.3 People with a researcher training in positions of expertise

Knowledge, know-how and innovation together with skills of cooperation and communication are in ever greater demand in the modern workplace. More and more often now, employees are expected to show not only broad skills and knowledge but also flexibility, the ability to use and process large amounts of data and a readiness to learn.

Most PhDs in Finland today work in universities, central government or in the municipal health care sector; only a small minority are engaged in private business companies. A growing proportion of newly graduated PhDs work outside the university system. About one-third of all PhDs are engaged in other than R&D positions (Husso 2002). A new emerging challenge for universities and indeed for the whole innovation system is how best to combine high level know-how in a special area of expertise with the expertise of application. In this world of accelerating change, the education system needs to show extraordinary flexibility.

A survey[10] conducted among more than one thousand organisations at the end of 2002 found a strong sentiment in favour of making researcher training less theoretically and more practically minded, especially among respondents representing ministries, public administration, government agencies and university cities (53% of respondents). This was also stressed by other research target groups in the survey. The importance of having a close enough understanding of working life was emphasised most particularly by government research institutes, but also by other government agencies and organisations in university cities. Major corporations, ministries, the administrative sector, government agencies and university cities were the keenest to stress the importance of closer cooperation between workplaces and universities; the same opinion was also shared, somewhat less frequently, by government research institutes and business companies.

The opinion that it would be useful for employees to be able to work while researching their doctoral thesis was raised in the responses of ministries, the administrative sector,

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[10] The survey is based on 1,140 interviews with the following target groups: 1) large, medium-sized and small enterprises, 2) major corporations with their own R&D operations, 3) ministries, the administrative sector, government agencies and university and other cities, and 4) government research institutes (PhDs in Finland…2003).

From graduate school to human resource development manager – shuttling between research and practical development

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Human Resources Development Manager
VTT Corporate Management and Services

I graduated with a Master of Arts in Education from the University of Helsinki in 1989, majoring in adult education. Ever since, my career has kept me shuttling in the middle ground between research and practical human resource development. I started as education planner for human resources at the Technical Research Centre VTT. I had only just graduated and felt very much that I needed to know more about what I was supposed to be developing, so while I was doing this job I began my studies for the Licentiate. I started to research ongoing efforts at a VTT laboratory to set up research groups. When I completed my research in 1995 I was offered a place at the graduate school hosted by the University of Helsinki Center for Activity Theory and Developmental Work Research. Rather than working part-time on my research while working, I got the chance to try my wings as a full-time researcher. Inspired by my earlier studies I continued my investigations of research teams at VTT. My superior was very supportive and during my first two years at the graduate school I continued to work part-time in the human resources development team. In 2001, I returned to VTT after the graduate school and a period on maternity leave, and completed the writing of my doctoral thesis while working in human resources. As from the beginning of 2003 I started as human resource development manager and in June the same year I took my PhD.

During my years in research I attended international conferences and wrote my first ever scientific article. I soon realised how much effort it takes to develop your own distinctive approach and style of work as a researcher and to build up a career in research. I visited the New Mexico University to collect research data I needed; coping with all that was a major boost to my self-confidence. In the researcher's job I learned to express myself in the English language and received constant critical feedback. On the other hand I was in the position to concentrate on one single issue and to push myself to the very limits of my abilities. The further I progressed with my doctoral thesis, the more I became convinced that I wanted to return to human resource development. I felt the research I was doing would serve me in good stead in the practical job of development. My analysis of the development of a Finnish and American research team opened up a useful angle on understanding the dynamics of applied research. I ventured out into the fields of organisational learning and the sociology of science and asked how they could be put to better use in the development of research. When I returned to VTT my writing skills had improved, my English had improved and my ability to present my case had improved. I need all of these skills in my present job as well.

The move from research to practical development was not an entirely smooth process. Initially I did not feel at home with the language of human resources administration, and my own research-driven discourse seemed somewhat cumbersome in the context of human resource development. I needed to "translate" my research results to make them more easily intelligible. I had to try and hold in check my research instincts and learn to share my time among several development projects. The main discovery I made while shuttling between practical development and research was the realisation that research groups engaged in applied technical research move in exactly the same way between the realms of practice and research, switching angles every now and then. In order that they can find solutions that will benefit their clients and at once generate new knowledge for their research communities, researchers have to cross these boundaries.

I feel that in my HR development role I am only just beginning to put to use the results of my research: the challenge for me is to maintain a living contact with this field of research. It is only by continuing to shuttle between these realms that I can feel I will be able to continue to develop as an expert and a human resource developer.

Doctoral thesis: The Pulse of Change in Research Work. A Study of Learning and Development in a Research Group.

government agencies and university cities. Major corporations and their R&D units would also be keen to recruit PhDs who were more closely integrated in working life. There was also a strong opinion that the themes covered in doctoral theses should be more clearly oriented to working life and the business world, and that the research subjects provided by industry were meaningful. Some criticism was voiced about PhDs not having enough understanding about business.

A small field of research as a case in point: art history PhDs and working life

Riitta Nikula, professor
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Art historians are primarily engaged in 1) museums and galleries; 2) research and protection of the built environment; 3) teaching duties at universities, polytechnics and art schools; 4) popular education and leisure supervision; 5) the media; and 6) research posts and other positions at universities and the Academy of Finland. A typical career in the field of art history runs from intermittent jobs while one is still studying through the Master's degree to jobs in cultural institutions that are gradually upgraded into permanent positions. People build up their expertise over time, through their studies and on the job.

Full courses in art history are taught at the universities of Helsinki, Jyväskylä and Turku and at Åbo Akademi University. Students at the universities of Tampere and Oulu can take art history as a minor subject. In all there are six full professorships.

Although the first public examination of a doctoral dissertation in art history dates back all the way to 1878, organised postgraduate training in Finland did not get under way until the first Academy-funded projects in the 1980s. Up until then, participation in international congresses was negligible and very few research groups were set up; it was all based on independent thinking and silent seminars. Prior to 1980 a total of 33 PhDs had been completed in the field of art history; at the beginning of 2003 the figure stood at 103.

Postgraduate training started in 1995 in the form of a nationwide network. The first meeting of postgraduate students brought together 51 research plans. At the first summer school in 1996, organised with Academy funding, 15 select students had the opportunity to talk about their research with three foreign professors under the heading "The History of Art and Its Paradigms". Summer schools became a recurring institution, and the visiting professors who have taught at these schools have gradually become an expanding international network. Each summer has had its own set theme (literature and teachers) through the lens of which doctoral students have reflected upon their own work. The main emphasis has been upon theoretical issues. The graduate school proper has received funding since 1999; the number of new student places over the past three years has been 5+2+5, the number of applicants 28+19+27, respectively. At summer schools the core group has always been joined by a number of other students working on their thesis with other sources of funding or while working.

People with a PhD in art history have had little difficulty finding work. Some have remained unemployed, though, mainly because they have been reluctant to do anything else except independent research. There have also been some complaints that PhDs have not always been given preference when vacant posts have been filled. Nonetheless it is widely recognised by now that especially the development of the country's museums calls for an increasingly innovative attitude. The only way forward in this typically female-dominated, low-pay sector is through training.

One special challenge for postgraduate training is represented by those museum professionals who want to take the doctorate so that they can deepen their expertise. In these cases supervision has been provided according to individual needs and timetables. To me it is important that postgraduate training in art history always remains open for both young students and more experienced scholars. It is never easy to bring together expertise on the subject matter and fresh theoretical angles, but it is always necessary – both in postgraduate training and in the world of work.

The protection of buildings is an important aspect of community development; ill-informed decisions cause irreparable damage. Sustainable argumentation calls for a high level of education. Understanding values is one of the most difficult specialist tasks for the humanist in modern society. Although the EU is now beginning to register natural values, it is still hard to find experts with the necessary competencies to evaluate layers of the built environment.

Contemporary culture consists essentially of visual communication. Keen to understand advertisements, the media, the human image, art history has seen a growing trend of multidisciplinary research into visual culture. The development of critical visual literacy is also among the goals of free popular education.

3.3 The researcher's profession: under pressure of change?

Universities have seen quite dramatic changes in their operating environment during the 1990s and early 2000s. The principles of management by results have been installed, and universities' own administration has swelled. The growth of external funding has meant that the number of project researchers hired on a fixed-term basis has increased. Teaching staff hired with universities' core budget funds have less time to devote to research, and new knowledge production is increasingly done on the strength of outside resources (Nieminen & Kaukonen 2001, Ylijoki 2003). Orientation to the commercial marketplace is now relatively common in universities, although the extent to which that is required does vary depending on the application potential in the field of research concerned (Nieminen & Kaukonen 2001, Ylijoki 2003). Each discipline's internal culture as well as institutional cultures will also have a bearing on adaptation (e.g. Räsänen & Mäntylä 2001, Ylijoki 2003).

University research today is walking a tightrope between different kinds of research orientations and social interests. Hakala and Ylijoki (2001) identified four different research orientations: academic, market-oriented, administrative and civil society oriented. The researchers they interviewed felt that these different orientations presented conflicting pressures. For all researchers the academic orientation had a strong and prominent position. The market orientation was most prominent in the engineering field, although it was certainly not alien to other fields either. Some researchers had adapted well to the requirement of having to apply for and administer outside project funding, and they worked closely with the organisation applying their research results. In the administrative orientation the focus of research was upon different decision-makers: such fields in the research material were represented by the social sciences and agriculture and forestry. The civil society orientation was weak: for instance, there was hardly any cooperation at all with civic organisations. (Hakala & Ylijoki 2001, Hakala et al. 2003.)

University researchers' main complaints and problems had to do with securing funding, time pressure and the stress that came from their having to produce results. Lacking staff skills and inadequate research equipment also caused some difficulty. Human relations and scope for cooperation were the least of their problems (Nieminen 2000, Hakala et al. 2003). Several researchers have found that in recent years, research communities have regarded researcher autonomy, work load, time management, social status and pay levels as problematic (Winter et al. 2000, Aittola 2001, Barry et al. 2001, Räsänen & Mäntylä 2001, Ylijoki 2003). The researchers interviewed by Hakala et al. (2003) felt that the researcher's job requires above all a capacity to tolerate stress as well as diverse talents. Some researchers were concerned about the dwindling freedom and independence of their job, which may eventually affect the human interest in and blur the meaning of doing science as well as undermine the professional commitment to the principles of science and research ethics.

Nonetheless many researchers value and appreciate the university atmosphere, the freedom and independence of the job, so they are prepared to make sacrifices: if they decided to change jobs and go somewhere else to work, they would not do so lightly. Resources, funding and the research environment are all crucial factors, whereas status and pay have not had such a major influence on researchers' career choices. Many researchers take the view that the prestige and honour of an academic career have declined, but the university was still seen as a special place to work, in spite of all the time pressures and in spite of the fixed term job contracts (Hakala et al. 2003).

Different fields of research differ from one another in terms of how often researchers join forces in research groups; this depends, among other things, on traditions and needs within individual disciplines. Teamwork has increased in all disciplines, but going it alone is most common in the social sciences and the humanities. Research cooperation across disciplinary boundaries has also increased with the increasing complexity of research questions. The shared use of expensive research equipment and the organisation of business activities in the near vicinity have influenced the development of biocentres, for example. Younglove-Webb et al. (1999), for instance, say that the key advantages of groupwork include scientific dialogue, cooperation, support from other group members and efficiency. The main drawback is that other group members have to be taken into account, but questions of time management and various conflicts also come into play.

Practices of research management in different disciplines depend upon the nature and methods of research work in those disciplines. According to Kekäle (2001) physics and biology departments that represent the applied natural sciences have been the keenest to adopt manager-driven practices that draw upon management by results. In more theoretical disciplines research is more clearly expert-driven, with greater emphasis placed on creativity and freedom, and it is less amenable to management in the traditional sense. Historical research, for instance, is traditionally an individually minded discipline where it is harder to set up joint research projects than in, say, experimental natural sciences.

Research management should emphasise the distinctive features of creative research and researcher training environments, without ignoring the differences between individual disciplines. Traditionally, the aim has been to identify the common features of such environments, such as the promotion of open interaction, openness to new ideas and the development of know-how and confidence (e.g. Graversen et al. 2002). It is also necessary to have a clear research strategy, clear objectives and clearly defined tasks for research. Science Nobelists, according to Hurley (1997), say it is especially important that the scientist can enjoy freedom of thought as well as the freedom to choose her/his research subjects, and to do so in a constructive work climate. However, there has been very little research into how different disciplines and fields of research differ from one another, and we have also very limited evidence on creative solutions in different fields of research.

3.4 Conclusions

R&D personnel

Concerted efforts are needed in both the public and the private sector to further raise the quality of research and development in Finland with a view to maintaining and strengthening the competitiveness of the national economy. R&D quality can be raised by recruiting competent people and by providing those people with the best tools and facilities available. It is particularly important to ensure that staff members have the skills and competencies they need as well as a sufficiently high level of education. Special attention needs to be given to the recruitment of PhDs in the private business sector and on the other hand to improving the professional competencies of technicians and associate staff for instance in the use of new instruments and equipment.

Professional careers in research

The science policy targets set for the promotion and development of the professional research career have been reasonably well achieved. There is now in place an established graduate school system and researcher training is effective and of a reasonably high standard. A large fraction of PhDs proceed to the postdoctoral stage. Nonetheless there remain major challenges for the development of the professional research career.

Key development objectives include the removal of obstacles to a professional career in research, maintaining the competitiveness of the researcher's career and securing career continuity. This can only succeed in a coordinated and concerted effort in researcher training, in the allocation of research funding and in the development of infrastructures. Young people in Finland are still interested in researcher training and the option of a career in research, which is by no means the case in all western countries.

Stiffening international competition for talented young researchers presents a major challenge for research and researcher training environments in Finland, which need to increase their appeal. It is important that the differences between individual disciplines and fields of research are taken into account in developing research and researcher training environments. With the pace at which science is now advancing, there is growing pressure on research infrastructures as well, especially in the natural sciences and engineering where the technical instruments are developing very rapidly and where the quality and maintenance of those instruments is a crucial consideration. Again, the priority concern must be to ensure the high quality of training and research.

Creative problem-solving should be encouraged from an early age, and efforts should be stepped up to inspire greater interest among young people in science and research. Later on, training at universities should equip young students with the skills and resources they will need in researcher training and provide the impetus for a career in research. Among the threats on the horizon are the declining quality standards of education, the declining number of students and the growing numbers of dropouts. Development efforts may focus on the learning environment as well as on the cooperation between teachers and students. In addition, adequate structural and economic support should be made available to students. Compared with other jobs, the career prospects in research and its financial incentives do not necessarily live up to the long-term commitment that is required.

The structure of first and higher university degrees in Finland is currently being revised in the context of the Bologna Process in line with the objectives set for the European University Area. This supports the extension of researcher training to the stage preceding the Master's degree and the entry of research oriented students into research teams during their basic and subject-related studies. The right of students flexibly to move between universities guarantees access to a diverse range of courses.

Graduate schools are the main avenue to the doctorate and to a career in research. Steps are also needed to support doctoral students outside graduate schools. University faculties, for instance, could set up their own graduate schools. International networking among graduate schools is also important. In addition, teaching in foreign languages should be more readily available, and the number of foreign students enrolled in graduate schools should be increased.

The first years of a career in research are often dogged by fixed-term contracts, poor pay and working on grants. Better pay levels, rewards for good results and support for the researcher's family would all provide important incentives for young people who are considering a career in research and possibly help persuade them to remain on that career path. Grants awarded by funds and foundations represent a major source of funding for doctoral students. Immediate steps are needed to improve the socio-economic position of researchers working on grants. In particular, for reasons of gender equality it is essential that maternity and parental allowances are made available to researchers working on grants. The Ministry of Social Affairs and Health has in 2003 appointed a working group to look into the social security of grant recipients.

It is important that young people setting out on a research career can look forward to a clear set of objectives. The postdoctoral stage should support the researcher's quest for independence. It is usually at this stage of the research career (depending on the field of research) that people start to set up their own research teams. At the postdoctoral stage a sufficient number of talented researchers should be persuaded to continue to work in research because a certain number always take up other jobs or move abroad. Obstacles to a research career include the lack of satisfactory job opportunities and difficulties in career advancement. At this stage of their career researchers often spend a couple of years abroad, so questions related to the mobility of researchers and their family as well as to their social security must also be resolved. This will require joint efforts by authorities in several administrative sectors.

Steps are needed in both the public and private sector to open up career opportunities that are based exclusively on research. Researchers who have had good success in their job should have the right to a permanent job contract with reasonable certainty. The researcher's career path should allow for greater flexibility: for instance, researchers should have the option of flexible retirement or early retirement, on the other hand they should be allowed to work beyond retirement age if they continue to remain active.

As they proceed with the reform of their systems of teaching and research posts as well as their pay systems, universities and government research institutes should give better recognition to the role and contribution of young researchers. They should also invest in the later stages of the research career and create opportunities for career advancement with increasing qualifications. Universities have now joined forces in the reform of their systems of teaching and research posts. At the beginning of 2003, the Finnish Council of University Rectors appointed a working group charged with exploring the prospects of harmonisation. This is important, among other reasons, for ensuring the equality of researchers at different universities. Adequate resources must be made available for supervision, bearing in mind the role of postdoctoral researchers in the supervision of doctoral theses. Academy of Finland funding is not closely tied to researcher training, but the emphasis has been shifted towards funding the postdoctoral stage.

Attracting foreign researchers to Finland and persuading them to stay are an important part of the overall effort to develop the research career. Although visits by foreign students to Finnish universities have increased, the number of foreign nationals working in R&D in Finland is much lower than the average figure for EU countries. Job vacancies should be opened for international application. Adequate start-up monies should be granted to researchers recruited. Good research facilities and the high quality of research will not alone suffice to attract researchers to Finland; their choices will also be influenced by several factors outside the research environment, such as pay and taxation, children's schooling, opportunities for spousal employment and immigration policy. All these factors need to be explored and thresholds lowered in a concerted effort among all the relevant authorities.

Positions of expertise outside R&D

It is important for the development of the information society that knowledge and know-how can move to wherever they can be used in fresh and innovative ways. Various career paths and staff mobility between universities, public administration and the business sector should be made easier and more attractive. Doctoral students should be given the opportunity to work in business companies, and doctoral theses should be researched on issues that are of immediate interest to business and industry. People working in other than research positions should be given the opportunity to build up their expertise through training, and support should be made available for those researching their PhD while working. Most significantly, universities and business companies need to work more closely with one another.

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4 Measures of science policy aimed at supporting research

This chapter is concerned with measures of science policy. It discusses the way that universities are responding and adapting to changes in their operating environment; research and technology programmes that network and provide direction to research efforts; practical steps taken to promote the internationalisation of research; and practices of evaluating research and technology. As well as describing the measures through which science policy is pursued, this chapter also looks at the outcomes of those measures and where possible their impacts.

4.1 Universities and their operating environment[1]

4.1.1 Boundary conditions for the national development of universities

Finland has a large network of universities and polytechnics. In 2003, there are around 170,000 degree students in the country's 20 universities and some 126,000 students in 31 polytechnics. In the 1990s core budget funding for universities[2] was cut back, and at the same time the proportion of external competitive funding sharply increased. Central government appropriations earmarked for universities in the state budget were slashed in 1993–1994 and did not recover to the level of the early 1990s until towards the end of the decade. In nominal terms core budget funding for universities showed an increase, among other reasons because acquisition and operating costs for facilities were included under university expenditures. In 2001, university development legislation was so amended that in 2002, operating expense items for universities were increased by 40 million euros in addition to the cost effects of pay rises. Furthermore, a total of almost 3.4 million euros was set aside for regional development. Although public R&D investment in Finland is comparatively high, the scarcity of core budget resources at universities remains a major hindrance to long-term development. The increase in appropriations has not always been felt at departmental level.

A target outcome system was introduced between the Ministry of Education and universities in 1994: since then the amount of core budget funds made available to universities has been decided in negotiations on university performance and outcomes. The system has given universities greater operational freedom and increased their responsibility for outcomes. In particular, attention has been focused on the number of degrees completed. The student intake has grown, but there has been hardly any increase at all in the number of teaching posts.

The new Universities Act and decree that took effect in 1998 were designed to streamline legislation concerning universities in Finland. The law details the functions of universities and establishes their autonomy as well as the independence of research and education.

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[1] Changes in the universities' operating environment are discussed from the researcher's point of view under section 3.3.

[2] The development of research funding for universities and university hospitals is described in section 2.3.1.

In 2003, the Science and Technology Policy Council of Finland expressed the view that in the future development of this legislation, the aim should be to encourage universities to invest greater effort in the practical application of research results. Furthermore, the Council considered it essential that core funding for universities be increased as part of ongoing efforts to develop the information society. In 2002, a working group was appointed to look into the existing system of management by results in universities. It recommended that universities should have closer interaction and exchange with the rest of society and that they should take steps to increase the impact of their research findings. Work is currently under way to revise the legislation. Once these changes are in place, they may cause new tensions between the university's teaching and research functions, on the one hand, and service functions, on the other.

Adopted and endorsed by the Government, the Ministry of Education's Education and Research Development Plan for 1999–2004 sets out the science policy objectives for the work and operation of universities, which the universities coordinate with their own goals. The aim of universities is to maintain high standards of research, education and artistic activity; and to work more closely with cultural life and with business and industry. Furthermore, for reasons of more effective internal profiling, universities are committed to intensifying their cooperation and division of tasks. They are also committed to improving the facilities and resources available for research and education and to strengthening their core areas of expertise through continued structural development. The agreements on target outcomes signed between the Ministry of Education and universities include specific objectives concerning the allocation of basic resources, the development of the faculty and departmental structures and regional cooperation. Universities have their own strategies for operational and structural development.

4.1.2 Operational and structural changes in universities

Finnish universities have seen some significant changes of late through national and internal reorganisation and reprofiling as well as through the intensification of regional, national and international cooperation. Universities have invested in quality and sought to diversify their interaction with the rest of society. The growth of internationalisation at universities has extended from student and teacher exchange through to various bilateral and multilateral agreements of cooperation, research cooperation, associations, exhibitions and conferences. Budgetary constraints together with the rapid growth of project-based research have thrown up major new challenges.

Universities have *overhauled their organisations*. Many faculties and departments have become more clearly profiled than before. At the University of Helsinki, for instance, the main emphasis in reforming the faculty and departmental structures has been on strategic management and quality assurance, as well as on the efficiency of administration and customer service. At the University of Jyväskylä, the aim is a broadly-based multidisciplinary organisation, which has been supported by the establishment of the Agora Centre, a department organised around the networking principle.

In line with their management-by-results goals and objectives, all universities reinvested from 1999 to 2002 three per cent of their 1999 level of basic resources towards improving research and education and strengthening their core areas of expertise. Several universities have poured funds into libraries, information administration and into learning facilities. Support has been made available to key areas of emphasis, or to those that have expanded rapidly. For instance, both Helsinki University of Technology and Lappeenranta University of Technology have allocated resources to the growth sectors of electrical engineering and information technology.

Universities have *pooled their resources*. Arts universities have concentrated operations, or are each in the process of bringing operations under the same roof. The Media Centre at the University of Art and Design Helsinki is used jointly by all arts universities. The University of Turku and Åbo Akademi University have stepped up their cooperation and now provide integrated research services. The economics units at the University of Helsinki, the Helsinki School of Economics and Business Administration and Hanken, the Swedish School of Economics and Business Administration will be moving to the same premises during 2003. Work to build a joint scientific library and learning centre for the University of Vaasa, Hanken and Åbo Akademi University was completed in 2001.

New openings have been created in the fields of university education and research. For example, education and to some extent research in economics and business administration has expanded to several universities, including Joensuu, Kuopio, Lapland and Oulu as well as Lappeenranta University of Technology. At Tampere University of Technology, the opening of a new Department of Science and Engineering and a training programme have strengthened the position and increased the exposure of natural sciences. The University of Turku has launched a new Functional Foods Forum and IPR University Center, which it shares with other universities. The University of Oulu has expanded into environmental sciences. The universities in Kuopio and Turku have opened new faculties in information technology.

In the mid-1980s, steps were taken in Finland to encourage and support the concentration of research in the biosciences into *multidisciplinary units*. Between 1986 and 1995, six administratively independent biocentres were set up at or in conjunction with five universities. The number of staff working at biocentres has increased by more than one-quarter from 1997 to 2001. The national evaluation of biotechnology (Biotechnology… 2002) concluded that biocentres have played a major role in modernising university structures and education and contributed significantly to raising the quality of research and infrastructures. They have also stressed the importance of cooperation and assembling a critical mass. However, some biocentres now face the risk of reduced funding for core functions.

A new opening in the humanities and social sciences was the launch in 2001 of a new independent institute at the University of Helsinki, the multidisciplinary Helsinki Collegium for Advanced Studies. Each year the Collegium recruits newly graduated PhDs and more experienced scholars on the basis of merits and competition. In 2003, the Collegium has a research staff of 35 whose terms range from one to five years. The purpose of having researchers from different fields working under the same roof is to promote cooperation across disciplinary boundaries and to encourage the creation of a transdisciplinary community. Furthermore, the Collegium is intended as an international meeting-place for scholars. As an institution, the Helsinki Collegium is unique in Finland. Its international models include several similar institutes in Europe and North America.

Rapid advances in information technology, new forms of learning and the principle of life-long learning have all combined to change the operating environment of *scientific libraries.* The changes taking place in the way that universities operate requires ever closer networking among libraries. The Helsinki University Library is Finland's National Library, which functions as a service and development centre for Finnish scientific libraries and is also charged with the responsibility of national and international cooperation. In 2002 it has been suggested that the duties of the National Library be expanded to cover general libraries, polytechnic libraries and specialised libraries.

Complemented by a number of other scientific libraries and information services, university libraries constitute the backbone of the Finnish system of scientific libraries. The growing clientele of university libraries includes not only university staff and students, but also polytechnics, public administration and the business sector. Funding for university libraries comes mainly from core university funds. The single biggest problem for university libraries has been the decline in the funds made available to them. In spite of the growing demand for their services, they have had to cut back their staff as well as acquisitions.

FinELib, the National Electronic Library, acquires Finnish and international resources to support teaching, learning and research. FinELib negotiates user-rights agreements for electronic resources on a centralised basis for its member organisations. The National Library of Finland is responsible for FinELib operations and development. FinELib's operation was evaluated in 2003 and found to be of a high quality (Varis & Saari 2003). The library was recognised as having a key role to play in the development of the information society. However, development needs were identified in such areas as strategy, funding, services, utility of statistics and cooperation. Work is continuing to develop the operation of FinELib on the basis of the recommendations made in the evaluation report.

Networking among universities has increased considerably. The Finnish Virtual University is a new form of collaboration aimed at developing and promoting university networking. Launched in 2001 as a project organisation, its aim is to develop online services as well as new forms of networking in the fields of university education, research and administration. Apart from diverse forms of national networking, Finnish universities are also involved in several international networks, in some cases in the capacity of coordinator. For instance, the national Arctic Centre at the University of Lapland coordinates the network of universities in northern regions, and the University of Turku is coordinator for a network of 16 universities in the Baltic Sea region.

Cooperation among universities working in the same region has been established in the form of *consortia*. For instance, the various university units and polytechnics operating in Vaasa have set up the Vaasa Consortium of Higher Education, which is committed to diversifying education and increasing flexibility. The university consortium in the Helsinki region includes four science and four arts universities as well as the National Defence College.

4.1.3 Interaction with the rest of society

Interaction and exchange between the university sector and the rest of society has continued to intensify. Looking forward to synergy benefits, universities have stepped up their cooperation with different educational institutions, research and technology centres, other public organisations, service businesses and industry.

The role of universities in regional research and development varies widely. In volume terms their involvement is highest in the southernmost region of Uusimaa, but in relative terms the figures here are lower than average because of the major contribution of other sectors. There are regions in northeastern Finland where universities account for almost one-half of research and development.

It is essential that universities have good cooperation with polytechnics in order that they can develop a strong regional innovation system. Polytechnics have been building up their networks of cooperation. Research and development at polytechnics is very much an applied effort geared to the needs of working life. Its goals are often tied up with local or regional objectives. Supporting industry in the SME sector and service production is therefore paramount.

Government research institutes are also important partners for universities, playing a major part in supporting the transfer of university research results into practice. For example, the Northern Environmental Research Network (NorNet) involves the University of Oulu, four government research institutes, regional environment centres as well as environment sector businesses operating in northern Finland. Promoting both scientific and societal objectives, the purpose of the project is to support cooperation between the research community and end-users, business and industry as well as the various bodies responsible for regional development. Among the concrete forms of cooperation are joint professorships and an environmental graduate school. The National Public Health Institute also has close cooperation with the University of Kuopio and the University of Helsinki, which has resulted in two centres of excellence based on networks of cooperation.

Many universities also provide degree programmes and adult education and engage in research outside their home town. In 2001, degree programmes were available in 23 locations around the country. One example of a new type of network arrangement is provided by the “regional university of Lapland” in which local educational institutions have joined forces to offer the widest possible range of educational services to the local population.

Another indication of the wide range and diversity of interaction between universities and the rest of society is provided by the artistic activities of arts universities. For instance, exhibitions and expertise in the fine arts represent the areas in which the Academy of Fine Arts has the greatest social impact. Performances by the Theatre Academy and concerts by the Sibelius Academy are the most visible part of the artistic activities of these universities.

Innovation at universities

Universities have adopted very differing ways of responding to the challenges related to knowledge and technology transfer (Paasio 1998, Nieminen 2000, Innovatiivisen toiminnan... 2001). In recent years universities have launched various services, units and posts (such as those for innovation ombudsmen) to promote the commercialisation of new research results and to protect the legal and financial interests of universities and their researchers.

In 2000–2001 the Finnish Council of University Rectors, with funding from the National Fund for Research and Development Sitra, commissioned a project[3] to overview existing innovation services in Finnish universities and to outline plans for the development of those services. The project identified several problems related to ethical and legal aspects of innovation as well as to questions of organisation and resourcing. A network was set up within which universities provide some of the basic services themselves and outsource others that they are unable to maintain. The project group did not consider it justified to adopt innovation as an outcome criterion for all universities, but recommended that it be applied on an experimental basis in selected fields of research (e.g. economic and business administration, engineering and certain natural sciences).

The overall situation has not been reviewed since the completion of this project, but services have been developed for instance at the universities of Oulu, Helsinki and Kuopio and at several specialised universities. Contract models have also been developed that help universities protect their financial and legal interests. Since the turn of the millennium, universities have drawn up their own innovation strategies, strategies for external activities as well as strategies for regional activities. The Ministry of Education has its own regional strategy and has identified the regional impacts of universities as one of its priority targets for the 2003 outcome negotiations. While these strategies are designed at the highest organisational level, the task of implementation and fitting the different requirements together remains for individual departments and laboratories: their job is to piece together the different functions of university into a balanced whole.

Organisations for knowledge and technology transfer

Knowledge and technology transfer is mainly in the hands of technology transfer companies, technology centres and business incubators. Technology transfer through business companies started up in the 1980s with support from Sitra, and they became an established part of the scene during the 1990s. Technology transfer companies have been set up in the five biggest university towns. Universities have provided some funding for these companies, mainly through their foundations. However, given their scarce resources and the comparatively small scale of their operation, transfer companies have not been able to channel a very significant proportion of universities' knowledge and technology transfer. Technology centres and business incubators, which have a

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[3] Project report in Finnish only: Innovatiivisen toiminnan tukipalvelut yliopistoissa. Projektin loppuraportti ja suositukset. Espoo 5.6.2001.

highly differentiated and diverse ownership base, have been an important complement to transfer companies.

Case studies of the University of Helsinki and Helsinki Science Park, Helsinki University of Technology and its Innovation Centre as well as the Helsinki School of Economics and Business Administration and LTT Research Ltd have shown that transfer organisations frequently have problems negotiating between the interests of different kinds of cultures (Pelkonen 2001, Tuunainen 2002). Case studies in the Jyväskylä and Tampere regions, for their part, have concluded that the role of the university and its relationship to the environment cannot be determined on the basis of one uniform model because each operating environment presents very different kinds of demands upon the university, its structures and the way it works. Depending on the situation, universities have served and can serve as the anchor, dynamo or magnet within their region (Kolehmainen et al. 2002).

Transfer organisations are now expanding from their traditional fields of knowledge and technology transfer to universities' cultural functions. For instance, the University of Art and Design Helsinki has joined forces with the Helsinki School of Economics and Business Administration and Helsinki University of Technology to set up the Design Innovation Centre Designium. The Sibelius Academy has had joint business incubator projects with Hanken, the Swedish School of Economics and Business Administration.

There has been no systematic review of the nature of knowledge and technology transfer in Finnish universities. The University of Joensuu has opened dedicated posts together with the Forest Research Institute, the Regional Environment Centre of North Karelia and most recently with Joensuu Science Park. At Helsinki University of Technology, technology transfer is primarily organised through joint research and development projects with industrial partners.

Collaboration with outside partners in technology transfer places special requirements on universities' support services. Effective strategic management requires clear definitions of the basic functions and the service role of universities in society, clear guidelines and agreements as well as strategies that set out the general framework of operations (Innovatiivisen toiminnan... 2001, Korkeakoulujen osallistuminen... 2002). Development efforts and evaluation of their outcomes is complicated by the large number of actors, interests and organisations involved as well as by deficits in the information systems for knowledge and technology transfer.

University participation in different kinds of programmes

In the 1980s and 1990s, universities also sought to establish closer contact both with the local community and with the broader society through their involvement in various kinds of programmes. The discussion below describes the centre of expertise programme (see also section 4.2.2) and EU structural funds from the vantage-point of interaction and exchange between universities and their environment. Tekes-funded technology programmes are covered separately under section 4.2.1.

As far as universities are concerned the centre of expertise programme serves primarily as a support structure for research and development. The university network together with polytechnics is of great significance for this programme. University inputs to centres of expertise have mainly been of an operational nature, but this has varied widely across centres and areas of expertise. The overall impact of these programmes has also varied, and it is difficult to provide a reliable assessment. On the one hand, the programme has increased and diversified the funding available, improved facilities and strengthened collaboration. On the other hand, different fields of research are quite differently placed, relying as they do on regional funding sources. At the same time, universities have become ever more dependent on the short-term output and impact demands imposed on them. The role of the centre of expertise programme from the point of view of cooperation is discussed under section 4.2.2.

For purposes of regional development, universities have received international funding particularly through the EU's structural funds. In recent years the annual amount that universities have received through these sources (including national funding) has been in excess of 30 million euros. A significant proportion of that sum has been channelled through the National Technology Agency Tekes. Funds have been allocated among other things for purposes of strengthening the research capacity of universities. The funding obtained through structural funds for R&D and innovation has clearly increased in recent years. Structural funds have increased universities' funding options, provided clearer direction to regional strategic thinking and promoted cooperation between different parties. Opinions are more sharply divided on the question of how far the structural funds can bolster universities' innovation policy (Kuitunen 2000, Korkeakoulujen alueellisen... 2001). It has been argued that certain features about EU structural funding – its bureaucracy and narrow scope, the focus on project work and individual regions – effectively undermine universities' own strategic control and the prospects of universities having a local impact.

All in all the regional strategies and other links discussed above increase the prospects of universities having a stronger local impact (through the joint use of infrastructures, improved networking and division of tasks, information dissemination, etc.), but they do not support immediate, short-term impacts. Some commentators believe that the decentralisation of universities and the regional network of knowledge and technology transfer have supported each other and strengthened the regional impacts of universities. However, there are also mutual tensions between innovation and regional policy. Both may furthermore be at lesser or greater variance with the responsibilities and challenges of basic research at universities. In addition, the science and technology policy objectives as well as the actors and instruments related to technology transfer are interwoven in such a way that it is rarely possible to make a clear distinction between the aims, outcomes and impacts of different actors. It is difficult to gain solid overall control (Kuisma 1998, Huippuosaamisesta... 2003).

4.2 Programmes

4.2.1 Research and technology programmes

Recent trends in funding for research and technology programmes provide a useful illustration of the significance of these programmes for research and development (Table 4.1). Programme funding from the Academy of Finland (for research programmes, on the one hand, and centre of excellence programmes, on the other) has increased substantially in recent years. Programme funding from Tekes has doubled from 1997 to 2002.

Table 4.1. Academy of Finland and Tekes programme funding in 1997–2002.

Programme funding*	1997	1998	1999	2000	2001	2002
	€ million	€ million	€ million	€ million	€ million	€ million
Academy of Finland research programmes	23.2	26.5	31.9	30.8	39.6	21.8
Academy of Finland centre of excellence programmes	5.6	3.0	24.7	–	16.0	30.3
Tekes technology programmes	95.4	148.8	185.0	157.3	185.0	204.0

*Volume of funding decisions indicated in the value of the respective year.

Sources: Academy of Finland Annual Operating Review 2002, Tekes Annual Reviews 1997–2002.

Research programmes coordinated by the Academy of Finland

Academy of Finland research programmes are composed of a number of research projects that are focused on a defined subject area or set of problems and that are scheduled to run for a set period of time under a coordinated management. Funding may also be allocated for a specific field of research, theme or purpose. Research programmes are important tools for developing research, science policy, research funding and cooperation. They may be motivated by internal development needs within a discipline or field of research, by needs to support a new, emerging field or by needs to produce new information on an issue or problem that is considered to be of great societal import. Usually running for three years, there have been some 20 ongoing research programmes each year during the period from 1998 to 2002. As from 2003, programme funding will typically be made available for four-year terms, which is the most appropriate period from the point of view of postgraduate training needs, for instance. (Suomen Akatemian… 2003.)

Academy research programmes can be seen as tools for promoting a new kind of research culture that revolves around diverse and multilayered interaction, networking and cooperation (Hakala et al. 2003.) According to the Academy's research programme strategy (2003), its general science policy objectives are
- to develop research environments
- to coordinate scattered research capacities
- to promote multidisciplinarity and interdisciplinarity
- to develop national and international cooperation between researchers, funding bodies and end-users of research results
- to increase the international exposure of Finnish research through closer cooperation between researchers, funding bodies and end-users of research results
- to promote researcher training and professional careers in research.

National and international cooperation among funding bodies has increased in recent years in the funding of research programmes. This has involved some coordination and harmonisation of divergent research interests, funding criteria, decision-making procedures and time frames. In the funding of its research programmes and targeted programmes in 2002, the Academy had cooperation with 26 private and public funding bodies from Finland and elsewhere. International partners were involved in the funding of six programmes. A total of seven ministries and three other public funding bodies, five domestic foundations and three other private funding bodies plus eight foreign funders were involved in the preparation and funding of Academy programmes. The National Technology Agency Tekes was involved in 10 Academy research programmes, the Academy for its part was involved in three Tekes technology programmes. Six of the foreign funding bodies were from Sweden, one from the United States and one from France.

The Academy is now taking active steps towards the international networking of its programmes, towards jointly funded programmes and towards opening up programme components and even whole programmes to the international research community. Programmes initiatives from foreign funding bodies are screened and selected according to current needs of cooperation. The Academy has supported in various ways the involvement of Finnish researchers in European and other international research programmes. The Academy is looking forward to coordinating and taking part in several ERA-NET programme networks under the EU's sixth framework programme. These programmes that are jointly funded by research funding bodies promote the networking of research and the opening up of research programmes.

The Academy's research programme strategy (2003) takes account of the challenges presented by what is an increasingly international operating environment and the needs to further develop national programme cooperation. The strategy recognises that carefully planned and well-managed research programmes provide one possible platform for expanded national and international cooperation. The research programme is a goal-driven, diverse form of research funding whose success is evaluated upon its completion. The results of evaluation are used for purposes of research development and science policy planning.

The attainment of the objectives of Academy research programmes is evaluated upon their completion by international experts. The following summarises the main findings of the evaluation reports[4] on research programmes evaluated in 2001–2003, and reviews the results of Hakala et al. (2003) on 12 research programmes from the late 1990s.

According to these assessments, the Academy's research programmes have supported the development of research environments and science communities and have had a positive impact on the development of the disciplines concerned. For the main part the scientific standard of the research projects has been excellent or good. This is only to be expected: after all the projects have been selected in rigorous processes of international peer reviews. In some cases the evaluations have concluded that the objectives set for the research programme have been too broad and ambitious when considered against the resources available.

The objectives set for researcher training have been met very well or well. The growth of postgraduate training has been the most significant change in all fields of research. At the same time, the programmes have provided training for experts in such fields as urban policy, environmental health and industry. One of the problems identified is that

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[4] The evaluation reports are listed at the end of this chapter under Other sources.

the three-year term of the research programme is not long enough for the completion of the doctoral degree. Most projects in Academy research programmes starting up in 2004 will be funded for a four-year period.

Research programmes have helped to promote multidisciplinarity. There is increased cooperation across disciplinary boundaries, and some programmes have created entirely new contacts between the humanities and social sciences on the one hand and the natural sciences, on the other. However, given the different vantage-points, concepts and traditions of different disciplines, it is clear that they must invest considerable effort in finding a common language and understanding: they cannot expect to achieve deeper interdisciplinary cooperation until some way down the road. Some programmes have set overly ambitious objectives.

Research programmes have also increased cooperation and networking among researchers representing different disciplines and organisations, providing a useful framework and the necessary resources for cooperation. The exchange of information and experiences as well as the description and comparison of results were the most common forms of cooperation. There was significantly less cooperation at a deeper level. Research programmes reinforced existing relations or helped collaborating projects find new partners with whom they thought they would benefit from cooperation. There was less cooperation in programmes that involved very different kinds of projects. The structure of the programme and the emphases of the projects involved as well as coordination can affect the shape that cooperation assumes. Consortia set up among several projects within the framework of a research programme have proved to be a very useful form of collaboration. There has also been some cooperation between programmes. The natural sciences have had good success in integrating basic and applied research.

Research programmes have helped to bolster international cooperation. In most cases existing relations of cooperation are strengthened during the course of the programme, but it is not very often that new contacts are established. International publishing and research cooperation have increased especially in projects in the humanities and social sciences. In a few programmes researchers have been unhappy with the opportunities offered for internationalisation.

Some Academy research programmes have been set specific targets with regard to their social impacts. In most cases the social impacts of programmes are not seen until several years later. However, they are evaluated immediately upon completion so that their immediate impacts can be identified – even though it is impossible at this stage to say anything definite about their indirect impacts. It is also worth considering how the impacts of the programme can be distinguished from the impacts of other activities.

Separate analyses of the social impacts of three different research programmes were carried out for the first time in 2002. Commissioned by the Academy, an outside consultant evaluated the national impact of the Biodiversity Research Programme (Otronen & Tirkkonen 2002). The social impacts of the Research Programme on Environmental Health were evaluated by a panel of national experts representing different fields of expertise (Ympäristöterveyden… 2003). End-users considered the Research Programme for Urban Studies so significant that the Ministry of the Interior commissioned an evaluation of how the results of the research programme impacted debate and discussion on urban policy and urban planning (Antikainen et al. 2002). In addition to the separate impact assessments mentioned above, international scientific evaluations have commented on the social impacts of research programmes.

Research programmes in the humanities and social sciences have produced useful information in support of political decision-making. The Russia and Eastern Europe Research Programme has helped to satisfy the growing needs for information and expertise in different sectors, primarily in the field of economics and political studies. The Research Programme for the Economic Crisis of the 1990s (LAMA) has drawn attention to and analysed issues relevant to social development and produced significant material for political debate.

The ministries involved in the Research Programme for Urban Studies (URBS) felt that the objectives set for the programme were met reasonably well. Designed to cover a broad range of different perspectives, it generated new information for various different policy sectors. Some of the projects have clearly highlighted the extent and significance of political themes whose importance has previously been underestimated. According to a separate study (Antikainen et al. 2002), the programme concluded that urban policy should also cover small and medium-sized urban regions and that measures of urban policy shall also take into account the growing tendencies of individualisation and give more attention to cultural as well as identity questions.

The Research Programme on Environmental Health (SYTTY) produced results that have been used for purposes of risk assessment, health protection and legislation. The programme has helped to raise the general esteem of this field, and large numbers of experts have been trained in its projects. Knowledge transfer and its application in decision-making were successful, and decision-makers were well aware of the programme. The immediate social impacts of the programme upon the quality and funding of environmental health research as well as upon researcher training were very significant indeed. However, there was only limited production of economically viable innovations and experimental interventions.

The Research Programme on Health and Other Welfare Differences between Population Groups (TERO) has had an impact on ongoing work within government to draft a national health programme as well as on national health policy. The programme has also increased awareness about flaws and problems in health policy.

The Finnish Biodiversity Research Programme (FIBRE) has enjoyed quite exceptional international exposure and has also had a significant impact on international policy. The general impacts of the programme have been to enrich biodiversity research and promote general awareness and sustainable development in society. Most social impacts are related to environmental protection, which also has socio-economic impacts. The Integration and Synthesis Project (BITUMI) brought together research results, promoted the application of those results, and increased exchange and discussion between FIBRE projects, the rest of the science community and end-users in line with the objectives set for BITUMI. In general this has been an innovative effort that has supported communication between researchers and end-users.

Universities and research institutes have worked closely with industry particularly in research programmes in the natural sciences and engineering. For instance, the Materials Research and Structures Research Programme (MATRA) and the Research Programme for Process Technology (PROTEK) involved close cooperation between universities and the business sector and produced important innovations and patents. Young researchers were recruited into industry. The MATRA programme also produced a few spin-off companies. The Research Programme for Electronic Materials and Microsystems (EMMA) inspired several researchers to try and find industrial applications for their research.

Tekes technology programmes

Programmes funded and administered by the National Technology Agency Tekes are aimed at organising technology development within larger projects that are focused on a certain area of technology, theme or problem. As well as running programmes that are aimed at increasing basic knowledge at a national level, Tekes coordinates programmes that are designed around industry needs.

The general aim of technology programmes is to support and strengthen the capacity of business companies for technological renewal; to produce new information, skills and technologies; to promote the dissemination and application of research results; and to improve national and international cooperation in R&D. Furthermore, each technology programme will have a more specific set of objectives. According to Tekes strategies and programme documents these concern:

- desired social impacts (promoting employment and welfare, diversification of production structures, etc.)
- desired industry impacts (promoting the internationalisation of new industries, promoting the commercialisation of industry products, etc.)
- desired direct impacts (promoting the interaction and networking among programme projects, boosting business and industry competitiveness, etc.).

Tekes technology programme funding in 1997–2002 is described in Table 4.1. The average budget for technology programmes ongoing in 2002 was around 33 million euros and their average duration 4.5 years. Tekes is keen to support and promote the cooperation and networking among different organisations by launching joint research and technology programmes together with other funding bodies. In particular, Tekes has intensified its cooperation with the Academy of Finland. In 2002, Tekes technology programmes involved a total of some 2,200 business participations and around 790 research unit participations. According to the agency’s annual report, Tekes had in 2002 a total of 48 ongoing technology programmes. Tekes and the Academy of Finland were collaborating in nine technology and research programmes; five of these were Academy of Finland research programmes.

Programme cooperation between Tekes and the Academy has increased and diversified in recent years, starting from the planning and implementation of joint programmes and extending through to joint evaluations and joint development efforts. So far cooperation between the two agencies has been most extensive in two programmes that have already been evaluated: the research and technology programmes in the field of electronics and telecommunications (ETX and TLX, launched by Tekes) and Telectronics I (launched by the Academy of Finland) as well as the Nanotechnology Research Programme. The programme components were jointly designed and implementation was coordinated, even though formal definitions were avoided. The programmes were aimed at boosting the growth and development of the Finnish IT sector, but they also had goals related to the development of the programme instrument which supported the interests of both Tekes and the Academy. Participation in planning and supervisions meant that Tekes gained access to the domain of strategic basic research, the Academy for its part gained a new angle on the needs of business and industry.

From the Academy's point of view, Telectronics I was one in a series of eight research programmes launched on the strength of the government's additional spending programme and geared at forging closer links between general science funding and Tekes technology funding (Evaluation of Finnish… 2002). This programme cluster provided business companies with a useful opportunity to develop their R&D operations by supporting and sponsoring business-driven projects that involved technological or financial risks and to take part in longer-term projects run by research organisations.

The Nanotechnology Research Programme shared the same goal of crossing the boundary between basic and applied research and between different funding bodies and improving the cooperation between Tekes and the Academy. Since the boundary line between basic and applied research is rather fluid in the field of nanotechnology and since the programme was driven towards multidisciplinarity, it was organised flexibly rather than having strict definitions imposed on the scope of its work. Because applications take a long time to mature in nanotechnology and because the programme was primarily oriented to basic research, there were no expectations of immediate commercial benefits. Some of the projects did proceed to produce commercially relevant applications, but commercialisation was hampered by patenting problems. (Nanotechnology… 2002.)

Technology programmes vary in their focus and they also have different objectives with regard to their impacts. According to a recent assessment the Tekes programme concept is being revised and technology programmes are focusing more and more closely on the development of a certain component of a sectoral innovation system (e.g. actors within a certain industry): under active programme management, the aim now is to achieve innovation benefits at system level (Autio et al. 2003). Examples of such programmes include the Kenno, Plastic Processing and Pigments technology programmes. The Kenno programme is aimed at stimulating light-weight product innovations in the metal industry. The Plastic Processing programme was focused on new product innovations in the plastic industry, while Pigments was concerned to develop new ways of using pigments in the paper industry. A more systematic overview of the new programme concept is provided in a technology review by Gustafsson et al. (2003). Focusing on weak signals, this review explores the role of technology programmes in the future and seeks to identify new approaches for the future. It proposes a distinction between five new types of programme[5].

For reasons of strategic emphasis the size of programmes and the scope of evaluations have been expanded. In addition to the electronics and telecommunications programmes mentioned above, relevant examples include the evaluations of the Static Electricity, Future Products and Control of Vibration and Sound programmes (Laine 2003). These three programmes were aimed at integrating the know-how of two industries or fields of research (e.g. the control of sound and vibration in buildings and machinery). Another example is provided by the evaluation of the GPB, ProBuild and Quality programmes (Kilpailukykyä... 2002). Here the focus is upon global project business, the progressing building process and quality in the network economy. The Information Technology and Electronic Power Systems Technology Programme TESLA and the Waste to Energy Technology Programme (Rajahonka et al. 2002) are concerned with the production of energy and the utilisation of waste energy as a new challenge in society. The orientation to broader programme entities has also contributed to the development of new type of cluster concept (Uusikylä et al. 2003). The sensitivity of programme evaluations to recognising, predicting and supporting ongoing changes has been improved by more closely integrating the functions of foresight and evaluation.

The social impacts of technology programmes are diverse and far-reaching. They have produced new knowledge and know-how, facilitated the strategic focusing of research, supported the networking of knowledge, activities and resources, strengthened competitiveness, increased the visibility of research and made possible a longer term approach to research (Tuomaala et al. 2001).

The impacts of technology programmes have changed over time. In the 1980s, they promoted and supported the introduction of new technologies. Today, programmes serve the purposes of creating new technology openings and developing technologies of great societal import (e.g. Rissa 2003). As well as having important benefits, programmes are also in need of development. The ambitious objectives set for technology programmes have not always led to radical reform. Problems and risks are related to the organisation and implementation of programmes, the application of their results, the way they are focused as well as to the loss of diversity in research and development (Berg 1999, Tuomaala et al. 2001).

The main development challenges that face technology programmes, according to evaluation reports, have to do with international networking and strengthening technologies that are environmentally friendly and have beneficial welfare effects. For reasons of strategic coherence, the programme concept needs to be clarified and methods of programme evaluation continually improved. Closer attention needs to be paid to the start-up phase of programmes (e.g. identification of targets) and their management, and the overall level of challenges should be raised. All this requires closer cooperation among the funding bodies and especially the inclusion of polytechnics and social research. The Research Programme for Advanced Technology

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[5] These are vision programmes; programmes supporting knowledge and know-how sectors; cluster programmes in different industries; user-driven technology programmes; and social megatrend programmes.

Policy (ProACT) has taken steps in precisely this direction. ProACT is a programme run jointly by the Ministry of Trade and Industry and Tekes, concentrating on questions of interaction between technology, business and industry and the rest of society. It comprises both research interests related to decision-making on technology policy and projects concerned with more traditional themes of social research.

4.2.2 Cluster programmes and centre of expertise programme

Cluster programmes

Cluster programmes were first launched in 1997 in the wake of the government's decision to open an additional spending programme aimed at boosting research and development. A cluster programme is built up around business companies and organisations that share a common goal and that are keen to reap the benefits of cooperation (Prihti et al. 2000). The aim of these programmes has been to strengthen the international competitiveness of the know-how clusters concerned. They have gone about this task by promoting the networking of public and private agents. There have been eight cluster programmes in Finland under the administration of five different ministries. Involving more than 300 projects, the combined volume of these clusters in 1997–1999 was in excess of 100 million euros. In its 2003 review the Science and Technology Policy Council of Finland recommended that cluster programmes redirect their focus to promoting social innovations and service innovations.

Ministries have had an important role in organising the work of clusters. Most of the public funding has come through Tekes, followed by the Academy of Finland. The discussion below provides an overview of the national cluster programmes that have been started up with funding from the government's additional spending programme and that have by now been evaluated. Since then cluster programmes have diversified and developed.

In 1997–2000, the Ministry of Agriculture and Forestry granted 2.1 million euros to support 12 research projects under the *Foodstuffs cluster*. The target set for the programme was to support the adaptation of Finnish agriculture and the food industry and to strengthen their competitiveness. According to the national evaluation of the cluster programme (Poutiainen & Salminen 2001) the projects by and large achieved their goals. New contacts of cooperation were created between the research organisations involved, and existing contacts were reinforced. Cooperation with the business sector, by contrast, left much to be desired: there were no more than a few projects in which business and industry took any significant part. Although the programme produced only very little information with immediate application in product development, it was thought that the results overall were encouraging and that they provided a useful foundation for future business, production and product development purposes. The reviewers recommended that cluster programmes in this sector be continued and that more than one funding body is needed.

Set up on the initiative of the Ministry of Agriculture and Forestry, the *Forest Cluster Research Programme* (Wood Wisdom) in 1998–2001 had a total budget of 33 million euros, with monies from public sources accounting for two-thirds or 22 million euros. The programme was funded by Tekes, the Academy of Finland, the Ministry of Agriculture and Forestry and the Ministry of Trade and Industry. Private sources and the research organisations themselves accounted for one-third of the funding. The aim of the programme was to promote the competitiveness of the forest sector in an ever-changing environment by combining the resources of the whole production chain so that the customer's expectations and demands with regard to the end-product can be satisfied. The research and technology programme cluster covers the whole chain of chemical and mechanical processing from the raw material through to the final product.

The scientific and technical standard of the programme was rated highly in an international peer review (Finnish Forest… 2002). It was described as well organised and coordinated. The consortia set up under the programme's umbrella promoted the development of research environments, and university projects had good success in researcher training. The consortia were successful in integrating basic and applied research and other aspects of know-how, adding to synergy benefits. National and international cooperation and networking among researchers was highly successful. The end-users of the results were also closely involved in the programme. According to the programme's self-assessment (Salo et al. 2002) it had reasonably good success in improving research cooperation and strengthening the knowledge base for industrial competitiveness. The programme brought together different kinds of funding organisations, university researchers, people from government research institutes and industry and created a new forum of discussion and deliberation on the cluster's challenges and future prospects. However, it was felt that more international networking and cooperation was needed.

Starting up in 2003, the sequel to Wood Wisdom – the Wood Material Science programme – is divided into two components: the production of new strategic knowledge on the material properties of wood and the development of new ways of using research results. The programme will be funded jointly from international sources, possibly within the ERA-NET scheme.

The Ministry of Social Affairs and Health spent close to five million euros on the *welfare cluster* in 1997–2000. This cluster comprised research into the technology and service products used in social welfare and health care as well as their development, production and use. It also comprised home help services and home health care, self-care and solutions promoting independent coping. In addition to general networking objectives, the cluster had the specific goal of improving the quality of social and health care services.

The biggest single project in this cluster has been the Macro pilot project, which involved 20 projects. The aim was to create seamless customer-driven service chains using information technology, to test a customer card supporting this service chain and to improve privacy protection. According to the evaluation of the programme, the best success was achieved with the introduction of experimental legislation. At the meso level, attention was drawn to the key significance of regions and health care districts; at the micro level the best results were achieved in encounters with the client and in the organisation of the service chain. The people involved in the projects learned better to understand one another. However, the Macro pilot had great difficulties attaining the targets set for it, apparently for reasons that have to do with preparation, organisation, supervision and scheduling. Many of the objectives (including the involvement of business companies, IT solutions, practical reforms in social and health care services, new significant strategies of action) were only partially met, some were not met at all. The programme did, however, have some indirect benefits. It encouraged the units that took part in the competition to weigh and consider their own ability to engage in cooperation across sectoral boundaries. In the Oulu region in northern Finland, the competition also led to determined efforts to build up cluster contacts. The project has continued to expand and its overall impacts are not yet fully visible. (Ohtonen 2002, Tarkiainen 2002.)

Transport Cluster and Telecommunications Cluster. At the Ministry of Transport and Communications, the funds made available through the government's additional spending programme were used to launch the Research and Development Programme of Transport Telematics (TETRA: 58 projects, total funding around 11.5 million euros), the Transport Chain Development Programme (KETJU: 36 projects, more than 14 million euros) and the Verkkokaveri Programme supporting datacommunications development (VEKA: 7.5 million euros). The aim of the TETRA programme was to support private R&D projects working to create new telematics products and services. KETJU, for its part, was a development programme aimed at increasing national know-how about international freight transport chains, at developing new products for the international marketplace and at promoting national objectives within EU transport policy. Finally, the purpose of VEKA was to provide concrete support and information to SMEs on the opportunities offered by the Internet, on different forms of online business and on practical solutions and in general on the application of IT and communications technologies in SME business.

For reasons of confidentiality, the interim evaluations in 2000 had only limited access to information on new projects launched under the umbrella of the TETRA and KETJU programmes (KETJU… 2000). The projects within the TETRA programme had led to certain products and services (e.g. personal navigators and personal digital systems). The programme provides useful support for various public sector operations and the development of private sector products and services. The projects will be brought to conclusion during 2002 and 2003. The appearance of the KETJU programme at Finland's premier logistics exhibition in 2002 is a good example of how a programme can support the commercial success of its projects. The programme had no clear guidelines for supporting small companies in their efforts to commercialise their products. According to an assessment carried out towards the final stages of VEKA in 2000 (Verkkokaveri… 2000), the targets set for the programme had been met both in terms of exercising an impact on SMEs and in terms of results. As for permanent incentive impacts, applicable strategy models and concrete implementation at company level, it was concluded that further effort was still required in order to meet the objectives.

Coordinated by the Ministry of Labour, the first term of the *Finnish National Workplace Development Programme* ended in 1999; its second term runs from 2000 through to 2003. Aimed at supporting development efforts within this field and at promoting the dissemination of knowledge and know-how, it received five million euros out of the government's additional spending programme. According to the programme evaluation, it achieved its objectives (Pitkänen et al. 2003), responding well to the development challenges in the workplace. The most important of these challenges was maintaining the competitiveness of the Finnish national economy in the global marketplace. The programme launched development projects aimed at increasing productivity and promoting the quality of working life. Its scientific and research impacts were considered somewhat limited. It had less contact with other programmes than would have been desirable.

The *Finnish Environmental Cluster Programme* is coordinated by the Ministry of the Environment and funded by the Ministry of the Environment, the Ministry of Trade and Industry, Tekes and the Academy of Finland. The programme received more than 13 million euros through the government's spending programme. Its aim has been to generate new information that would create a sound basis for developing the living environment and for resolving the key environmental problems of the immediate future. The purpose is to find new ways to save the environment, to create new innovations that can help promote welfare and people's living environment and to intensify cooperation between researchers, business and industry, the authorities and funding bodies. Carried out in three phases, the main theme of the programme has been that of eco-efficiency. Not all projects in the programme have been selected primarily on the basis of the scientific standard of their research. The programme's steering group commissioned an outside evaluation of the programme for internal use upon completion of the first stage. After the second stage, the programme was refocused in line with the recommendations of a separate study (Heinonen et al. 2002). The programme's third term starts in 2003 and continues through to 2005.

Centre of expertise programme

Based on the Regional Development Act (602/2002), the *Centre of expertise programme* is aimed at promoting the national goals set for regional development. The programme consists of 14 regional centres of expertise and two centres built around a national network which operate in connection with technology centres. In 2001 a total of 430 interest groups were represented on the advisory boards and steering groups of centres of expertise, with 1,100 experts from different fields engaged in the expert groups responsible for supervision. A total of 3,075 companies, 460 research and training units and 480 other development organisations were involved in the programme in 2001. (Huippuosaamisesta... 2003.)

The programme has the aim of facilitating the placement and development of internationally competitive business and research that requires a high level of expertise. The original idea of the centre of expertise concept – to increase interaction and cooperation between the business sector and research – has for the main part been successful. Its most significant impacts are thought to have included an increased level of know-how, a higher standard of technology and an improved readiness to make use of research and development resources. (Osaamiskeskukset... 2001, Huippuosaamisesta... 2003.) The significance of the centre of expertise programme from the point of view of universities is discussed under section 4.1.3.

4.2.3 Centre of excellence in research programmes

Several countries around the world have earmarked funding for centres of excellence in research (Malkamäki et al. 2001). In Finland there are two ongoing centre of excellence programmes in 2003: the 26 centres appointed for the 2000–2005 term and the 16 centres appointed for the 2002–2007 term. The programmes are funded by the Academy of Finland, Tekes, universities, research institutes and foundations. The centre of excellence programmes are evaluated upon their completion.

The programme is open to all disciplines. The units taking part are selected on a competitive basis, and funding is provided for two consecutive three-year periods. A centre of excellence may operate within a university or research institute, and it may also include groups from the private sector. The centres appointed to the programme are either at or very close to the international cutting edge in their own field of expertise. The centre consists of one or more high-profile research groups who share a clear set of objectives and who work under the same management. The criteria applied in the selection of centres of excellence are their scientific merits and outputs, their research and action plan, the research environment they provide as well as success in researcher training.

Each centre of excellence has its own international scientific advisory group whose job it is to support, promote and monitor the work that is done at the centre. Depending on the field of research, two or more centres of excellence may have partly or wholly the same advisory group. The 42 centres of excellence in the two programmes have a total of 38 advisory groups, who usually convene once a year in the centre's premises. Often a seminar is organised to coincide with the meeting to give senior fellows and junior researchers the opportunity to introduce their work. In addition, advisory groups have been introduced to laboratories and fieldwork. The advisory groups report to the Academy and other funding bodies on the scientific and organisational development of the centres of excellence, the development of research careers, infrastructures, cooperation, social impacts, international exposure and the added value gained from the status of centre of excellence. There is a separate chapter in this review on the social impacts of individual centres of excellence.

The Academy promotes international networking among centre of excellence programmes, and it has had an active role in planning and starting up the Nordic centres of excellence programme. Within the context of this programme, the Nordic Natural Science Research Councils (NOS-N) and the Nordic Council of Ministers provided in 2003–2007 funding for four units in the field of global change research. This is a pilot programme that is expected to yield useful experiences and ideas for the further development of Nordic research cooperation.

In 2002 the Academy of Finland and the National Natural Science Foundation of China invited applications from Finnish centres of excellence and high-level research groups in China for joint projects. Four such joint projects were granted funding in the fields of population biology, forestry research, signal processing and chemical engineering for a period of three years. The funding organisations are closely monitoring progress, with special reference to the added value generated in cooperation.

4.3 Internationalisation of research

In Finland, responsibility for technology policy and the preparation and coordination of matters related to EU science and technology policy lies with the Ministry of Trade and Industry. The Ministry of Education is responsible for international cooperation in the field of education and to some extent in research. The Academy of Finland and the National Technology Agency Tekes serve as national points of contact for and as experts on several international science and technology organisations. The foundation for cooperation is provided by the payment of membership fees to international associations, or by bilateral and multilateral agreements. The most important objective of cooperation is to facilitate the internationalisation of universities, research institutes and other organisations involved in research and development. The discussion below provides an overview of the main forms of international cooperation from the point of view of science policy.

4.3.1 National competitive funding from the point of view of internationalisation

The Academy of Finland's mission is to raise the standards of research and education in Finland and to support international mobility and cooperation among researchers. The Academy promotes international cooperation in research and researcher training by funding and supporting research projects and posts, researcher training as well as research programmes and centres of excellence. Virtually all Academy-funded projects involve international cooperation. In addition, the Academy awards grants for purposes of supporting bilateral researcher exchange and work abroad. The Academy also provides support for foreign researchers working in Finland; for the organisation of international conferences; and for the preparation of joint international projects.

The Academy has bilateral agreements of research cooperation with 37 organisations and 25 countries. For purposes of reviewing applications it receives, the Academy relies to an increasing extent on the services of foreign experts. In 2000 they reviewed 18 per cent of the applications received for general purpose funding, in 2002 the figure was up to 41 per cent.

The National Technology Agency Tekes promotes the internationalisation of business companies, research, technology and the whole innovation system by awarding funding for the preparation of international research and product development projects and joint international projects. According to the agency's 2002 annual report, well over one-third of the R&D projects it funded in 2002 (754 out of 2,017) were internationally networked. In over half of these it had cooperation with EU countries, in over one-quarter with the United States and in five per cent with Japan. In 2002, Tekes had 48 ongoing technology programmes, 44 of which involved international collaboration. Close to half or 43 per cent of the projects in these programmes were international.

4.3.2 Nordic cooperation

The Ministry of Education, the Ministry of Trade and Industry and the Academy of Finland are all represented on the Nordic Council of Ministers' education and research committees and advisory boards. The most important bodies are the research policy council (FPR) and the steering committee within higher education (HÖGUT). Finland last chaired the Nordic Council of Ministers and its bodies in 2001. During Finland's chairmanship the main emphasis in education and research cooperation was on promoting the mobility of researchers, information society policy and life-long learning. Special attention was also paid to the start-up of the centres of excellence programme and to cooperation among distance universities.

The project to build up a European Research Area has presented a host of new challenges as well as new opportunities for Nordic cooperation. The Nordic Council of Ministers has commissioned an inquiry into the Nordic research cooperation and structures and into the need for reform. The aim is to make the Nordic countries a leading international force in research and innovation. The findings of the inquiry will be published in autumn 2003.

The Academy's Research Councils are represented on the Joint Committees of Nordic Research Councils (NOS-S, NOS-H, NOS-M, NOS-N). Their aim is to promote collaboration among the Research Councils in their respective fields and to improve coordination. The Nordic Joint Committees prepare and issue joint statements on questions of international research policy and suggest new research and postgraduate training projects in the Nordic countries. Some Committees award funding for joint Nordic research projects and for hosting Nordic scientific conferences. All four Academy Research Councils are involved in the Nordic Data Grid project, which in Finland is coordinated by the Centre for Scientific Computing under the Ministry of Education. Organised as part of the European GRID project, its purpose is to facilitate the processing and application of scattered research data and to develop the related infrastructure. In the natural sciences, NOS-N has joined the Nordic Council of Ministers in funding the Nordic centres of excellence pilot programme in 2002–2006, which is concentrated on the theme of global change. There is also close cooperation with the Baltic countries.

Researcher mobility is supported and promoted through the Nordic Academy for Advanced Study (NorFa). As part of the Nordic centres of excellence programme, NorFa provides funding for Nordic graduate schools in the natural sciences and engineering; as from the beginning of 2004 it will also be supporting graduate schools in social and cultural research together with NOS-S (Joint Committee of the Nordic Social Science Research Councils) and NOS-H (Joint Committee of the Nordic Research Councils for the Humanities). Tekes promotes international cooperation in research and development projects through the Nordic Industrial Fund, and cooperation between business companies and research organisations through Nordic Energy Research.

4.3.3 European cooperation

Intensified cooperation and networking as well as increased research funding are all geared to improving the quality and competitiveness of European education, research and knowledge-intensive business. The ultimate aim is to create a European Research Area (ERA). The European Union has set itself the target of increasing, by 2010, EU research investments to three per cent of its Member States' combined GDP. ERA will also help to strengthen the Northern Dimension and increase cooperation among the Nordic countries and with the neighbouring areas. Among the steps taken to build up the ERA are to increase the number of doctoral students and young researchers (and women in particular), to promote the international mobility of researchers and to improve the cooperation among public and private funding bodies.

Finland has been actively involved in ongoing work to build up the ERA. In this work the European Commission has consulted independent advisory bodies, most notably the European Research Advisory Board (EURAB). EURAB is made up of top level research and technology policy experts who have been nominated in a personal capacity, not as country representatives. There are two Finnish members on the board, one of whom has been nominated on the recommendation of the European Science Foundation. In addition, a Finnish representative has chaired the European Union Research Organisations Heads of Research Councils (EUROHORCS).

In connection with the ERA project there has been some discussion about the need for a European Research Council. The aim is to strengthen basic research in all fields of research, to improve the mechanisms of European research funding and to provide consistent, long-term support for scientific research. The Academy of Finland has been actively involved in discussions on the start-up of the Council and taken, in principle, a positive stance on the initiative.

One of the new tools of ERA implementation is network cooperation through ERA-NET. It is expected that these networks will increase cooperation among the various bodies involved in funding and organising research. In Finland this may involve not only the Academy of Finland and Tekes but also ministries, various foundations, innovation organisations and regional centres. It is hoped that the ERA-NET scheme will help to strengthen national and regional cooperation and open up a workable channel of communication and planning between different countries. Finland has taken numerous ERA-NET initiatives and been an active partner in applications coordinated by other countries in 2003.

The EU's five-year research framework programmes have been the Union's most significant tool of science and technology policy. By the end of March 2003, a total of 12,700 projects had been approved under the fifth framework programme (1998–2002), of which 1,380 (11%) had at least one Finnish participant. Some 320 million euros of EU funding has been channelled into these projects. Almost two per cent of all projects or 235 were coordinated by Finnish partners. Close to one-third or 29 per cent of all project proposals with Finnish participants were accepted. Among Finnish projects, universities accounted for 32 per cent, research institutes for 31 per cent, business companies for 30 per cent and others for seven per cent.

Major new forms of cooperation in the sixth framework programme (2002–2006) include broadly-based, integrated projects, networks of excellence and the networking of national research programmes and opening these to international cooperation. The framework programme is also aiming to intensify cooperation with EUREKA and COST. In Finland, main responsibility for the coordination of the sixth framework programme rests with the Academy and Tekes. In 2002 the content of the framework programme was defined for the first time on the basis of expressions of interest, the aim being to find out which areas of the framework programme were of most interest in the research community. In Finland, 70 per cent expressed an interest in integrated projects, 30 per cent in networks of excellence. Universities and research institutes accounted for more than 85 per cent of all expressions of interest from Finland, while the business sector accounted for eight per cent. The framework programme's first calls for applications proper were issued in spring 2003, attracting considerable interest.

European Cooperation in the Field of Scientific and Technical Research (COST) is an EU sponsored forum for research cooperation that involves 32 states. Each year COST awards some two billion euros towards the costs of research networking. All in all some 30,000 researchers are involved. In 2002 there were almost 200 ongoing COST projects; Finland was involved in 137 of these. National COST coordination is the responsibility of Tekes.

Cooperation through EUREKA provides for businesses, research institutes and universities a channel for the development of new products, processes and services in the context of cooperation or cluster projects. In 2002 Finnish partners joined 15 new EUREKA projects. The main emphasis was on information and communications technology. Finnish interest in cooperation has increased in recent years. EUREKA cooperation in Finland is coordinated by Tekes.

Finland is also actively involved in European research cooperation through the European Science Foundation (ESF), the European Space Agency (ESA), the European Organisation for Nuclear Research (CERN), the European Molecular Biology Laboratory (EMBL) and the European University Institute (EUI).

The ESF's mission is to promote European science and basic research of high quality, which it does through research programmes, exploratory workshops, networks and EURESCO conferences. In 2002 the Academy of Finland took part in 37 research programmes. A new form of ESF funding is represented by Collaborative Research Programmes (Eurocores). Programmes are jointly prepared by the ESF and member organisations, with the latter providing the funding for the research projects. In 2002 the Academy was involved in two Eurocores programmes, with six programmes under preparation. ESF activities are managed under disciplinary committees, which among other things submit proposals for the start-up of new programmes and networks. The Academy of Finland has a representation on these committees. The Academy also has experts on other ESF committees, thematic programmes, working groups and networks, putting it in a good position to shape and influence the contents and start-up of European research cooperation and new programmes

The European Space Agency (ESA) has 14 member states, all of which are involved in space science, general technology and investment programmes and on a selective basis in other programmes. Finland's annual membership fee is two million euros, in addition to which participation in compulsory programmes costs the country 5.5 million euros a year. Furthermore, in 2002 seven million euros was spent on optional programmes. All active members states get commissions for research and development projects in proportion to their membership fee. Finland has been very active in this regard. National coordination rests with the Ministry of Trade and Industry and Tekes; the Academy of Finland is responsible for the space science programme. The Academy supports research in ESA satellite projects through general purpose appropriations and through the ANTARES research programme in 2001–2004. Finnish space research is of high standard, and the same goes for expertise in building space equipment. The number of Finns on the ESA payroll remains quite modest. The most widely publicised of ESA's operations are its satellites, which also incorporate Finnish know-how.

The European Southern Observatory (ESO) has emerged as the world's leading astronomical organisation whose flagships are the VLT (Very Large Telescope) and the forthcoming ALMA (Atacama Large Millimetre Array). Finland is currently negotiating membership of the ESO, which would happen in summer 2004 earliest. Finnish astronomical research is well placed to take advantage of ESO equipment.

The European Organisation for Nuclear Research (CERN) involves 20 member states from across Europe. In 2002 Finland's membership fee was almost nine million euros. Finland was the first member state to evaluate its own operation within CERN (Evaluation of … 2001), with positive results. Some 15–20 Finnish experts are involved in research and technology positions at CERN, but none of them at the very highest level of the organisation. Drafted under Academy supervision on the basis of the findings of the recent evaluation, Finland's new CERN strategy emphasises the importance of visible participation in basic research, the promotion of accelerator based physics and applied research, postgraduate training, the commercial utilisation of projects and increasing public awareness of these activities (Suomen kansallinen… 2002). The Helsinki Institute of Physics (HIP) will assume an ever more prominent role in national coordination through CERN activities.

Funded by 16 states, the European Molecular Biology Laboratory (EMBL) is an international research organisation that engages in high-level molecular biology research. It runs, among other things, an international PhD programme. The European Molecular Biology Conference (EMBC) is an international organisation made up of 24 states whose main function is to promote international cooperation and the development of research in modern biosciences by funding researcher mobility. EMBC operations are run by the European Molecular Biology Organisation (EMBO), a science academy type of organisation. In 2002 Finland paid 727,000 euros to EMBL in membership fees, the membership fee to EMBC was 125,000 euros. The Academy of Finland is represented on both EMBL and EMBC committees. In 2003 the EMBL Council was chaired by a Finnish delegate.

Jointly run by EU Member States, the European University Institute (EUI) offers doctoral training programmes and research facilities for doctoral students and researchers. It has four departments: economics, history and civilization, law, and political and social sciences, plus a Robert Schuman Centre for Advanced Studies. Finland's membership fee in 2002 was 228,000 euros. The Academy of Finland has representation on the EUI's budget and student selection committees. There are 15 Finnish postgraduate students at the Institute during the 2003–2004 term.

4.3.4 Global cooperation

Finland is a member of many international scientific organisations and networks. From a science policy point of view, key organisations among these – apart from European contacts of cooperation – are the OECD and UNESCO. Finnish ministries and funding bodies have also signed numerous bilateral and multilateral agreements of cooperation which in many cases are essential for establishing contact and getting research cooperation off the ground with countries outside the European Union. The Academy of Finland is taking steps to develop and upgrade bilateral agreements of research cooperation from quota-based researcher exchange towards a more strategic orientation of programme-based cooperation and exchange of experts. One example of joint international cooperation among Finnish organisations is provided by the agreement of cooperation that the Academy of Finland and Tekes have signed with the Japanese National Institute of Science and Technology Policy (NISTEP) to promote cooperation among experts in methods of scientific and technological foresight and evaluation as well as comparisons of those methods. The Finnish National Fund for Research and Development Sitra and VTT Finland are also involved in this cooperation.

Ministry of Trade and Industry and Ministry of Education officials are involved in intergovernmental cooperation through the OECD's Committee for Scientific and Technology Policy. Finnish representatives are active in the working groups under this committee, including the Working Party of National Experts on Science and Technology Indicators (NESTI), the Working Party on Biotechnology (WPB), the Global Science Forum (GSF) and the Working Party on Innovation and Technology Policy (TIP).

Finland's participation in UNESCO is coordinated by the Finnish National Commission for UNESCO, which assists the Ministry of Education and the Ministry for Foreign Affairs. Major intergovernmental science programmes concentrating on the natural sciences and social sciences represent an important part of UNESCO's science sector. The Academy of Finland administers Finland's participation in UNESCO science programmes. The Academy provides funding for Finnish projects in the programme and helps to organise international meetings.

One of the key functions of UNESCO is to draft international guidelines on research ethics. Ethical issues surfacing in the field of science and technology are considered, among others, by the UNESCO Biotechnology Action Council (BAC) and the World Commission on the Ethics of Scientific Knowledge and Technology. COMEST has the mission of disseminating information, experiences and ideas to decision-makers and ordinary citizens, in the recognition that open debate and discussion facilitates the forecasting and prevention of risks and threats. Finnish experts have taken part in joint seminars organised by COMEST.

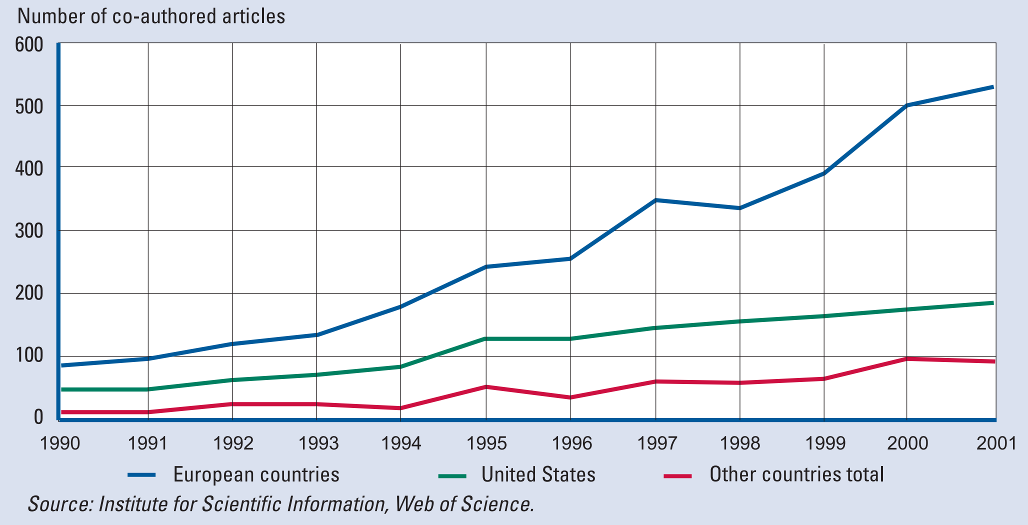
The North Atlantic Treaty Organisation's (NATO) science programme is aimed at promoting science and technology through various support mechanisms and at increasing international scientific cooperation. Finnish researchers are involved in NATO-supported research cooperation through the Euro-Atlantic Partnership Council. The Academy of Finland has national responsibility for the science programme.

One example of an international research institute is the International Institute for Applied Systems Analysis (IIASA), which not only provides a research environment but also facilitates international multidisciplinary research cooperation and networking. In 2003 this cooperation involves 16 countries. Finland's IIASA member organisation is the Finnish IIASA working group. In 2002 the Academy of Finland paid out 580,400 euros in IIASA cooperation participation fee. The Academy also supports IIASA cooperation by awarding grants for conference and researcher visits.

4.3.5 Finnish researchers' international cooperation: how it has developed

One way to study the internationalisation of Finnish research is to study the trends of international articles co-authored with colleagues from other countries. The number of articles that Finnish researchers have co-authored with foreign researchers has shown strong growth during the 1990s. According to a report by the National Science Foundation (Science… 2000), 34 per cent of the articles published by Finnish researchers in international series in 1995–1999 were published jointly with international organisations. Cooperation with EU countries increased during the latter half of the 1990s more rapidly than it did with the United States and Canada. There was most cooperation with Sweden, Great Britain, Germany, France, the Netherlands and Denmark. A survey in the field of biosciences and medicine shows that the number of joint publications between Finnish and foreign organisations increased in 1997–2001 by 50 per cent with European partners and by 25 per cent with US partners (Figure 4.1).

■ Figure 4.1. Articles co-authored by Finnish and foreign researchers in 83 biosciences and medical journals in 1990–2001.



Source: Institute for Scientific Information, Web of Science.

Participation in EU framework programmes has helped researchers establish new international contacts and increased awareness of Finnish research organisations around the world. Researchers themselves say that cooperation through the European Union has strengthened and diversified other international cooperation as well. The most important partners of Finnish university researchers come from Sweden, Great

Britain and Germany, and outside Europe from the United States. However, universities are now becoming ever more selective. The standard of research in EU programmes has not always lived up to expectations. The EU should invest more funds in long-term basic research and greater effort in enhancing the flexibility of its administrative practices. (Niskanen 2001, Hakala et al. 2002.)

4.4 Research evaluations and the use of their results

Evaluation is understood here as referring to a procedure undertaken by a science policy organisation to compare scientific research or the system underlying and steering that research against a given set of evaluation criteria for purposes of establishing its quality, impacts or some other aspect that is deemed important. As science policy tools, evaluations are intended primarily to provide assistance and guidance to decision-making: they provide a platform for social value judgements as well as learning processes (Kekäle & Lehikoinen 2000, Oksanen 2000, Valovirta 2000).

The Nordic countries are the first in Europe to have adopted evaluations in their science policy and science administration toolbox (Luukkonen 2002). Evaluations can be used in various different ways. It is very rarely that decision-making is based essentially upon information produced by evaluations. In most cases evaluations have only an indirect effect: they provide background information for decision-making purposes, open up useful new perspectives, challenge traditional ways of thinking and help find new solutions to existing problems. (Luukkonen 1997, Valovirta 2001.)

All conducted by international panels of experts, evaluations of research institutes are one example of an evaluation that can have significant and immediate impacts. For instance, following on the evaluation carried out at the National Public Health Institute, work here has concentrated on a smaller number of projects with greater social impact.

Several factors combine to determine the use value of evaluations. One of the key factors is the extent to which the evaluation ties in with the planning, preparation and implementation of science policy tools, operational steering systems and policy measures taken in other administrative branches (Boekholt et al. 2001,Virtanen 2002).

The following provides an overview of the kind of evaluations[6] that are currently employed in science policy. The most significant of these are 1) assessments of disciplines and fields of research organised by the Academy of Finland, 2) reviews of the current state and quality of scientific research in Finland and 3) technology evaluations and foresight carried out in Finland. The aim is to draw a clearer picture of the premises of evaluations, the use of their results and key problems.

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[6] Evaluations are discussed among others by Oksanen 2000, Hjelt et al. 2001, Valovirta 2001, Eerola & Väyrynen 2002. These (meta) evaluations do not systematically review the completion or attainment of different evaluation functions or objectives. In the Science and Technology Policy Council's 2003 review on Knowledge, Innovation and Internationalisation, the Ministry of Education and the Ministry of Trade and Industry are charged with the responsibility of general maintenance and development of evaluations. Public funding and research organisations, for their part, are required to monitor and evaluate science and technology development, launch studies and inquiries looking ahead to future trends in development, and promote dialogue between citizens and decision-makers.

1) *Academy of Finland assessments of disciplines and fields of research and their utilisation*

The initial impetus behind the first reviews and evaluations of scientific research in the early 1980s was provided by the growth and expansion of the university system; concerns about funding for basic research; the scarcity of international contact in Finnish research; ambitions of reunifying Finnish science following the highly politicised period of the 1970s; and the example set by Sweden. All these factors combined to create the foundation for discipline and field of research assessments.

Discipline and field of research assessments have usually been concerned to study inputs, the research process and outputs. It is impossible to lay down any detailed, unambiguous criteria as to what counts as “good research”. In practice, the scientific standards of research have been compared to the work done in the same field internationally, and the impacts of research have been weighed against the objectives set and the resources made available. The social impacts of research have received only limited attention in discipline and field of research assessments. (Oksanen 2000, Valovirta 2001.)

The results of discipline and field of research assessments have for the most part had indirect use. In some cases the evaluations have led to institutional and organisational development. For example, the problems and recommendations raised in the evaluation reports have influenced decisions to start up graduate schools, to launch research programmes or visit programmes, or to facilitate international cooperation among researchers. As far as individual researchers are concerned, evaluations have encouraged them to weigh up the premises of their work and provided arguments to support their funding applications.

Discipline and field of research assessments have had two main benefits: first, their have helped to identify weaknesses in Finnish research and the Finnish research system, and second, they have provided important opportunities for the development of evaluation practices (Helander 2002, Karjalainen 2002). One way to further strengthen those opportunities is to extend the scope of evaluation to comprise not only research but also education, to emphasise the role of self-assessment and where possible to include other elements of participatory evaluation. Other challenges for evaluation include securing the independence of experts conducting the evaluations; resolving the problem of evaluation fatigue caused by repetitive evaluations; and the need to compare inputs and outputs.

The international biotechnology evaluations of 1996 and 2002 are examples of evaluations that have led promptly to development efforts. Underlying these biotechnology evaluations is the biotechnology development programme that was launched in 1987 under the Ministry of Education. One of its outcomes has been the decision to establish biocentres in five Finnish cities. In 1996 the Academy of Finland conducted a discipline assessment commissioned by the Ministry of Education that was focused upon Finnish molecular biology and related biotechnology research.

In 2002, the Ministry of Education joined forces with other ministries and funding organisations to assess the impacts of public funding for biotechnology (Biotechnology…

2002). This was a follow-up of the evaluation carried out in 1996 and the subsequent development efforts. The emphasis on this occasion was not on the evaluation of research projects, but on the structures and impacts of research as well as on the use of research results. Action programmes have been compiled on the basis of the evaluation reports' recommendations; the first of these programmes has by now been implemented, the second is about to get under way (Biotekniikan… 2003).

2) Reviews of the state and quality of scientific research in Finland and their utilisation

Reviews of the state and quality of scientific research in Finland have become an integral part of the Academy's evaluation repertoire. Once during the three-year term of its Research Councils, the Academy presents an assessment of the current state and quality of research in Finland. These reviews have covered the resources of research, its organisational structures, processes, standards, outputs and impacts, with the specific focus varying from one review to the next. Internal quality assessment of research and the broader horizon of science policy overlap and complement each other.

The Academy's reviews have produced background information on the state of research and technology, on current challenges as well as on development efforts required, aiming this information at research funding bodies as well as science policy makers. These reviews have been cited in development work, they have been used as a statistical source as well as in organisations' own analyses. The reviews have not always singled out the responsibilities and impacts of individual agents, which has detracted somewhat from the use value of their results.

There has been some variation by fields of research and problem areas in terms of how the recommendations of these reviews have been met. For instance, the Academy's Research Council for Health observed in 2000 that most of the recommendations made in the 1997 review were met, and overall it was satisfied with the progress made (The State … 2000). Among the examples mentioned by the Council were the establishment of new graduate schools, the refocusing of doctoral training, the launch of new research programmes and collaboration with the National Technology Agency Tekes.

In their reports included in this review, all the Academy's Research Councils comment on how the recommendations made in the 2000 review have been met. Generally, it is felt that the recommendations have been met at least satisfactorily, although this does vary depending on the field or problem concerned as well as on the time spans and the bodies responsible. In the case of researcher training, for instance, there has generally been good progress in line with the recommendations. At the same time, though, the concentration of resources in certain key areas has adversely affected the development of postgraduate training in certain fields. There still remain bottlenecks in research funding, most particularly in the funding for instruments. To help alleviate these problems, the Academy of Finland will be carrying out an infrastructure programme in 2004.

3) Technology foresight and evaluation and their utilisation

In a European comparison Finnish practices of technology foresight and evaluation are still quite young and lack coherence as well as strong institutions. No resources have been allocated for purposes of broadly-based foresight and evaluation functions at the national level (Eerola & Väyrynen 2002). The Ministry of Trade and Industry project on technology visions, the VTT Finland project on energy visions and the Tekes Technology and Future project have been chiefly aimed at producing instrumental information that supports decision-making. Among the issues not covered in the analyses are the societal processes required in tackling future challenges as well as alternative values to technology. However, the criteria of foresight and evaluation have also sought to take into account premises that lie outside the realm of technology: it is precisely in this direction that international foresight and evaluation of technology is gradually moving. (Hjelt et al. 2001, Eerola & Väyrynen 2002.)

The above-mentioned Ministry of Trade and Industry and Tekes national projects had no immediate interface with decision-making. In surveys focused on specific sectors and technologies, these links with decision-making have been clearer. In an overall assessment the strength of Finnish foresight and evaluation lies in its close ties with other future-oriented activities (e.g. planning, building research and technology programmes). Foresight and evaluation are used in a variety of different ways in decision-making. One of the key challenges for foresight and evaluation is to increase the impacts of operations. It has also been felt that more attention needs to be given to inspiring public debate. (Eerola & Väyrynen 2002.)

The following three points summarise the main concerns with regard to the use of evaluation results:

1) The impacts of evaluations are indirect and multilayered. This is also seen in the assessments of disciplines and fields of research organised by the Academy of Finland, the Academy's reviews of the current state and quality of scientific research in Finland, as well as in the technology foresights and evaluations organised within the administrative branch under the Ministry of Trade and Industry. Evaluations are an integral part of the science and technology system's pursuit of self-understanding in which different actors aim to find their roles and define their limits vis-à-vis the science community and society (Hemlin & Wenneberg 2002). The impact of evaluations extends from decision-makers to disciplines, individual fields of research and researchers.

2) Evaluations have led to concrete development and corrective measures or contributed to those measures. These include the establishment of new graduate schools and the refocusing of education, new research programmes and programme cooperation with other funding bodies, facilitating international cooperation and resolving specific problems with funding.

3) Many impacts of evaluations are not seen until in the longer term. As far as science policy is concerned the most important choice has to do with whether evaluations are used and processed primarily as a tool of control and coordination or as a tool

> for developing operations in the science community. The latter, if conducted as a bottom-up evaluation procedure, may support supervision and coordination, but on the other hand it may also prove to be a complication. Secondly, bottom-up evaluation procedures (e.g. participant evaluation) have been quite rare, both at the national and international level (Diez 2002). However, the current review is one instance where steps have been taken in this direction: researchers have been given the opportunity to assess the impacts of their own work and the manifestations of those impacts.

Organised by the OECD or the Finnish Higher Education Evaluation Council, university evaluations at Jyväskylä, Helsinki and Oulu have applied a more diversified range of criteria and at once provided opportunities for a new kind of development effort. One of the positive consequences of the diversification of evaluation and its criteria is that the actors involved have begun to work more closely with one another. One example is provided by the increased cooperation between the Academy of Finland and Tekes. Evaluations by universities themselves provide useful examples of diverse evaluations with diverse impacts (Mustajoki 2002).

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Contents

5 Scientific and social impact of research

5.1 Scientific publishing in Finland: an international comparison

This section looks at the number of publications by Finnish researchers and the number of citations received by these publications, and compares these statistics with corresponding figures for other countries. The number of citations received by Finnish publications are related to total publication numbers and compared to the figures for different countries. The purpose is to see how Finnish research compares internationally with respect to its scientific outcomes and impacts and visibility in the 1990s and early 2000s.

5.1.1 Evaluation of scientific outcomes and impacts in the light of publication numbers and citations

Science administration and research organisations have begun increasingly to use bibliometric methods for purposes of evaluating scientific outcomes and impacts. The US-based Institute for Scientific Information (ISI) maintains widely used bibliometric databases, one of which will be used here: the National Science Indicators (NSI) database.[1] With certain reservations,[2] publications and the citations they receive can be regarded as measures of the outcome of scientific activity. The use of the NSI database is limited, among other things, by the overrepresentation of American and English-language scientific journals. This is particularly the case in the social sciences and humanities.

Analysis of publication numbers and citations is best suited for purposes of assessing scientific publishing within an individual country or internationally, or for an examination of publishing within a certain field of research. It is also useful as a complement to peer evaluations by experts when comparing the output of organisations or research groups within a certain field of research.

Bibliometric indicators have limited utility. For instance, there is no point comparing the standards of research in different fields of research because they may differ widely in terms of how quickly they respond to new literature, in terms of the life-span of publications and in terms of publishing and citation practices. In medicine and molecular biology, research results may become outdated within a matter of years, in the social sciences many studies are still cited decades after their publication.

5.1.2 Publishing in Finland

The Finnish publishing profile

The total number of Finnish publications in the scientific journals included in the NSI database increased rapidly throughout the 1990s from some 4,000 publications in

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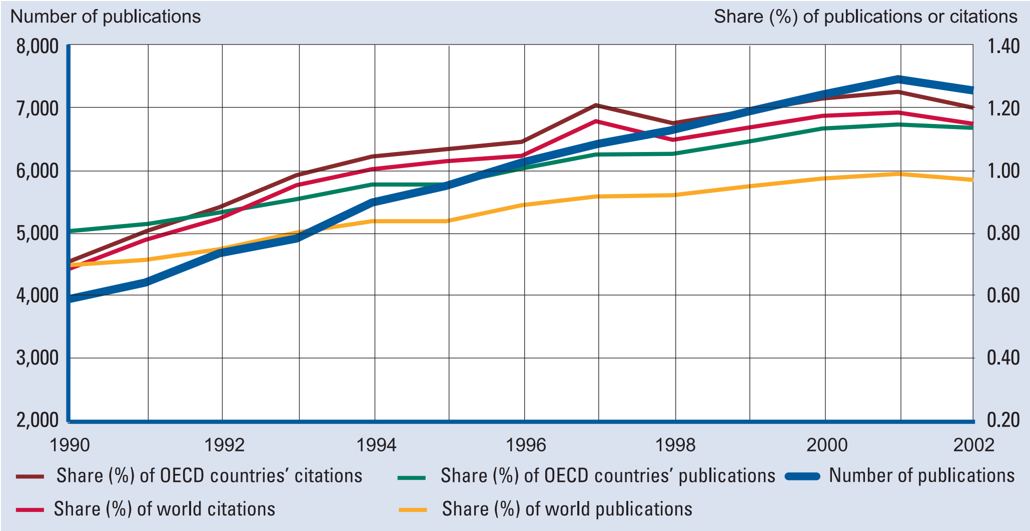
[1] The National Science Indicators 1981–2002 (NSI) database is described in Appendix 1.

[2] For more details, see e.g. Husso, Kai & Maija Miettinen (2000): Scientific research and bibliometric indicators. Appendix 1 in The State and Quality of Scientific Research in Finland. Publications of the Academy of Finland 7/00.

1990 to almost 7,300 in 2002 (Figure 5.1). The number of Finnish publications as a proportion of all publications in the OECD countries has also grown, rising from 0.81 per cent in 1990 to 1.14 per cent in 2002; the one per cent mark was reached in 1996. Finland's share of OECD citations has likewise increased, rising from 0.72 per cent in 1990 to 1.20 per cent in 2002. Here the one per cent mark was reached in 1994.

Figure 5.1. Number of Finnish publications and number of Finnish publications and citations as a proportion of OECD and world publications and citations in 1990–2002.



Source: Institute for Scientific Information, NSI 1981–2002.

Table 5.1 compares the development of Finnish publication and citation numbers during three five-year periods from the 1980s through to the early 2000s. This analysis irons out year-on-year fluctuations. In 1998–2002, Finnish researchers produced 35,550 publications, accounting for 1.11 per cent of all publications in the OECD countries. The number of publications was 52 per cent up on the figure for the period from 1990 to 1994.

Finnish publications released in 1998–2002 received almost 174,000 citations during the same period. This was 126 per cent more than during the period 1990–1994. In 1998–2002, Finland's share of all OECD citations was 1.19 per cent. The share of citations showed relatively rapid growth in the 1990s.

The impact factor[3] and relative citation impact,[4] which provide rough measures of the visibility of research and its scientific impact, have also developed favourably. During the period from 1990 to 1994 the impact factor was 3.3, from 1998 to 2002 the figure

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[3] Impact factor describes the average number of citations received by publications in each country.

[4] Relative citation impact describes how many per cent more or less citations the publications of the country concerned have received in comparison with the average for the group of countries with which it is being compared (index = 1).

was 4.9. In the 1980s and early 1990s Finland's relative citation impact was weaker than the average for the OECD countries (index = 1), but from 1998 to 2002 the number of citations received by Finnish publications was seven per cent higher (relative citation impact = 1.07) than the average figure for publications in the OECD countries.

■ Table 5.1. Finnish scientific publications and citations received by these publications: numbers, trends and shares of OECD publications and citations in 1982–1986, 1990–1994 and 1998–2002.

	1982–1986	1990–1994	1998–2002
PUBLICATIONS			
Number of publications	16,024	23,345	35,550
% change in number of publications to previous period under review	–	46	52
% share of OECD countries' publications	0.77	0.88	1.11
CITATIONS			
Number of citations	44,392	76,748	173,710
% change in number of citations to previous period under review	–	73	126
% share of OECD countries' citations	0.68	0.79	1.19
Impact factor[a]	2.77	3.29	4.89
Relative citation impact[b]	0.89	0.90	1.07

[a] Impact factor = number of citations / number of publications.

[b] Relative citation impact = impact factor for Finland / impact factor for OECD. (E.g. in 1998–2002, the impact factor for Finland was 4.89 and for OECD 4.57, i.e. the index value is 4.89 / 4.57 = 1.07.)

Source: Institute for Scientific Information, NSI 1981–2002.

Maintained by the Ministry of Education, the KOTA database provides systematic information on publishing by Finnish university researchers (Table 5.2). In 2002 the total number of publications was 21,710. Almost 70 per cent (15,000) of these publications were international, with 9,703 published in foreign peer-reviewed scientific journals. (The NSI database covers 7,274 publications, or 75 per cent of the number reported in KOTA.) The number of publications by Finnish university researchers in international peer-reviewed journals increased by 15 per cent from 1998 to 2002. During the same period the total volume of international publishing by university researchers increased by 16 per cent, while domestic publishing decreased by 10 per cent.

Figures from both the KOTA and the NSI database suggest that during the 1990s and early 2000s, Finnish researchers published far more often than previously on international fora. Raising the quality standards of publishing and increasing its international visibility have been among the key objectives of Finnish science policy, so in the light of the information above it seems that those objectives have been well met.

International publishing in Finland by major fields of science [5]

According to the NSI database the natural sciences and the medical sciences together accounted for 84 per cent of all academic publishing in Finland in 2002 (Table 5.3). The figures for other major fields of science (hereinafter "fields of science") were

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[5] Scientific publishing is also described in the reviews of the respective Research Councils.

Table 5.2. Publishing* by university researchers in 1994, 1998 and 2002.

Publishing by university researchers	Number of publications			% change	
	1994	1998	2002	1998–2002	1994–2002
Finnish publications total	6,974	7,505	6,719	–10	–4
Publications in Finnish refereed journals	2,302	1,777	2,044	15	–11
Publications in Finnish edited volumes or printed conference proceedings	3,248	4,569	3,823	–16	18
Finnish monographs	654	770	524	–32	–20
Publications in university series	770	389	328	–16	–57
Foreign publications total	11,046	12,969	14,991	16	36
Publications in foreign refereed journals	7,536	8,458	9,703	15	29
Publications in foreign edited volumes or printed conference proceedings	3,388	4,348	5,125	18	51
Foreign monographs	122	163	163	0	34
All publications total	18,020	20,474	21,710	6	20

* According to publications indexed in the Ministry of Education KOTA database. Data available from 1994 onwards.

Source: KOTA database, Ministry of Education.

markedly lower: engineering and technology accounted for around eight per cent, the social sciences for less than five per cent and agricultural sciences for 2.5 per cent. The humanities accounted for 0.6 per cent of Finnish publications indexed in the NSI database. There have been some minor shifts in the relative shares of different fields of science in 1990–2002. The figures for the natural sciences, engineering and technology, and social sciences have increased, whereas those for medical sciences, agricultural sciences and the humanities have declined.

The periods of most intense internationalisation have not necessarily coincided in different fields of science. In the natural sciences, engineering and technology, and medical sciences, the number of international publications increased most sharply from 1990 to 1994. Publication volumes in the agricultural sciences, the social sciences and the humanities, for their part, showed the strongest growth from 1994 to 1998. During the period from 1998 to 2002, the rate of increase has slowed down in all fields of science with the exception of engineering and technology.

Finland's share of OECD publications increased in all fields of science except the humanities from 1990 to 2002. In 2002, Finnish publications in the agricultural sciences accounted for 1.4 per cent of all OECD publications in this field. Finnish publications also accounted for more than one per cent of the total volume of OECD publications in their respective fields in medical sciences (1.3%), natural sciences (1.2%) and engineering and technology (1.0%). From 1990 to 2002, the sharpest increase in the fraction of Finnish publications at 0.5 percentage points was recorded in the natural sciences. During the same period the share of publications in engineering and technology, agricultural sciences and the social sciences increased by 0.4 percentage points, while the figure for medical sciences was 0.1 percentage point. In all years under review Finnish publications in the humanities accounted for 0.3 per cent of OECD publishing.

Table 5.3. Profile of Finnish publishing by major field of science in 1990, 1994, 1998 and 2002.

Major field of science / Year	1990	1994	1998	2002	% change 1990–2002
Natural sciences					
Number of publications in Finland	1,813	2,617	3,280	3,955	118
Share of publications in Finland %	41.4	42.7	43.9	48.5	
% change in no. of publications to previous year under review	–	44	25	21	
Number of publications in OECD countries	258,425	299,606	325,789	335,814	30
Finland's share of publications in OECD countries (%)	0.7	0.9	1.0	1.2	
Relative publication index [a]	0.86	0.89	0.93	1.01	
Engineering and technology					
Number of publications in Finland	253	467	541	665	163
Share of publications in Finland %	5.8	7.6	7.2	8.2	
% change in no. of publications to previous year under review	–	85	16	23	
Number of publications in OECD countries	45,428	56,365	65,257	64,398	42
Finland's share of publications in OECD countries (%)	0.6	0.8	0.8	1.0	
Relative publication index [a]	0.68	0.84	0.76	0.89	
Medical sciences					
Number of publications in Finland	1,956	2,627	2,985	2,880	47
Share of publications in Finland %	44.7	42.9	40.0	35.3	
% change in no. of publications to previous year under review	–	34	14	–4	
Number of publications in OECD countries	162,579	190,224	214,618	215,799	33
Finland's share of publications in OECD countries (%)	1.2	1.4	1.4	1.3	
Relative publication index [a]	1.48	1.40	1.28	1.15	
Agricultural sciences					
Number of publications in Finland	129	137	198	201	56
Share of publications in Finland %	2.9	2.2	2.7	2.5	
% change in no. of publications to previous year under review	–	6	45	2	
Number of publications in OECD countries	12,668	12,837	14,275	14,745	16
Finland's share of publications in OECD countries (%)	1.0	1.1	1.4	1.4	
Relative publication index [a]	1.25	1.08	1.28	1.17	
Social sciences					
Number of publications in Finland	172	236	414	398	131
Share of publications in Finland %	3.9	3.9	5.5	4.9	
% change in no. of publications to previous year under review	–	37	75	–4	
Number of publications in OECD countries	42,773	46,105	50,858	53,023	24
Finland's share of publications in OECD countries (%)	0.4	0.5	0.8	0.8	
Relative publication index [a]	0.49	0.52	0.75	0.65	
Humanities					
Number of publications in Finland	51	44	50	51	0
Share of publications in Finland %	1.2	0.7	0.7	0.6	
% change in no. of publications to previous year under review	–	–14	14	2	
Number of publications in OECD countries	14,754	16,186	16,766	16,586	12
Finland's share of publications in OECD countries (%)	0.3	0.3	0.3	0.3	
Relative publication index [a]	0.42	0.28	0.27	0.26	
TOTAL					
Total number of publications in Finland[b]	4,374	6,128	7,468	8,150	
Number of Finnish publications in the database	3,977	5,486	6,637	7,274	

[a] Relative publication index = Number of publications in the field of science as a proportion of all publications in Finland / number of publications in the field of science as a proportion of all publications in OECD countries. The index value of natural sciences in 2002, for example, was 1.01, i.e. natural sciences accounted for one per cent more of all publications in Finland than they did in the OECD countries on average. In engineering and technology, on the other hand, Finns published 11 per cent (index 0.89) less than the OECD average.

[b] The note is due to the qualities of the NSI database. When publication and citation data are first searched by individual field of research and then combined into larger groups, some publications may be included more than once. Therefore the total annual publication numbers that are obtained by adding together the number of publications from all six fields of science are about 10–13 per cent higher than those obtained in an overall database search.

Source: Institute for Scientific Information, NSI 1981–2002.

Medical sciences as well as agricultural sciences are the most prominent fields of science in the Finnish publishing profile. At the beginning of the 2000s that profile has a broader and a healthier foundation in that the share of medical sciences has declined at the same time as that of other fields of science has increased. In 2002, the number of publications in medical sciences as a proportion of all publications in Finland was 15 per cent higher than the corresponding fraction of this field among all OECD publications (relative publication index = 1.15). In agricultural sciences, the corresponding figure was 17 per cent higher. In 2002, the fraction of humanities publications among all publications in Finland was 74 per cent lower and that of social science publications 35 per cent lower than their corresponding shares of OECD publications on average.

The relatively low volume of publications in the humanities and social sciences as a proportion of all OECD publications and their low relative publication index are explained in part by certain features of the NSI database[6]. Although Finland does not seem to have a very strong position in these fields of science in the light of the indicators just mentioned, these fields have nonetheless fared extremely well in a comparison of their relative citation impact with other OECD countries (see Table 5.10).

Figures from the KOTA database indicate that publications by Finnish university researchers in international peer-reviewed scientific journals increased in all fields of science from 1998 to 2002 (Table 5.4). The largest number of publications in international peer-reviewed journals was recorded in the medical sciences at 3,872 (2002) and the lowest in the humanities at 354 (2002). The number of publications increased most in engineering and technology, by 66 per cent, followed by the humanities at 48 per cent. Publication volumes in the social sciences and in the agricultural sciences increased by one-fifth. In the natural sciences and the medical sciences, the figure was up by around ten per cent. By contrast publishing in the Finnish language declined from 1998 to 2002 in almost all fields of science. The significance of domestic publishing on scientific fora varies between different fields of science. It is particularly important in many disciplines in the humanities and social sciences[7].

5.1.3 International comparison of publishing

Publication and citation numbers and trends

In 2002, a total of some 746,500 titles were published in the scientific journals indexed in the NSI database. Finnish researchers accounted for 7,274 of these titles, or 0.97 per cent of all publications. The OECD countries published a total of some 640,600 publications, or 86 per cent of the total. The share of publications from the EU countries (273,216) was 37 per cent. Among the OECD countries Finland ranked eighteenth, among the EU countries tenth in this comparison.

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[6] The predominance of English-speaking countries and the United States in particular is most pronounced in the social sciences and humanities.

[7] The distinctive features of publishing in the social sciences and humanities are described in more detail in the review by the Research Council for Culture and Society.

Table 5.4. Publications* by university researchers by major field of science in 1994, 1998 and 2002.

Natural sciences	1994	1998	2002	% change	
				1998–2002	1994–2002
Finnish publications total	618	467	338	–28	–45
Foreign publications total	2,351	2,761	2,936	6	25
of which publications in foreign refereed journals	1,756	2,102	2,303	10	31
Engineering and technology	1994	1998	2002	% change	
				1998–2002	1994–2002
Finnish publications total	1,415	955	808	–15	–43
Foreign publications total	2,192	2,709	3,906	44	78
of which publications in foreign refereed journals	792	791	1,313	66	66
Medical sciences	1994	1998	2002	% change	
				1998–2002	1994–2002
Finnish publications total	1,601	1,317	1,450	10	–9
Foreign publications total	4,082	3,894	4,168	7	2
of which publications in foreign refereed journals	3,663	3,502	3,872	11	6
Agricultural sciences	1994	1998	2002	% change	
				1998–2002	1994–2002
Finnish publications total	153	293	232	–21	52
Foreign publications total	314	435	497	14	58
of which publications in foreign refereed journals	208	307	369	20	77
Social sciences	1994	1998	2002	% change	
				1998–2002	1994–2002
Finnish publications total	1,985	2,395	2,252	–6	13
Foreign publications total	1,059	1,468	1,918	31	81
of which publications in foreign refereed journals	502	745	911	22	81
Humanities	1994	1998	2002	% change	
				1998–2002	1994–2002
Finnish publications total	886	1,606	1,318	–18	49
Foreign publications total	488	793	841	6	72
of which publications in foreign refereed journals	183	239	354	48	93

* According to publications indexed in the Ministry of Education KOTA database. Data available from 1994 onwards. The subject category of a small part of the publications is classified as unknown.

Source: KOTA database, Ministry of Education.

In 1998–2002, the number of publications by Finnish researchers increased on average by 2.3 per cent a year: this was the fifteenth highest figure in the OECD group and the eighth highest in the EU (Table 5.5). In 1990–1994, the number of publications by Finnish researchers increased on average by 8.4 per cent a year. At that time Finland ranked ninth among the OECD countries and fifth in the EU group. In the 1990s the number of publications from so-called emerging economies and countries with less advanced research infrastructures showed faster growth than in Finland. Since 1990–1994 when publishing in the OECD countries showed an average annual growth rate of 3.7 per cent, the figure has dropped to an annual rate of 0.4 per cent in 1998–2002. Just one country recorded a faster growth rate in 1998–2002 than in 1990–1994, i.e. Poland.

Table 5.5. Overall change in OECD countries' publication numbers and average annual rate of change in 1990–1994, 1998–2002 and 1990–2002.

OECD countries	1990	1994	% change in 1990–1994	Average % change per year	1998	2002	% change in 1998–2002	Average % change per year	% change in 1990–2002	Average % change per year
Australia	13,296	17,054	28	6.4	20,560	21,498	5	1.1	62	4.1
Austria	3,647	4,689	29	6.5	6,492	7,258	12	2.8	99	5.9
Belgium	5,870	7,588	29	6.6	9,508	10,280	8	2.0	75	4.8
Canada	28,979	33,736	16	3.9	32,784	33,523	2	0.6	16	1.2
Czech Republic	–	3,279	–	–	3,903	4,527	16	3.8	–	–
Denmark	4,718	6,251	32	7.3	7,464	7,576	2	0.4	61	4.0
Finland	3,977	5,486	38	8.4	6,637	7,274	10	2.3	83	5.1
France	30,547	39,326	29	6.5	46,303	46,051	–1	–0.1	51	3.5
Germany	43,068	50,729	18	4.2	63,825	64,447	1	0.2	50	3.4
Greece	1,932	3,115	61	12.7	4,283	5,375	25	5.8	178	8.9
Hungary	2,488	2,878	16	3.7	3,512	3,927	12	2.8	58	3.9
Iceland	146	205	40	8.9	312	363	16	3.9	149	7.9
Ireland	1,398	1,830	31	7.0	2,550	2,861	12	2.9	105	6.1
Italy	16,622	23,201	40	8.7	28,958	31,866	10	2.4	92	5.6
Japan	44,182	55,836	26	6.0	67,078	69,290	3	0.8	57	3.8
Luxembourg	36	49	36	8.0	81	94	16	3.8	161	8.3
Mexico	1,547	2,543	64	13.2	4,101	5,213	27	6.2	237	10.6
Netherlands	12,676	16,090	27	6.1	18,425	19,063	3	0.9	50	3.4
New Zealand	2,856	3,447	21	4.8	4,300	4,303	0.1	0.02	51	3.5
Norway	3,072	3,901	27	6.2	4,734	4,981	5	1.3	62	4.1
Poland	5,452	6,512	19	4.5	8,066	10,085	25	5.7	85	5.2
Portugal	839	1,379	64	13.2	2,306	3,597	56	11.8	329	12.8
Slovakia	–	1,827	–	–	2,011	1,777	–12	–3.0	–	–
South Korea	1,594	4,059	155	26.3	9,684	15,705	62	12.8	885	20.9
Spain	9,336	14,479	55	11.6	19,870	23,382	18	4.2	150	7.9
Sweden	10,060	12,144	21	4.8	14,464	14,942	3	0.8	49	3.3
Switzerland	8,191	11,261	37	8.3	13,147	13,320	1	0.3	63	4.1
Turkey	944	2,013	113	20.8	4,057	7,771	92	17.6	723	19.1
United Kingdom	48,441	60,243	24	5.6	67,766	67,478	–0.4	–0.1	39	2.8
United States	223,345	246,629	10	2.5	252,563	253,215	0.3	0.1	13	1.0
European Union*	182,308	226,946	24	5.6	268,127	273,216	2	0.5	50	3.4
OECD*	493,811	571,763	16	3.7	630,465	640,588	2	0.4	30	2.2

* The note is due to the qualities of the NSI database. A joint publication by authors from different countries is counted as one publication in the statistics for each country. The NSI database eliminates some of this overlap, so the total number of publications obtained for all EU and OECD countries is lower than the total figures for individual EU countries or individual OECD countries.

Source: Institute for Scientific Information, NSI 1981–2002.

The United States produced the largest number of publications, some 253,200 in 2002, or almost 40 per cent of all OECD publications (Table 5.6). Other countries with shares in excess of ten per cent were Japan, the United Kingdom and Germany. Together, these four countries accounted for 71 per cent of all OECD publications in 2002; in 1998 the corresponding proportion was 77 per cent. The next highest proportions were recorded by France (7%) and Canada (5%). The shares of both the United States and Canada

Table 5.6. OECD countries' shares (%) of all scientific publications in OECD countries in 1990–2002.

OECD countries	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Australia	2.69	2.75	2.79	2.88	2.98	3.07	3.12	3.20	3.26	3.30	3.25	3.31	3.36
Austria	0.74	0.74	0.78	0.81	0.82	0.90	0.91	1.01	1.03	1.05	1.07	1.14	1.13
Belgium	1.19	1.19	1.24	1.25	1.33	1.38	1.42	1.45	1.51	1.54	1.53	1.55	1.60
Canada	5.87	5.95	6.01	5.97	5.90	5.77	5.67	5.45	5.20	5.29	5.21	5.12	5.23
Czech Republic	–	–	–	–	0.57	0.55	0.61	0.60	0.62	0.62	0.63	0.67	0.71
Denmark	0.96	0.97	1.05	1.03	1.09	1.08	1.09	1.12	1.18	1.17	1.20	1.20	1.18
Finland	0.81	0.83	0.87	0.91	0.96	0.96	1.01	1.05	1.05	1.09	1.13	1.15	1.14
France	6.19	6.31	6.62	6.66	6.88	6.91	7.02	7.26	7.34	7.40	7.33	7.32	7.19
Germany	8.72	8.83	8.79	8.72	8.87	9.02	9.30	9.80	10.12	10.07	10.12	10.15	10.06
Greece	0.39	0.45	0.47	0.48	0.54	0.55	0.60	0.63	0.68	0.68	0.72	0.81	0.84
Hungary	0.50	0.54	0.53	0.52	0.50	0.52	0.51	0.54	0.56	0.59	0.60	0.63	0.61
Iceland	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Ireland	0.28	0.28	0.29	0.31	0.32	0.32	0.36	0.37	0.40	0.40	0.42	0.42	0.45
Italy	3.37	3.56	3.77	3.82	4.06	4.14	4.38	4.44	4.59	4.62	4.69	4.87	4.97
Japan	8.95	9.02	9.58	9.56	9.77	9.79	10.11	10.16	10.64	10.78	10.74	10.86	10.82
Luxembourg	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01
Mexico	0.31	0.33	0.38	0.41	0.44	0.49	0.55	0.59	0.65	0.71	0.73	0.77	0.81
Netherlands	2.57	2.55	2.70	2.76	2.81	2.83	2.87	2.97	2.92	2.87	2.93	2.92	2.98
New Zealand	0.58	0.55	0.56	0.56	0.60	0.60	0.64	0.65	0.68	0.67	0.69	0.67	0.67
Norway	0.62	0.62	0.67	0.66	0.68	0.72	0.72	0.74	0.75	0.76	0.75	0.77	0.78
Poland	1.10	1.10	1.12	1.10	1.14	1.22	1.24	1.21	1.28	1.35	1.41	1.51	1.57
Portugal	0.17	0.18	0.21	0.22	0.24	0.27	0.30	0.34	0.37	0.45	0.47	0.52	0.56
Slovakia	–	–	–	–	0.32	0.33	0.33	0.31	0.32	0.30	0.29	0.28	0.28
South Korea	0.32	0.38	0.46	0.56	0.71	0.90	1.06	1.29	1.54	1.74	1.94	2.26	2.45
Spain	1.89	2.01	2.32	2.43	2.53	2.62	2.83	3.05	3.15	3.29	3.35	3.49	3.65
Sweden	2.04	2.01	2.01	2.10	2.12	2.14	2.24	2.26	2.29	2.31	2.28	2.37	2.33
Switzerland	1.66	1.75	1.84	1.91	1.97	1.93	1.95	2.07	2.09	2.15	2.16	2.08	2.08
Turkey	0.19	0.23	0.26	0.30	0.35	0.40	0.52	0.57	0.64	0.74	0.78	0.93	1.21
United Kingdom	9.81	9.92	10.18	10.20	10.54	10.63	10.84	10.59	10.75	10.85	11.16	10.75	10.53
United States	45.23	45.66	44.58	44.41	43.13	42.88	41.65	41.19	40.06	39.65	39.54	39.59	39.53
EU countries	36.92	37.34	38.27	38.57	39.69	40.07	41.04	41.83	42.53	42.69	42.96	42.90	42.65
OECD publications	493,811	511,364	543,420	541,170	571,763	600,938	607,504	609,624	630,465	638,978	635,246	650,853	640,588

Source: Institute for Scientific Information, NSI 1981–2002.

have declined during the 1990s and early part of the 2000s. In 2002 Finland accounted for 1.14 per cent of all OECD publications (1998: 1.05%).

Publication numbers relative to population give some indication of the output of research relative to the size of the nation. In 1990, Finland had the ninth highest per capita publication rate in the OECD countries; in 1994 Finland ranked fifth and in 1998 and 2002 fourth (Table 5.7). Switzerland, Sweden and Denmark were in relative terms the most productive countries in 1990–2002. However, the number of publications released is just one measure of scientific activity: not all of that activity is geared primarily to high visibility on international fora. Publication numbers can be compared not only to population numbers, but also to such indicators as number of R&D personnel and GDP. However, the efficiency of different countries' research systems cannot be compared simply on the basis of bibliometric analyses, which can only serve as tentative indicators.

In an examination of total *citation* numbers and citation shares we need to bear in mind that the information in the database is complemented each year with data from previous years. However, on the basis of the total number of citations it is possible to calculate citation shares for individual countries from the citations received by all publications in OECD countries[8] and then to compare these sets of figures (Table 5.8). In 2002 the United States accounted for 52 per cent of all citations received by OECD publications. The next largest shares were recorded for the United Kingdom (13%), Germany (12%) and Japan (9%). The US share has declined to some extent in 1990–2002. The two countries showing the strongest growth are South Korea and Turkey.

The number of citations received by Finnish publications as a proportion of all OECD citations increased from 0.72 per cent in 1990 to 1.21 per cent in 1997. In 1997–2002, the figure has varied between 1.15 and 1.25. Since 1994 Finland's share of all OECD citations has been in excess of one per cent. Finland's share of OECD citations was 17th highest in 2002, while the country ranked fifteenth throughout the 1990s.

Figure 5.2 shows how different OECD countries' shares of all OECD publications and citations have developed from the early 1990s through to the early 2000s. The figure indicates for each country the percentage change of these shares between 1990–1992 and 2000–2002. In the countries above the regression line, the increase in the proportion of citations has on average been faster, in the countries below the line the increase has been slower than might be assumed on the basis of the change in publication shares and in comparison with other OECD countries.

There are marked country differences in the trends for publication and citation shares. Finland belongs to the group of countries where the relative increase in the citation share has on average been slower than might be presumed on the basis of the trends in publication shares and in comparison with other OECD countries. In a comparison with other OECD countries, Finland lies slightly below the regression line. In other

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[8] Citations may accrue unevenly to publications from different countries. Therefore the country citation shares that are calculated on the basis of the total counts may change in the future.

Table 5.7. Publication numbers in OECD countries per 10,000 population* in 1990, 1994, 1998 and 2002. The countries are rank-ordered according to relative publication numbers in 2002.

OECD countries	1990	1994	1998	2002	% change 1990–2002
Switzerland	12.2	16.1	18.5	18.4	51
Sweden	11.8	13.8	16.3	16.8	43
Denmark	9.2	12.0	14.1	14.1	54
Finland	8.0	10.8	12.9	14.0	76
Iceland	5.7	7.7	11.4	12.7	122
Netherlands	8.5	10.5	11.7	11.9	40
United Kingdom	8.4	10.3	11.4	11.3	34
New Zealand	8.5	9.6	11.3	11.2	32
Norway	7.2	9.0	10.7	11.0	52
Australia	7.7	9.5	10.9	11.0	42
Canada	10.5	11.6	10.8	10.8	3
Belgium	5.9	7.5	9.3	10.0	70
Austria	4.7	5.8	8.0	8.9	89
United States	8.9	9.5	9.3	8.9	–1
Germany	6.8	6.2	7.8	7.8	15
France	5.3	6.6	7.7	7.6	44
Ireland	4.0	5.1	6.9	7.5	87
Spain	2.4	3.7	5.0	5.8	142
Italy	2.9	4.1	5.0	5.5	88
Japan	3.6	4.5	5.3	5.4	52
Greece	1.9	3.0	4.1	4.9	158
Czech Republic	–	3.2	3.8	4.4	–
Hungary	2.4	2.8	3.5	3.9	64
Portugal	0.8	1.4	2.3	3.6	322
South Korea	0.4	0.9	2.1	3.3	792
Slovakia	–	3.4	3.7	3.3	–
Poland	1.4	1.7	2.1	2.6	82
Luxembourg	0.9	1.2	1.9	2.1	125
Turkey	0.2	0.3	0.6	1.1	574
Mexico	0.2	0.3	0.4	0.5	176
European Union	5.2	6.1	7.1	7.2	38
OECD	5.9	5.9	5.7	5.6	–4

* Latest population statistics available for 2001, from the United Kingdom for 2000.

Sources: Institute for Scientific Information, NSI 1981–2002; OECD, Main Science and Technology Indicators 2002/2.

words, Finland's international publishing activity has developed somewhat more favourably than the international visibility and impact of scientific research activity. Other countries in this same category include the United Kingdom, Japan, France and Sweden.

In Spain, Germany and Poland, for instance, the relative increase in the citation share has on average been faster than one might assume on the basis of the change in publishing shares and in comparison with other OECD countries. Canada and the

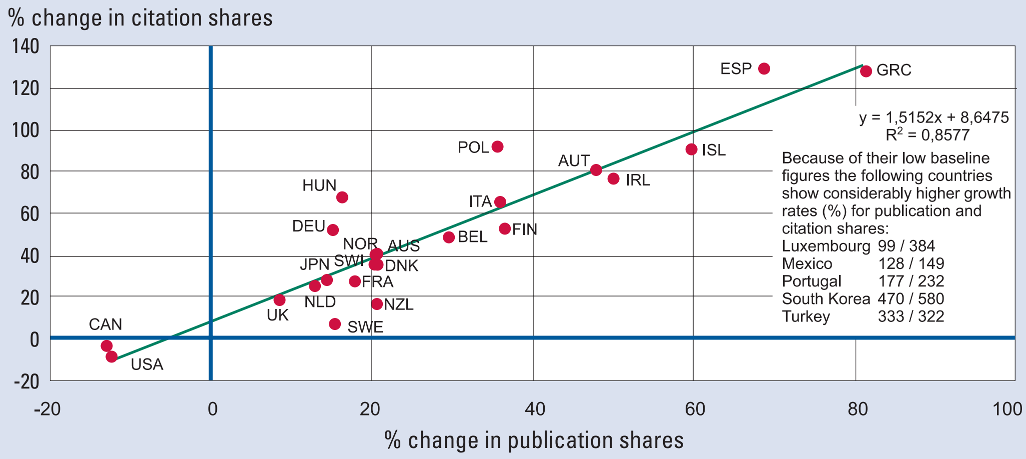
Table 5.8. OECD countries’ shares (%) of total citations to OECD publications in 1990–2002.

OECD countries	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Australia	2.25	2.36	2.42	2.52	2.64	2.79	2.83	2.81	3.02	3.04	3.06	3.22	3.29
Austria	0.59	0.64	0.74	0.75	0.76	0.84	0.88	0.99	1.00	1.08	1.10	1.19	1.27
Belgium	1.09	1.12	1.23	1.27	1.41	1.48	1.52	1.58	1.59	1.70	1.62	1.73	1.76
Canada	5.45	5.62	5.95	5.91	5.84	5.72	5.89	5.65	5.57	5.51	5.50	5.37	5.61
Czech Republic	–	–	–	–	0.26	0.28	0.31	0.32	0.34	0.37	0.40	0.44	0.49
Denmark	1.11	1.14	1.15	1.26	1.27	1.27	1.24	1.35	1.41	1.42	1.45	1.56	1.57
Finland	0.72	0.81	0.88	0.99	1.05	1.07	1.09	1.21	1.15	1.19	1.23	1.25	1.20
France	5.42	5.80	5.98	6.23	6.53	6.56	6.86	7.09	7.32	7.16	7.31	7.49	7.28
Germany	7.42	7.47	7.78	8.27	8.67	8.82	9.53	9.89	10.53	10.77	10.99	11.44	11.92
Greece	0.21	0.22	0.25	0.26	0.29	0.34	0.38	0.38	0.42	0.42	0.52	0.50	0.52
Hungary	0.25	0.30	0.33	0.32	0.33	0.31	0.33	0.35	0.38	0.42	0.44	0.49	0.54
Iceland	0.03	0.03	0.04	0.06	0.04	0.06	0.05	0.06	0.05	0.06	0.06	0.06	0.07
Ireland	0.20	0.21	0.23	0.22	0.25	0.24	0.27	0.34	0.36	0.40	0.35	0.37	0.41
Italy	2.67	3.06	3.23	3.38	3.76	3.85	4.14	4.30	4.67	4.72	4.78	5.02	5.03
Japan	6.97	7.12	7.64	7.46	7.73	7.78	8.02	8.38	8.85	9.01	9.24	9.61	8.91
Luxembourg	0.001	0.002	0.004	0.004	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mexico	0.17	0.17	0.22	0.23	0.24	0.28	0.31	0.34	0.36	0.39	0.44	0.44	0.50
Netherlands	2.81	2.90	3.01	3.17	3.26	3.41	3.36	3.65	3.56	3.64	3.63	3.66	3.69
New Zealand	0.48	0.41	0.46	0.46	0.48	0.50	0.53	0.54	0.53	0.53	0.55	0.49	0.54
Norway	0.55	0.54	0.61	0.60	0.62	0.68	0.63	0.70	0.73	0.71	0.74	0.74	0.88
Poland	0.46	0.52	0.52	0.50	0.57	0.64	0.64	0.65	0.70	0.78	0.87	0.95	1.05
Portugal	0.10	0.11	0.15	0.15	0.17	0.18	0.20	0.24	0.27	0.34	0.36	0.46	0.41
Slovakia	–	–	–	–	0.09	0.12	0.13	0.13	0.14	0.14	0.14	0.16	0.16
South Korea	0.16	0.20	0.23	0.29	0.38	0.45	0.56	0.70	0.82	1.02	1.23	1.37	1.40
Spain	1.17	1.27	1.58	1.74	1.92	1.96	2.28	2.43	2.59	2.79	3.03	3.05	3.15
Sweden	2.38	2.46	2.42	2.45	2.50	2.49	2.61	2.63	2.63	2.58	2.59	2.65	2.54
Switzerland	2.19	2.39	2.45	2.60	2.84	2.71	2.79	3.11	3.01	3.09	3.14	3.20	3.18
Turkey	0.07	0.08	0.11	0.12	0.15	0.17	0.21	0.23	0.26	0.29	0.32	0.39	0.38
United Kingdom	10.51	10.41	10.88	10.96	11.16	11.36	11.41	11.73	11.87	11.94	12.36	12.27	13.10
United States	57.13	57.03	56.21	55.51	54.93	54.55	53.70	52.54	51.81	51.23	51.01	51.67	52.41
EU countries	32.98	33.88	35.13	36.21	37.27	37.97	39.04	40.32	41.06	41.59	42.27	42.30	42.54
OECD citations	9,052,018	9,029,875	9,202,559	8,993,915	8,661,669	8,258,648	7,360,730	6,577,657	5,657,170	4,413,746	2,910,123	1,388,938	235,901

Source: Institute for Scientific Information, NSI 1981–2002.

United States are the only countries whose shares of all OECD publications and citations declined during the period under review.

Figure 5.2. OECD countries' shares of all OECD publications and citations: percentage change of share from 1990–1992 to 2000–2002. For example, Finland's share of OECD publications was 0.8 per cent in 1990–1992 and 1.1 per cent in 2000–2002, i.e. its share increased by 36 per cent. At the same time the share of citations increased by 52 per cent (from 0.8% to 1.2%).



Source: Institute for Scientific Information, NSI 1981-2002.

Impact factors and relative citation impacts

Impact factor and relative citation impacts provide rough measures of the visibility of research and its scientific impact. When these two indicators are compared side by side, the rank order among OECD countries is not affected (Table 5.9). The impact factor indicates the average annual number of citations received by publications from each country. The relative citation impact, then, indicates how many per cent more or less the publications of each country have received in comparison with the average for the OECD countries (index = 1).

The impact factor for OECD countries showed relatively steady growth during the 1990s and early 2000s. During the period from 1998 to 2002, the impact factor for the OECD countries was 4.57, somewhat higher than the figure for the EU countries (4.45). The six top countries with impact factors higher than five in 1998–2002, were Switzerland, the United States, the Netherlands, Denmark, Sweden and the United Kingdom. Finland ranked tenth in the 1988–1992 period and eighth in the 1998–2002 period.

In 1988–1992 there were six OECD countries with a relative citation impact of 1 (corresponding to the average for the OECD countries) or higher. In 1998–2002 there were 13 countries with an index of one or higher. During this 1998–2002 period Finland ranked eighth, with four other EU countries ahead of it: the Netherlands, Denmark, Sweden and the United Kingdom. Among the top countries ahead of Finland, Switzerland's and Sweden's relative citation impacts have shown hardly any growth. Finland's relative citation impact in 1998–2002 was 1.07, i.e. Finnish publications received seven per cent more citations than publications from the OECD countries on average.

Table 5.9. Development of OECD countries' impact factor and relative citation impact in 1988–1992, 1993–1997 and 1998–2002. The countries are rank-ordered according to the values for the most recent period.

Impact factor[a] / OECD countries	1988–1992	1993–1997	1998–2002	Relative citation impact[b] / OECD countries	1988–1992	1993–1997	1998–2002
Switzerland	5.05	5.91	6.67	Switzerland	1.46	1.47	1.46
United States	4.34	5.19	5.93	United States	1.26	1.29	1.30
Netherlands	3.79	4.61	5.64	Netherlands	1.10	1.14	1.23
Denmark	3.58	4.62	5.54	Denmark	1.04	1.15	1.21
Sweden	3.89	4.53	5.14	Sweden	1.13	1.12	1.12
United Kingdom	3.58	4.31	5.09	United Kingdom	1.04	1.07	1.11
Iceland	3.03	4.64	4.92	Iceland	0.88	1.15	1.08
Finland	3.04	4.15	4.89	Finland	0.88	1.03	1.07
Germany	3.06	3.98	4.88	Germany	0.89	0.99	1.07
Belgium	3.20	4.14	4.85	Belgium	0.93	1.03	1.06
Canada	3.03	3.99	4.84	Canada	0.88	0.99	1.06
OECD	3.45	4.03	4.57	OECD	1.00	1.00	1.00
Italy	2.75	3.61	4.56	Italy	0.80	0.90	1.00
France	3.11	3.84	4.55	France	0.90	0.95	1.00
Austria	2.74	3.60	4.50	Austria	0.79	0.89	0.98
European Union	3.07	3.77	4.45	European Union	0.89	0.94	0.97
Norway	2.78	3.39	4.38	Norway	0.81	0.84	0.96
Australia	2.92	3.37	4.24	Australia	0.85	0.84	0.93
Ireland	2.19	2.82	4.06	Ireland	0.63	0.70	0.89
Japan	2.90	3.21	3.84	Japan	0.84	0.80	0.84
Spain	1.94	2.88	3.76	Spain	0.56	0.71	0.82
New Zealand	2.49	3.00	3.57	New Zealand	0.72	0.74	0.78
Luxembourg	0.79	2.24	3.44	Luxembourg	0.23	0.56	0.75
Hungary	1.73	2.60	3.18	Hungary	0.50	0.65	0.70
Portugal	1.81	2.42	3.17	Portugal	0.52	0.60	0.69
Greece	1.67	2.12	2.76	Greece	0.48	0.53	0.60
Czech Republic	–	1.52	2.63	Czech Republic	–	0.38	0.58
Poland	1.56	2.05	2.53	Poland	0.45	0.51	0.55
Mexico	1.62	1.95	2.46	Mexico	0.47	0.48	0.54
South Korea	1.26	1.63	2.35	South Korea	0.37	0.40	0.51
Slovakia	–	1.13	2.21	Slovakia	–	0.28	0.48
Turkey	0.98	1.21	1.56	Turkey	0.28	0.30	0.34

[a] Impact factor = number of citations by Finnish publications, for example, divided by the number of Finnish publications.

[b] Relative citation impact = each country's impact factor divided by impact factor for OECD countries. For example, the relative citation impact for Finland in the period 1998–2002 is calculated as follows: 4.89 / 4.57 = 1.07.

Source: Institute for Scientific Information, NSI 1981–2002.

Table 5.10. OECD countries’ relative citation impact* by major field of science in 1998–2002.

	Natural sciences		Engineering and technology		Medical sciences		Agricultural sciences		Social sciences		Humanities	
1	Switzerland	1.40	Switzerland	1.49	United States	1.29	Luxembourg	3.73	United States	1.15	Greece	2.16
2	United States	1.37	Denmark	1.28	Switzerland	1.26	Netherlands	1.56	Netherlands	1.04	Netherlands	1.56
3	Netherlands	1.19	United States	1.23	Iceland	1.23	Finland (3.)	1.52	Belgium	1.00	New Zealand	1.35
4	United Kingdom	1.18	Netherlands	1.12	Canada	1.21	Denmark	1.47	Canada	0.99	Finland (4.)	1.33
5	Denmark	1.14	Belgium	1.08	Netherlands	1.21	Switzerland	1.34	Italy	0.99	Portugal	1.26
6	Germany	1.06	Germany	1.08	Finland (6.)	1.17	Belgium	1.31	Finland (6.)	0.97	United Kingdom	1.23
7	Sweden	1.04	Sweden	1.07	Denmark	1.14	United Kingdom	1.31	United Kingdom	0.96	United States	1.19
8	Canada	1.02	France	1.07	Belgium	1.13	Sweden	1.23	Switzerland	0.93	Australia	1.17
9	Austria	0.95	United Kingdom	0.98	United Kingdom	1.12	Ireland	1.15	Sweden	0.92	Japan	1.16
10	Belgium	0.95	Austria	0.98	Sweden	1.11	United States	1.13	France	0.85	Turkey	1.14
11	France	0.95	Ireland	0.96	Norway	1.06	France	1.10	New Zealand	0.82	Denmark	1.00
12	Finland (12.)	0.93	Italy	0.95	Italy	1.02	Norway	1.05	Norway	0.81	Hungary	0.94
13	Australia	0.93	Canada	0.94	Australia	0.99	Canada	1.04	Australia	0.80	Canada	0.92
14	Ireland	0.92	Norway	0.94	New Zealand	0.98	Australia	1.00	Hungary	0.80	Belgium	0.82
15	Iceland	0.90	Australia	0.93	France	0.97	Spain	0.97	Germany	0.80	Germany	0.77
16	Italy	0.89	Finland (16.)	0.93	Germany	0.96	Italy	0.96	Denmark	0.77	Sweden	0.75
17	Norway	0.85	Spain	0.91	Ireland	0.94	New Zealand	0.96	Austria	0.73	Norway	0.74
18	Japan	0.80	Hungary	0.91	Austria	0.91	Germany	0.92	Iceland	0.73	Iceland	0.60
19	Spain	0.79	Japan	0.87	Portugal	0.88	Portugal	0.87	Luxembourg	0.67	Ireland	0.59
20	New Zealand	0.74	Czech Republic	0.87	Spain	0.82	Austria	0.83	South Korea	0.65	Italy	0.57
21	Luxembourg	0.69	Portugal	0.82	Luxembourg	0.82	Japan	0.81	Ireland	0.63	Poland	0.57
22	Portugal	0.63	New Zealand	0.73	Hungary	0.78	South Korea	0.78	Portugal	0.63	Switzerland	0.55
23	Greece	0.62	Mexico	0.71	Japan	0.75	Slovakia	0.76	Spain	0.61	Mexico	0.49
24	Hungary	0.61	South Korea	0.71	Czech Republic	0.72	Greece	0.76	Japan	0.58	South Korea	0.47
25	Czech Republic	0.54	Slovakia	0.70	Slovakia	0.67	Iceland	0.75	Poland	0.55	Slovakia	0.44
26	Mexico	0.51	Greece	0.68	Poland	0.65	Poland	0.69	Mexico	0.51	Spain	0.41
27	South Korea	0.50	Iceland	0.64	Mexico	0.58	Mexico	0.67	Turkey	0.48	Austria	0.38
28	Poland	0.50	Poland	0.62	Greece	0.58	Turkey	0.52	Greece	0.45	France	0.36
29	Slovakia	0.46	Luxembourg	0.59	South Korea	0.52	Hungary	0.50	Czech Republic	0.28	Czech Republic	0.31
30	Turkey	0.37	Turkey	0.58	Turkey	0.28	Czech Republic	0.39	Slovakia	0.19	Luxembourg	0.00
	European Union	0.96	European Union	0.99	European Union	0.94	European Union	1.07	European Union	0.88	European Union	0.85

* The relative citation impact has been calculated by dividing each country’s impact factor for the major field of science by the corresponding impact factor for the OECD, while the relative citation impact for the OECD is one. In agricultural sciences, for example, the relative citation impact for Finland is 1.52, which means that agricultural publications produced in Finland have accrued 52 per cent more citations during the period 1998–2002 than agricultural publications in all OECD countries on average.

Source: Institute for Scientific Information, NSI 1981–2002.

Neither the impact factor nor the relative citation impact should be used for purposes of direct comparisons between different disciplines. What we can do is see how Finland compares with other OECD countries within different fields of science (Table 5.10). Although Finland's shares of OECD countries' publications and citations are relatively small, we rank fairly high in a comparison of citation impacts. In the light of this comparison the Finnish fields of science that performed best in 1998–2002 were the agricultural sciences, ranking third and receiving 52 per cent more citations than OECD publications in this field on average. The humanities came fourth in this comparison, receiving 33 per cent more citations than OECD publications in this field on average.

Finnish medical sciences as well as the social sciences also fared well in this comparison, both ranking sixth. However, the number of citations received by studies in the social sciences was three per cent lower than the average for OECD publications. The natural sciences ranked twelfth, engineering and technology sixteenth. Publications in these fields received seven per cent less citations than OECD publications in these fields on average.

5.2 The social impacts of research

This section begins with a discussion of how the social impacts of research have been described in research on science and technology policy and innovation policy. Following a general introduction, the text proceeds to look at the technological and economic impacts of research and its broader impacts on society. Finally, some of the obstacles and bottlenecks impeding impacts are discussed.

5.2.1 The social impacts, outcomes and impact mechanisms of research

It is commonplace to highlight the technological and economic aspects of the social impacts of research[9], but those impacts can also be considered in a broader sense as comprising, for instance, health, environmental and cultural effects.

It is important to distinguish between the social effects of research and the outcomes of research. The results of research include:

- new information that citizens can use in building up their world-view, or that can serve as a source of technological and social innovations
- new research instruments, methods and techniques that may be taken into use in industry and in different fields of research
- the knowledge base produced for the assessment of broader social and ecological impacts
- solutions to complex technological problems
- new spin-off companies
- research skills and competencies (know-how in scientific research) that are transferred, along with researchers, into industry and the rest of the science community
- access to expert and information networks through involvement in research.

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[9] Unless otherwise implied by the context, research refers here primarily to basic research conducted at universities and research institutes.

The process in which research outcomes unfold into social impacts involve certain common distinctive features. These impacts materialise through various kinds of institutions and mechanisms. Their diffusion takes place primarily in social networks and cooperation. Furthermore, the mobility of researchers, their involvement in consultancy and counselling, and publishing all contribute to the dissemination of impacts (Molas-Gallart et al. 2000).

The changing relationship between science and society has given rise to growing demands upon the assessment of the impacts of research funded from the public purse. These changes have included (Arnold & Balazs 1998):

- changes in the economic environment of research: globalisation, growing competition and new technological challenges call for more attention to be paid to safeguarding the technological and economic impacts of basic research
- the growing costs of research instruments, equipment and other infrastructure
- the general emphasis on management by results, cost-effectiveness and impacts of public funding
- the growing scarcity of research resources and the expectation that assessments shall focus not only on areas of strength but also on weaknesses
- the growing role of international funding organisations in the funding of research, which has given greater weight to the social criteria of impacts.

5.2.2 How have the social impacts of research been described or assessed?

In the science community's own practices, the scientific quality of research has remained the predominant criterion of research assessment. In the business sector, too, this is still considered an important measure (Arnold & Balazs 1998, Nieminen & Kaukonen 2001). However, more and more attention is now being paid to the social dimensions of scientific knowledge. At the same time, research has been discarding its simplistic models of impact mechanisms and adopting instead more complex models (Fuller 1988, Arnold & Balazs 1998). These are some of the points that have been raised in the field of innovation research with regard to the social impacts of research, their assessment and the criteria of impacts:

- The social impacts of research are not a one-way street but interactive processes.
- Social impacts, impacts mechanisms and outcomes cannot be uniformly assessed in different fields of research because they all vary across those fields.
- The diffusion of the social impacts of research is not usually a mechanistic process, but they are mediated through various kinds of application and impact mechanisms. The cooperation, mutual dependence and joint learning of the different actors involved is paramount.
- Most impacts of research are of an indirect nature, they take a long time to filter through and they are difficult to operationalise and measure.

So while virtually all disciplines and fields of research do have both economic and other social impacts (such as those on welfare), their indirect nature and the long time spans involved mean it is impossible to provide accurate assessments (e.g. impacts of different learning processes, impacts of changes in diet habits, impacts of changes in people's experiences of safety with more liberal legal regulation, etc.). There are no straightforward, universal indices that provide a meaningful description of those impacts (Arnold & Balazs 1998, Teigland 2000).

5.2.3 Technological and economic impacts of research

The impact relationship between research and technology is indirect and interactive. Technological innovations and technological development take place through the diffusion of existing knowledge rather than through the generation of new information. In so far as research which generates new information contributes to the evolution of new technologies, it will usually be not through basic research, but rather research by business companies as well as company cooperation (Pavitt 1991, Innovaatiotutkimus… 2003). In some fields (such as information technology, pharmacy, petrochemistry), publicly funded basic research has also proved to be hugely valuable to companies (Arnold & Balazs 1998).

Technological development facilitates and contributes to economic growth. Economic growth is primarily driven not by research, however, but by the adoption of new technologies from other actors (diffusion, learning and imitation). Both technological development and economic growth do, though, rest upon the accumulation of human capital and scientific knowledge (Helo & Hedman 1996). Scientific research is thus an important background factor for both technological development and economic growth, even though in the last instance both are explained by other factors.

In order to identify the economic impacts of research, we need information on business companies, on the impacts of research on regional economies and on the impacts at the level of the national economy.

Using data collected in business questionnaires, Statistics Finland has described the impacts of innovation at the business level in 1998–2000 (Table 5.11). According to their Innovation Survey in 2000, innovation improves the quality of products and services and broadens the product and service range. Other benefits are either minor or insignificant. This may be due to the fact that, for whatever reason, the potential benefits of innovation do not get transferred into the company's everyday business

Table 5.11. Impacts of innovation at company level (all industries total).

Impacts of Innovation	Very significant %	Significant %	Minor %	Not relevant %
Wider product and service range	13.6	45.1	25.1	16.2
Expanded markets	10.4	38.2	34.0	17.4
Improved quality of products and services	13.9	47.3	24.8	14.0
Improved flexibility in production	6.7	33.5	35.0	24.8
Increased production capacity	6.6	27.0	33.6	32.8
Lowered labour costs per unit produced	7.3	26.0	36.6	30.1
Reduced materials and energy consumption per unit produced	4.1	14.7	38.9	42.3

Source: Innovaatiotutkimus 2000.

In interpreting these results it is important to note that only just over one-third of innovations in manufacturing and less than one-third of innovations in other industries are based directly on information received from universities and public research institutes (Innovaatiotutkimus… 2003). Therefore the estimates in Table 5.11 do not directly represent the benefits that companies reap from basic research at universities, but rather the benefits of their own innovation. On the other hand, most of the innovation in the business sector is undertaken by researchers with a university training. These observations lend support to the impression that the impacts of publicly funded research at the company level are primarily of an indirect nature.

Both Finnish and international studies have confirmed that universities promote economic growth and innovations within their area. The economic impacts of universities at the local level consist mainly of the human capital and the new scientific knowledge they produce. Furthermore, universities disseminate within their area all the human capital and scientific knowledge that is brought in from elsewhere. (Helo & Hedman 1996.)

The regional impacts of university research are intricately interwoven with education and other university functions as well as with other impact chains. Furthermore, these impacts are dependent on companies' decision on where to locate their business, in which the proximity of a university is just one consideration among many others.

Research has shown that in Finland, the regions of Uusimaa, Oulu, Turku and Pori and Häme are streets ahead of other regions in terms of their ability to make use of human capital in production. In these regions the impacts of research on the regional economy are the most significant. However, there is considerable mobility of human capital from one educational province to others, at least in industry. In the regions mentioned the monies invested in universities also have the greatest incentive effect on business R&D expenditure (Helo & Hedman 1996, Alueellisen innovaatiotoiminnan tila... 2002). The positive economic effects of universities also emerge clearly in evaluations by third parties, although these also point at various shortcomings and development needs (Dahllöf et al. 1998, Goddard et al. 2000).

At the level of the national economy and the innovation system, various indicators have been applied to describe the technological and economic impacts of research. In an international comparison, the impacts of Finnish research can be described by reference to the indicators shown in Table 5.12 (for the limitations of this comparison, see Benchmarking S&T... 2002).

On most indicators Finland compares very favourably indeed, both in terms of its current situation and especially in terms of the pace of development during the latter half of the 1990s. The biggest challenges are included in the third category (impacts of the knowledge-based economy on competitiveness), particularly in the development of knowledge-intensive services. There also remain significant development needs in the commercialisation of technology. In spite of these challenges and development needs, Finnish research appears to have significant and positive economic impacts.

Table 5.12. Impacts of Finnish R&D in an international comparison.

	Finland in 2000	EU average in 2000	Finland's ranking among EU countries in 2000	Finland's ranking among EU countries in 1995–2000 on the basis of growth rate
Technological performance				
* no. of patents, EPO / million pop.	283	139	2	8
* no. of patents, USTPO / million pop.	130	74	4	6
Success of technology commercialisation				
* world market share of exports of high-tech products (%)	0.89		9	2
* export:import ratio of technical knowledge and services (%/GDP)	0.08		11	2
Impacts of knowledge-based economy on competitiveness				
* value added of high-tech production (%/total production)	9.99	7.77	3	1
* employment in high-tech production (%/total labour force)	7.22	7.60	5	2
* value added of knowledge-intensive services (%/total production)	11.17	32.92	12	2
* employment in knowledge-intensive services (%/total labour force)	37.93	32.31	6	15

Sources: Towards a European Research Area. Science, Technology and Innovation. Key Figures 2002; Third European Report on Science & Technology Indicators 2003.

5.2.4 Mechanisms promoting the economic impacts of research and their problems

Networking, cooperation and joint learning

The processes in which innovations unfold and in which they are commercialised, involve certain features that are tied to time and place. A study based on extensive materials (some 2,400 innovations) shows that new scientific breakthroughs and technologies are of key significance especially in the development of complex innovations. These include innovations that profoundly change existing modes of activity. In this context research cooperation between business companies and universities has immediate relevance as a foundation for new innovations. Public support, a financially healthy business sector and large company size all contribute to strengthening the foundation of complex innovations that requires long-term investment. Radical innovations, for their part, usually come from new and small companies. The way that public support works in practice and the conditions under which innovations and the commercialisation succeed or fail, are still poorly understood. (Tanayama 2002.)

One of the arenas that provides a useful illustration of the diffusion of research impacts through research cooperation is that of drug development. Technological change (in the shape of genetic engineering) is leading to a reorganisation of drug development into a network of small, highly specialised companies in which research and product development are closely interwoven. The emerging business models are based upon a splitting up of the value chain of the drug development process into viable business concepts that are carried out by closely collaborating organisations. A drug development network is created involving research groups engaged in basic research at universities, drug development companies, service organisations, technology companies as well as marketing businesses, or traditional pharmaceuticals companies (Kivisaari et al. 2001, Tulkki et al. 2001). An example of a drug development project organised in the form of a network is provided by the following Hormos Medical Oy project aimed at developing a drug for male urinary dysfunction (Kivisaari et al. 2001).

Cooperation and networking in drug development

The project was inspired by the studies of a research group at the University of Turku in the role of the female hormone in the male organism. A group of experts at the major pharmaceuticals producer Orion took an interest in the studies of this group and in 1991 Orion began to finance their research. The research group was studying several of Orion's products, but they soon focused their attention on a few key drugs. This research effort at the university would not have been possible without Orion's support. Orion decided to discontinue its funding in 1995, and the final report was written in 1996. Project management was taken over by Hormos Medical Oy. Tekes began funding the project in 1997 and continued to support it for three years: Tekes funds were used to finance clinical patient studies. In 2000, the project was continued with the company's own funding, and the drug proceeded to the clinical stage. Since the patient trials, the drug development company has been looking for international partners that could take over production, marketing, distribution and further development. It is crucial that it finds partners so that it can commercialise its research results. At this stage everything hinges on the company's licensing plans: in order to get the drug into the marketplace as planned in 2005, they need to succeed with licensing.

The original idea for the project came from university sources. New information about the mechanisms at work in the disease was produced in basic research. Leaning on that information, the drug development company's job was to develop and produce a new drug and to show that the drug did what it was supposed to do. Since the company did not have the necessary multidisciplinary research and documentation know-how in-house, it purchased the research and other services from outside contractors. Several service companies were involved in the network, the majority of which worked in connection with universities. The drug development company worked closely both with the service companies and with the research group at the university.

Although there are many reasons for changing the business concepts that promote cooperation and networking among the actors involved, the main reason has to do with new gene technologies. With these technologies, the critical innovation stage has moved very close to basic research. The utilisation of new technologies requires new models of collaboration and new ways of organising business. Overall the concept is not yet ready and properly structured. In the example described above, the different parties also had divergent expectations. For instance, it was considered somewhat problematic that the rules of the game were not entirely clear. (Kivisaari et al. 2001.)

Although Finland generally provides a good infrastructure and environment for innovations (Georghiou et al. 2003), organisations producing knowledge-intensive services (e.g. measurements, reporting, training and consultancy services) have been singled out as a weakness in the Finnish innovation system (The Impact... 2002). There have been improvements and advances, though, and Finland is actively involved in the OECD development project on Knowledge Intensive Service Activities, for instance. New service concepts have been developed and networking has been promoted for instance through the Ministry of the Interior's centre of expertise programme and technology centres. In this way cooperation and networking as well as the economies of production have also involved a regional dimension.

Networking and cooperation also make it easier to take into account the needs of research and technology end-users. There are examples where the technologies produced have remained underutilised or completely unused because planning has failed to take account of the needs and expectations of end-users (Miettinen 2002). The following example of a development project in process management and control describes the possibilities that are offered by the development of user-oriented technologies (Kovalainen 2002).

Electronic diary for process control and management

Insufficient communication about process control and management may lead to quality defects or even stoppages or production shutdowns the costs of which in a paper mill, for instance, may run up to 20,000 euros an hour. Empirical studies have shown that one of the key conditions for effective process control is the ability to remember earlier problems and experiences. In practice, this information has a tendency to be lost. Traditional tools of process control (folder diaries) are one of the storage places of information. However, these tools do not support interactive learning, nor are they available for use in environments beyond the single workplace.

In this case example, the research and development process started out from a practical problem. Working closely with the end-users of information, the research team joined forces with the company in question to develop and commercialise an electronic diary for process control purposes. In all, the development process lasted seven years. During the course of the process the key needs for communication and information dissemination were identified in the paper and energy industry, and a software application supporting the relevant functions was developed from concept to product. The diary is now in active use for instance in production reporting within a paper manufacturing corporation. User statistics indicate that the electronic diary has become the most widely used intranet application in the different production units. As well as promoting the organisation’s collective memory and learning, the diary increased communication and exchange of information related to key events during the shift, which is particularly important in the event of malfunctions. Follow-up studies in 2004 will allow for firmer conclusions to be drawn about the impacts of the changes on the corporation’s productivity and the generalisability of the results.

Spin-off companies

Where networking and collaboration have not sufficed to turn research results into commercial, marketable products, research may have been organised into a business format. Fitting together the divergent cultures of research and business has proved particularly challenging in the university environment.

Opportunities and challenges of commercialisation in universities

Juha Tuunainen, University of Helsinki

Commercial application of university research is not always easy; witness the efforts of the research team under Professor Eija Pehu in the field of applied plant biotechnology in 1990–2000. Their aim was to integrate the three main elements of their work: the breeding of agricultural plants, the development of new research methods and the production of high-level scientific knowledge. Since the research group was working closely both with international research teams and with plant breeders, they were exceptionally well placed to act as a bridge between academic research and the commercial application of research results (Tuunainen 2001). Even though the group had good success in commercialising its research results – it led to the founding of Finland’s first ever business venture in plant biotechnology – the process of commercialisation was far from unproblematic. There were difficulties with patenting the research results, the critical attitude of European consumers towards GM foods and with drawing the dividing line between private business and academic work.

Funding bodies and the launch of a biotech company. In the field of biotechnology, business is one of the key mechanisms through which research results can be transferred from university to wider use in society. In our case example, the establishment of a spin-off company was the net effect of several different factors. The foundation was provided by the research group's application-driven research programme that was funded by the Academy of Finland. This programme produced scientific innovations that were protected by patents. Having secured funding from the National Technology Agency Tekes, the research group then extended its research programme. A key condition with regard to starting the company was that all Tekes-funded projects are required to have concrete cooperation with the business sector: this gave greater solidity to the burgeoning relations with business companies. In the last instance it was the investment and expert assistance provided by the National Research and Development Fund Sitra that made possible the start-up of the company, allowing the research group to move from the university into the world of business.

Patenting research results. Prior to the launch of the company, in the mid-1990s, the research group produced several research results with potential commercial application. They decided to protect some of these results (a virus-resistant potato and a transgenic form of turnip rape) together with Helsinki University Licensing (HUL). As HUL undertook to cover the costs of patenting, ownership of the patents was transferred from the research group to HUL. When a few years later the group decided to set up a company, it was not entirely clear on what conditions the patents held by HUL could be released to that company: the two companies found themselves in competition, which threatened the commercialisation of the research results. After protracted negotiations it was agreed that the researchers' company would market the innovation related to the virus-resistant potato (Tuunainen 2002), while the transgenic form of turnip rape would remain in HUL ownership. This case gives cause to consider the question of how to fit together divergent economic interests without throwing into jeopardy the practical application of innovations.

Critical attitude of consumers towards plant biotechnology. Having patented a virus-resistant potato, the research group continued to develop the innovation into a commercial product together with a Danish plant breeding company: the aim was to produce commercially marketable virus-resistant potato varieties. The research went very well and the results were promising. However, in spite of the encouraging start, the Danish company decided to withdraw from the project in the late 1990s. At the same time it discontinued its whole transgenic potato breeding programme. Clearly, it was worried by the critical attitude of the European Union and European consumers towards foods produced by plant biotechnology methods. In spite of high hopes, there were no markets in Europe for a transgenic potato variety (Tuunainen 2002).

The dividing line between business and academic research. When the research group founded its company in 1998, it was still working at the University of Helsinki. At this point the group had not yet decided to leave the university, but it tried to fit together its academic work and the biotechnology business. This led to many awkward problems: How to divide the Professor's working hours between two essentially different operations, i.e. business and teaching at university? On what conditions can the company use the research equipment and materials acquired with public project funding? Can the company and the academic research group share the same facilities? In more general terms, this case gives cause to consider the question of how the university can meet its increasingly diverse tasks and responsibilities: How can it simultaneously improve researcher training, develop its first and higher degree programmes, publish internationally and commercialise research results? On the basis of this case study it seems that at least in small departments that have limited staff resources, it is extremely difficult to reconcile these tasks (Tuunainen 2003).

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This case example highlights some of the cultural, political, ethical, juridical and administrative problems that are involved in fitting together the public and the private in the university context. It also illustrates some of the new challenges that are related to the position of science and modern technology in society. As yet, the discussion on these challenges has not received sufficient weight (Miettinen & Väliverronen 1999), but it has been largely overshadowed by the more technically-minded debate on the rules of the game. Apart from debate and rules, another requirement is sensitivity to trends of change.

5.2.5 The political, regional, organisational and cultural impacts of research

Research may impact human action either by providing, directly or indirectly, a tool for resolving a problem; or by influencing deliberations and judgement. Cultural and social research can also be expected to have cultural impacts, providing building blocks for world-views and supporting the personal growth and development of citizens on various dimensions (Lehtisalo 2002). It follows from the nature of impacts that the social impacts of research need to be studied in the context of the processes in which they appear. (Molas-Gallart et al. 2000.)

In the following case example (Table 5.13) the original description of impacts, compiled exclusively for the field of health research (Koskela 1998), is used as a more general

■ Table 5.13. How the social impacts of research unfold in an interactive field involving multiple actors.

	Elements of impact as events	Content of events	Participants in event
1.	new discovery (e.g. a substance causes cancer or some factor causes social problems)	a situation triggering a new discovery has emerged, basic research creates new information	researchers, innovators
2.	demonstration of the existence of a health hazard or social problem	research	researchers
3.	communication about the existence of the hazard or problem	publishing research results, organising scientific meetings, publishing news, popularisation, compiling and organising information	researchers, events organisers, communication officers, science popularisers, information specialists at libraries
4.	calls to remove the hazard or problem	communication about research results, administrative measures, defending interests, legislation, controlling labour protection, influencing public opinion	researchers, administrators, communication officers, labour protection officers, interest organisations, other organisations, MPs, customers
5.	exploring measures aimed at removing hazard or problem	research, measurements, planning, technical solutions, implementation	researchers, measurement specialists, planning officers, engineers, implementors
6.	communication about the prospects of removing the hazard or problem	training, publishing, making products, making methods products, communication	training staff, publishers, information specialists, communication officers
7.	meeting demands, i.e. implementing changes at shopfloor level (workplace etc.)	measures by employers, employees' experiences, controlling labour protection at shopfloor level, measures taken by authorities	employers, occupational health and labour protection people, employees, authorities
8.	demonstrating improved health or satisfactory solution of social problem, i.e. demonstrating impact	research, compiling statistics on absence from work, illness or accidents, compiling profit and loss statements	researchers, statisticians, publishers, financial administrators

Source: Koskela 1998.

framework for studying the social impacts of research. The description is applicable to situations where the social impacts of research, in order to materialise, require an understanding of the social problems or their underlying causes as well as a concerted effort in society to bring these problems under control. The purpose of the description is not to demonstrate that the social impacts of research develop in a linear process, but rather it illustrates the way in which those impacts tie in with numerous mutually dependent elements (1–7) and cooperation among actors. These elements may appear side by side, there may be breaks between them, long time lags and feedback processes.

The need for interdisciplinary cooperation emerges as a challenge for research impacts early on in the process, for instance in demonstrating the existence of a social problem or a health hazard (element 2). The following example illustrates a case of successful cooperation between a methods science (statistics) and basic science during the early stages of the impact process. Furthermore, the example demonstrates the possibilities and needs for cooperation between different actors, the pursuit of scientific and social impacts in the same process (new areas of research and methods, public health benefits) and the risk factors involved in the unfolding of the impact (the short-term nature of project work, the concentration of expertise, the boundary line between science and non-science).

The nature of multidisciplinary research in modelling infectious diseases

Erika Mattila, University of Helsinki

INFEMAT, a multidisciplinary research project for modelling infectious diseases was launched at the initiative of the National Public Health Institute (KTL) in 1994. The purpose was to set up a new, multidisciplinary research programme that would produce new tools and know-how for designing vaccination programmes and for predicting the spread of infections. KTL was joined in the effort by the Rolf Nevanlinna Institute (RNI) from the University of Helsinki, and Helsinki University of Technology (HUT). Each of the three partners had their own objectives for cooperation: RNI began to set up its own research area in the field of biometrics, HUT worked on strengthening its know-how in visual programming and simulation methods, and KTL strengthened its know-how needed for designing vaccination programmes. The aim of the project was to build individually based simulation models that predict the spread of infections at population level and to plan vaccination programmes.

Establishing a multidisciplinary research tradition

The project was characteristically a multidisciplinary effort: the researchers involved in the project had received their training in various different disciplines: mathematics, statistics, medicine and computer science. At the time that the project was launched there was no other corresponding programme in Finland, but it was based on an international example. The phenomenon modelled is extremely challenging and therefore requires a multidisciplinary approach: the infected person who is carrying the bacterium is often asymptomatic, the rare instances where the disease does break out are difficult, and neither infection nor having the disease guarantees immunity. When this phenomenon is described using mathematical models, we need to apply both mathematical and statistical tools and information technology in order to produce useful overall picture.

How was the multidisciplinary approach built up in practice? First of all, from early on the researchers took active part in seminars which involved reading the literature on modelling and introducing their own research. The group was visited by foreign scientists, some of whom became long-standing partners in cooperation. The researchers also wrote joint articles: during the process of writing up their research they had to explain to participating colleagues the premises of their work and the methods they had employed. Initially the group had some problems getting its results published. A major medical journal once replied: Is this modelling really science?

The problems formulated for the research were also shaped and influenced by the multidisciplinary approach: in order to find a satisfactory solution the researchers brought together their expertise in the modelling project.

Genuinely multidisciplinary results were preceded by cooperation during which medical researchers had to familiarise themselves with the basics of statistical modelling and simulation, while statistics and IT experts studied the epidemiology of the bacterium that was modelled. This was an important period of personal learning for the researchers involved.

Construction and diffusion of expertise
Fitting together different kinds of premises and vantage-points is a slow and awkward process, particularly in project-based research. However, the importance of cooperation is clearly seen in the fact that some members of the research group continue to work together even though they have moved on to new jobs and funding for the project has ended. The personification of expertise presents a challenge to the applicability of research results. Only the researchers involved in the project are familiar with modelling and its possibilities with regard to application: it is difficult to transfer expertise that is tied to individuals.

Nonetheless KTL remains very much interested in the potential application of modelling. During the INFEMAT project three doctoral theses were completed in a field that had previously not been researched very intensively in Finland. The researchers who took part in the project have either continued their research at KTL in the modelling of different infections, or they have moved on to positions of expertise in other research organisations. Through various joint projects, research in modelling infectious disease and the related expertise has also become embedded in international research networks. Know-how is thus applied in the modelling of current epidemiological problems and as a tool of vaccination design and counselling.

The easiest way to illustrate the interconnectedness of health effects with the political impacts of research is from the vantage-point of the fourth element in Table 5.13 (calls for removing the health hazard). This includes providing information about research results, articulation of interests, civic debate, swaying public opinion, legislative work as well as administering and controlling compliance with legal regulations. Among the disciplines whose contribution will be needed to help eliminate the health hazards are (applied) ethics, political science and legislation research. In a sense, these fields of research serve as mirrors of society vis-à-vis political decision-makers. They should reflect upon, organise and question the direction and the ways in which society is being steered, weigh and assess activities in society and produce information about the state of society at each moment in time.

As the situation stands today, the social impacts of the fields of research mentioned above cannot be considered satisfactory, never mind their political impacts (Hertzberg 2000, Tala 2001, Lampinen 2002). However, opinions vary as to the political impacts of research, the problems involved, their causes, and the ways in which they should be rectified.

It is rarely that research has the effect of improving health (see element eight in Table 5.13) unless it also has political as well as regional and organisational impacts. In order that the results of social and health research and, say, environmental research can have an impact on society, a system will often be required that provides for the regional and local organisation of services, that controls businesses and other communities and that also works together with them as well as with local residents. This system conveys information, for instance, about the possibilities of eliminating a health hazard (sixth element), controls the response to the demand (seventh element) and takes part in demonstrating impacts by collecting information in connection with its control and service function (eighth element).

The following case example describes the social impacts of information produced by environmental sciences as well as the dependence of all activities in society upon the factual information produced by environmental research. At the same time, the description goes to show how those impacts evolve over a long period of time, the need for cooperation between different actors and the fact that the new information produced by research (the first element in the process) is a necessary condition for creating effective demands for the elimination of problems (fourth element) and for monitoring and controlling the response to these demands (seventh element).

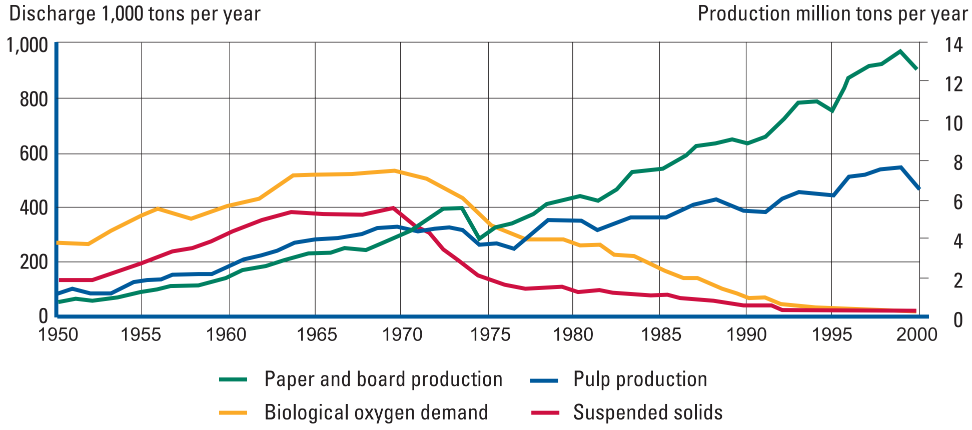
Water protection and related research

Mikael Hildén, Juha Kämäri, Seppo Rekolainen; Finnish Environment Institute

Practical water protection and research in this field are closely interwoven with each other in Finland. The University of Helsinki established a professorship in limnology the same year that the Water Act took effect in 1962. The new legislation required information on the state of water system and on factors impacting its quality. At the same time, increasing public awareness meant that issues of water protection took on increasing social significance as well.

Initially the main focus was upon emissions from residential communities and major industrial installations and the impacts of those emissions. Nonetheless, the time lag from research to practical implementation was still quite long. A good example is provided by emission and production trends in the pulp and paper industry: throughout the 1960s emissions increased in almost direct proportion to production (see Figure below).

Finnish pulp and paper industry: production volumes and waste water load



Sources: Finnish Forest Industries Federation & Finnish Environment Institute.

It was not until the early 1970s that things began to change, both as a result of technology changes and as result of active measures of water protection. Water protection studies provided the main impetus for reducing levels of biological oxygen demand and for developing new reduction techniques. Likewise, it was not until the 1970s that significant advances were seen in the treatment of community waste water: with phosphorus effluents, the efficiency of purification rose from around 25 per cent to more than 80 per cent within the space of about ten years. Today, the figure is over 90 per cent. Progress has been slower with nitrogen effluents, although in the past few years it has been speeding up.

One of the keys to successful emission reduction has been close interaction between the concerned parties, which has promoted the use of the latest knowledge available. This interaction has been channelled through water protection programmes, for instance, in which research knowledge has been organised into practical applications. Various interest groups have taken part in the discussions on these target programmes. The first programme was published by the National Fund for Research and Development Sitra in 1970. The National Board of Waters then set up a programme in 1974, the Ministry of the Environment followed suit in 1988 and 1998. In addition, the Ministry of the Environment launched in 2002 Finland's Programme for the Protection of the Baltic Sea. These programmes have recognised the current state of affairs and set targets that have been cited in the application of legislation. The Academy of Finland launched the Baltic Sea Research Programme (BIREME, 2003–2005) in 2002.

As levels of industry and community emissions have continued to drop, agriculture has come to account for an ever greater proportion of overall nutrient discharge volumes. The first research results pointing in this direction were completed in the late 1970s. Research on the methods and need to reduce emission loads gathered momentum in the late 1980s, particularly through the MAVERO project (Rekolainen et al. 1992). The research results were put to immediate use both for purposes of informational guidance as well as in various administrative contexts; one example is the Environment programme for rural areas (Ministry of the Environment 1992). In the absence of relevant legislation, the application of research results to practical water protection has been a much slower process. It is only since Finland's membership of the European Union and the agricultural environment programme which this entailed that tools have been made available for implementing methods of reducing discharge levels (see Palva et al. 2001).

Research is set to become even more closely integrated with practical water pollution control than it is today. The EU Water Framework Directive presupposes that the aims and means of water protection are chosen by reference to research and that research is consulted more extensively in monitoring water quality.

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The social impacts of research in the humanities are often cultural by nature. In this case the kind of problem-solving process illustrated above can provide only a limited description of these impacts. The cultural impacts of research are manifested, for example, in people's ability (or inability) to recognise the foundations of their world-view, in how they understand the times in which they live, in their ability to define their own local, regional and global identity and in their ability to orientate to the factors determining the boundary conditions for human activity. These impacts take a long time to filter through, and they mainly affect people's judgements rather than provide a basis for actually resolving problems (Molas-Gallart et al. 2000). If the cultural impacts of research are examined simply in terms of economic benefits, that is bound to give a distorted picture of their nature.

The following case example describes how the results of language technology research at the University of Helsinki Department of General Linguistics gradually unfolded into social impacts.

The unfolding of the social impacts of research involves simultaneous and overlapping impacts from various different disciplines and fields of research. In order to properly understand these impacts it is necessary to examine these disciplines and fields of research as interactive processes whose purpose is to provide the actors involved in that process with skills and competencies for orientation and action (understanding the situation, objectives, means, etc.).

Language technology research in a social analysis

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The Department of General Linguistics at the University of Helsinki has been a major pioneer in language technology research not only in Finland but internationally. Research in this field got under way at the Department in the early 1980s, when (in spite of its technological orientation) the work was still pure basic research. Since then the situation has radically changed: with the breakthrough of PCs, data networks and information technology, language technology has become an integral part of everyday life. Language technology research at the University of Helsinki Department of General Linguistics has gained recognition mainly for two of its innovations, viz. two-level morphology and constraint grammar. These tools allow for an analysis, at word level, of the morphology and surface syntax of written text. This method of sentence analysis is needed not only for purposes of word processing, but also for much more complex applications of language technology, such as speech recognition, where it can be used as a module.

The most obvious way to approach the social impact of research in language technology is through commercial applications. Staff at the Helsinki Department of General Linguistics have indeed started two separate language technology companies that are taking advantage of research carried out at the Department. However, an exclusive focus on these spin-off companies would give a somewhat distorted and rather superficial image of how research at the Department ties in with other areas of society. For instance, the Helsinki Department of General Linguistics has been involved in setting up and maintaining the University of Helsinki Language Corpus Server, which contains electronic text materials in more than 50 languages. It also provides language related computer services and software for linguists and corpus researchers. In addition, the Department of General Linguistics has been involved in starting up a national network of language technology teaching, and it has taken part in EU and Tekes programmes where it has had cooperation not only with academic but business partners as well. The impacts of these kinds of projects are generally indirect, unpredictable and can only be ascertained over a longer period of time – certainly beyond the duration of the projects themselves. Participation in different kinds of projects may also promote scientific research itself. One interviewee who is engaged in more traditional linguistic research, had this to say about the utility of the language technology projects at the Department: “new ideas and things that are based on new types of implementation, they require free association between different perspectives, different traditions. When the things we do differ from each other as widely as possible, that will give you completely new kinds of ideas.”

In the examples above, the social impacts of the results of health research upon occupational health and the impacts of environmental research on the state of the environment do not unfold in and of themselves, but through the collaboration of different fields of research and actors within those fields. The end results can be described as the welfare or environmental effects of research. In order that the process can develop smoothly, there must be good cooperation between different fields of research, a sufficiently long-term effort to establish the results and an appropriate period of analysis.

5.2.6 Social innovations

The unfolding of research impacts is also restricted and steered by changes within the science institution itself. By the seventeenth century the ideal of scientific inquiry, in all disciplines, was the pursuit of theoretical knowledge, universal laws and regularities that stood apart from the realm of practice. As science has continued to focus on unearthing universal laws, the practical context, the integration of theoretical knowledge with the needs and problems of everyday life, has remained something of a dead zone for science; some have gone so far as to call this the blind spot of our culture (Virkkala 1994, Toulmin 1998). The accent on the significance of social innovations is an indication of the appearance of the problem in society’s practices (Knowledge... 2003, Soete 2003). The creative integration of the scientific knowledge and technologies produced with societal needs interpreted through values remains the key challenge that provides direction for the effort at social impacts (von Wright 1987).

Given the complexity and diversity of social innovations it is extremely difficult to provide an exhaustive definition of them, and there is no universal agreement on existing definitions either. Social innovations may consist of new forms of organisation, new modes of control and regulation or ways of life which bring more effective solutions to problems and which have sufficient respect so that they can be imitated and/or institutionalised (Schienstock 1999).

Social innovations can be grouped into broader categories. The following classification does not propose to be an exhaustive description of the field of social innovations. Social innovations have been understood in several ways:

1) They have been regarded as crucial to the competitiveness and productivity of the national economy (Alueellisen innovaatiotoiminnan tila... 2002).
2) They have been defined as the process in which "knowledge, skills and expertise are interwoven into good cycles" (Social Capital… 2003). The aims of this interweaving may range from the immediate growth of economic potential to welfare and the "economy of happiness".
3) Social innovations have been understood as new ways of thinking, regulation ideologies and methods, which support social governance.

Although the need for and foundation of social innovations are built, in the last instance, in civil society, individual organisations and in workplace practices, social innovations can be developed and they can be shaped by means of science and education policy and other social policy (The Impact… 2002). Social innovations require a new way of perceiving the links between knowledge, technologies and practical problems as well as an ability creatively to link these together. For this reason the most important measures, at all levels, are those that directly or indirectly promote learning and un-learning the formation of creative and inspiring environments for work and other activities, that encourage people to question practices they have adopted and create other conditions for learning and creativity (Lehtisalo 2002, Negroponte 2003). Research in this area is slowly gathering momentum in Finland, too. One example is the Research Programme on Social Capital and Networks of Trust launched by the Academy of Finland in 2003.

5.2.7 The social impacts of research: obstacles and bottlenecks

Research results do not have the desired effects upon legal regulation or upon social and political decision-making unless they are conveyed through to the decision-makers. As yet we do not have a very clear understanding of the role of research in terms of how it could and should seek to influence decision-making (Tala 2001, Antikainen et al. 2002, Lampinen 2002). The bottlenecks impeding social impacts of research from getting through have also been traced back to problems occurring in the most concrete application environments for knowledge (Koskela 1998). In addition, the low level of participation by customers and service users in research and development processes as well as the inadequate involvement of different interest groups and citizens in procedures of foresight and evaluation may mean that the social impacts of research remain rather modest (Eerola & Väyrynen 2002).

Lack of knowledge is partly responsible for the presence of obstacles that should be open to influence. In the absence of a proper understanding of the impacts of research and their obstacles, it is also impossible to predict them or to take them into account (Koskela 1998, Tanayama 2002).

A further problem that has been identified with regard to the impacts of research has to do with shortcomings in the rules governing universities' outside activities (Kivisaari et al. 2001), the lack of institutional coherence due to the sheer number of organisations (Kuisma 1998) and the uncertainties and open questions surrounding academic entrepreneurship in Finnish society (Nyyssölä 1997).

Economic factors are amongst the most significant obstacles to innovation in business companies (Table 5.14). As for intraorganisational factors, lack of competent staff is identified as a bottleneck in around one-third of all companies. Other factors, such as inflexible legislation and the lack of customer interest in innovations, are less significant bottlenecks as far as companies are concerned. The scarcity of innovation in the business sector is primarily explained by the fact that it is not felt new innovations are needed, either because existing ones are considered adequate or because of reasons that have to do with the market situation. In no more than just over 20 per cent of all cases is it felt that the lack of innovation is due to impeding factors (Innovaatiotutkimus… 2003). Indeed, in the effort to strengthen the general preconditions for innovation, attention should be paid not only to business companies' concrete funding and other similar problems, but also to their strategic assessments of business opportunities and possibilities of influencing those assessments.

Table 5.14. Factors impeding innovation in business companies: businesses engaged in innovation in 1998–2000 by company size.

	Manufacturing				Other industries			
	Staff number				Staff number			
	Total	10–49	50–249	250-	Total	10–49	50–249	250-
	%	%	%	%	%	%	%	%
Economic factors								
Economic risk considered too great	33.8	31.7	33.6	45.2	33.2	34.1	29.4	38.0
Costs too great	38.2	39.8	34.5	38.2	40.8	38.9	47.2	36.2
Lack of suitable funding sources	20.0	23.3	15.5	13.6	17.6	18.0	17.2	14.2
Internal factors								
Organisational rigidities	17.6	17.4	15.0	24.5	22.6	21.7	25.9	20.9
Lack of competent staff	35.1	34.5	33.3	42.4	37.5	33.6	46.6	45.7
Lack of knowledge about technology	28.9	31.4	25.2	23.9	22.6	19.2	31.9	24.1
Lack of knowledge about markets	23.4	21.4	26.7	26.9	28.3	27.3	31.3	27.7
Other factors								
Inflexible regulation	7.1	7.5	6.2	7.1	7.9	8.4	8.2	1.3
Low customer interest in innovations	13.5	13.8	12.7	13.6	15.5	15.0	18.0	10.9

Source: Innovaatiotutkimus 2000.

The environment in which social impacts take place is of a high quality and in many respects competitive[10]. However, not only in Finland but internationally, too, advances in science and technology have been so rapid that governments have been unable to keep track of the new opportunities opened up by technology or to monitor the reactions of the general public (May 2001). Our understanding of what constitutes an ideal environment for research impacts is also incomplete. The impacts of rapid changes can only been seen in the future. (Tomperi 2001, Benchmarking the Promotion of RTD culture... 2002.)

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[10] The European Innovation Scoreboard 2002, for instance, shows that Finland has the highest proportion of people with an academic education; the highest proportion of people working in high-tech companies; and the highest level of business sector investment in R&D. See also, e.g., The Global Information Technology Report 2002–2003 (Dutta et al. 2003), where Finland's competencies come out on top (Networking Readiness Index Ranking) and Benchmarking the Promotion of RTD culture... 2002 and The Impact... 2002. According to Castells and Himanen (2001), it seems that the Finnish welfare state is a crucial factor in terms of guaranteeing the stable growth of the new economy.

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6 Conclusions

High-quality scientific research is the bedrock of the research and innovation system. In the Finnish research and innovation system, the business sector has played a major role in both funding and conducting research. Approximately one-quarter of R&D in Finland today is funded from the public purse. This must not be allowed to drop any lower. **Adequate public funding** must be secured in order to maintain a balanced structure of funding for our research system.

It is important for Finland's future that there are enough talented young people who are interested in researcher training and a career in research. At all levels of education, key areas of development include science education for children and young people that encourages critical thinking; creative learning environments; as well as support for closer interaction between teachers and students. Continuing efforts are needed to evaluate and develop the Finnish education system, **researcher training** and graduate schools. Graduate schools should invest in international networking, teaching in foreign languages should be more readily available, and the number of foreign students recruited in graduate schools should be increased. Support is also needed for doctoral training outside the graduate school system. It is important that there remain different routes to the doctorate and that new, alternative pathways are created. In the development of research and researcher training environments, the differences between disciplines and fields of research must be taken into account.

There has been a determined and consistent effort in Finland to develop the research career, and most of the recommendations made in the 1997 research career strategy have been put into practice. A new **research career strategy** needs to be drafted that takes into account both the needs of researchers and the development needs thrown up by internationalisation in different fields of research. In particular, more effort needs to be invested in creating a horizon of meaningful goals; in removing the obstacles in the research career; and in maintaining and strengthening the competitiveness of the research career. All this must be a concerted effort between funding bodies, universities, research institutes, business and industry and the rest of society. It is essential that different administrative branches cooperate so that the social obstacles to a career in research can be removed and so that the mobility of Finnish and foreign researchers can be facilitated.

The quality of research can be further enhanced by recruiting competent **R&D personnel**. One of the areas that needs to be developed is the recruitment of researchers at PhD level in both the private and public sector. Today only less than three per cent of R&D personnel in the business sector have a PhD. People with a researcher training have the important advantage of possessing significant international skills and competencies as well as networks of cooperation that they have built up while working in an international research environment.

A concerted intersectoral effort is needed to facilitate the mobility of people with a PhD between research jobs and other **expert and managerial positions**. Doctoral students and researchers must be given the opportunity to work in positions of expertise in government or the business sector. On the other hand, people working in public administration or business and industry should have more flexible options to upgrade their expertise by taking doctoral degree programmes. Fixed-term appointments for doctoral students and newly graduated PhDs in the business sector, and fixed-term university appointments for researchers working in business, are a good way of promoting genuine interaction and networking between academic research and business and industry. This also makes for more effective use and application of research results.

Continuing efforts are needed to develop the work and operations of **universities** so that a balanced relationship can be maintained between their responsibilities in research and education, on the one hand, and their regional and national societal service functions, on the other. In these efforts it is important to take into account the needs deriving from universities' profiles and strategic emphases. The sensitivity of universities to identify and fend off structures and practices that threaten their balanced development shall be supported by securing sufficiently long-term and broadly-based direction, evaluation and funding. In developing universities' funding structure, attention must be paid to the ratio between core budget funding and external funding, as well as to the continuity of funding from outside sources. In so far as these factors are in proper balance, competitive funding will ensure a sustained or improved quality of work.

It is essential for Finland to try to steer and influence the work of **international** science and technology organisations. There are Finns in key positions of influence, but not enough. Active initiatives and cooperation within the European Union and work to build up the European Research Area must be continued. The Academy of Finland has been actively involved in discussions on the formation of a European Research Council and taken, in principle, a positive stance. In the context of Nordic cooperation, the main focus is on measures aimed at increasing the competitiveness and exposure of Nordic research, these measures being based on the quality of research and open competition. Bilateral and multilateral agreements provide important platforms for cooperation particularly with countries outside the European Union. Existing agreements should be so revised that they better serve the needs of programme-based cooperation as well as other development needs in research.

Various kinds of **programmes** are designed and organised to coordinate research around a certain theme or question. For reasons of regeneration and renewal, though, it is important that the diversity of research is maintained as well. Risks must also be taken. Programme concepts need to be clarified by analysing the strengths and weaknesses of programmes in different environments. Programmes must be adjusted and fitted together with other tools of science policy. Further steps are needed to improve programme strategies and evaluation strategies. Work to develop different types of programmes (research and technology programmes, cluster programmes, centre of excellence programmes) and their evaluation has already produced important synergy benefits, but systematic cooperation between programme funding bodies, researchers and end-users can further add to those benefits.

The aims of research **evaluation** are usually related to enhancing the quality of operations or research, empowering the actors involved or increasing their self-understanding. It is important that the different objectives are reconciled and that the diversity of evaluation criteria employed is secured so that the various parties can retain their confidence in the legitimacy and validity of evaluation. The benefits gained from evaluation must always be weighed against the costs involved and against the obligations and costs incurred to the objects of evaluation. There have been improvements both with regard to the knowledge base and statistics, but there are still definite shortcomings. These shortcomings must be systematically addressed. Practices of participatory evaluation and development-oriented evaluation need to be strengthened and improved.

Science policy objectives with regard to the **quality and international visibility of publishing** have been met reasonably well. In several fields of science and research, Finnish research now enjoys more exposure than before. For instance, articles published by Finnish university researchers in international peer-reviewed series increased in all major fields of science in 1998–2002. Although Finland accounts for only a relatively small proportion of the publications and citations of all OECD countries, we compare favourably in an international examination of impact factors. On the basis of the indicators used it is not possible to draw more than tentative conclusions about the quantitative and qualitative development of research. The qualitative development of scientific research in Finland is discussed in more detail in the Research Councils' reports.

The **social impacts** of basic research are many and varied. For the most part they are of an indirect nature and take different amounts of time to come through. The technological and economic impacts of research are the easiest to detect, and they are based upon the broader entity that is made up of technological, economic and socio-cultural impacts. Case examples make it clear that research in different fields has very different and varied social impacts upon society. These impacts can effectively be enhanced by means of cooperation and networking. The maintenance of welfare requires an ability to organise research creatively so that society's needs can be conceptualised and predicted and so that the social and technological innovations which meet those needs can be produced. The balanced development of the different components of the Finnish innovation system requires a closer and clearer understanding of the interdependencies between the different impacts of research. The distinctive nature of these impacts must be taken into account when they are evaluated. Urgent steps of national and international cooperation are needed to develop approaches to and methods of evaluating the social impacts of research.

Research and its operating environment are changing. In this environment of constant change, it is a major challenge indeed to provide research with the infrastructure, facilities and resources it needs. The most important challenge of all is to secure the quality of research, which depends among other things on the know-how and competence of research personnel as well as on the science policy pursued. In order to make sure that researchers have a high enough level of skills and competencies, it is crucial that there is enough high-quality researcher training. Risks have to be taken, among other reasons in order to ensure the renewal and regeneration of research. Competitive research funding is crucial to sustaining and improving the quality of research and must be secured. High-quality research and the sensible allocation of resources must be supported by an anticipatory science policy approach. As soon as decision-makers, funding bodies and research organisations have done their own share and got the foundations in place, research can be expected to produce social impacts.

Appendix 1. Description of the National Science Indicators database

This review has made use of the National Science Indicators (NSI) database that is maintained by the Institute for Scientific Information (ISI). It contains publication and citation data for more than 170 countries in 1981–2002, broken down by field of research. It indexes some 5,500 scientific journals in the natural sciences and engineering and technology as well as 1,800 social science journals and 1,200 journals in the arts and humanities. All the journals indexed are peer-reviewed.

NSI classifies all scientific articles, reviews, notes and conference proceedings as articles. The database comprises a total of more than 13 million scientific articles from a period spanning 22 years. In around 106,800 of these articles, at least one of the authors is Finnish.

The articles are classified into different fields of research according to the scientific journals in which they have been published. However, articles appearing in multidisciplinary science journals (such as Science and Nature) are separately assigned to the most appropriate field of research. The discipline classification for scientific journals is based upon the Current Contents publications that the ISI has produced for purposes of describing the contents of these journals. The data for the NSI database are compiled from separate Current Contents publications. For this reason the journals that are classified under more than one Current Contents publication – and by the same token the scientific articles published in those journals – will be classified in more than one discipline category in the database.

The NSI database has two classification systems: the *standard* version comprises 24 fields of research and the *deluxe* version 105. The categories of the deluxe version correspond to the classifications of the Current Contents publications. The standard version, on the other hand, combines some of the Current Contents categories. Appendix Table 1 shows how the categories of the standard version of the NSI database have been fitted together with the six major fields of science used by the OECD. The classification has been complemented with the categories from the deluxe version because the humanities, for instance, are only represented in the deluxe version.

■ Appendix Table 1. Correspondence between OECD major fields of science and the classification used in the NSI database. Categorisation is based mainly on the standard version.

OECD major fields of science	NSI database classification
Natural sciences	Biology & Biochemistry Chemistry Computer Science Ecology / Environment Geosciences Mathematics Microbiology Molecular Biology & Genetics Physics Plant & Animal Science Space Science
Engineering and technology	Engineering Materials Science
Medical sciences	Clinical Medicine Immunology Neurosciences & Behavior Pharmacology Psychiatry (Deluxe)
Agricultural sciences	Agricultural Sciences
Social sciences	Economics & Business Education Law Psychology (Deluxe) Social Sciences, general
Humanities	Archaeology (Deluxe) Art & Architecture (Deluxe) Classical Studies (Deluxe) General (Deluxe) History (Deluxe) Language & Linguistics (Deluxe) Literature (Deluxe) Performing Arts (Deluxe) Philosophy (Deluxe) Religion & Theology (Deluxe)

Gender in the Finnish research system

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Women have been involved in doing science and research for as long as people have observed and studied the world around them. However, it was not until the latter half of the nineteenth century that women's career prospects in science and research began to improve, following the removal of the formal obstacles to their education at university level. Now, just over one hundred years on, women account for the majority of university students in Finland, and soon they will account for one-half of all PhDs awarded.

Why is it so important for women to be involved in the research community, alongside men? The most radical response says that the predominance of men in science and research and particularly their gatekeeper role largely determines the orientations of science and even the choices made within individual disciplines. In a more neutral vein, we might say that the promotion of gender equality is an important goal and value in its own right. From this vantage-point, the argument is that neither physical gender differences nor any alleged intellectual differences, nor indeed any differences in the position of men and women in the process of social reproduction, offer any valid reason as to why women could not be researchers and scientists just as well as men (Stolte-Heiskanen et al. 1991, Zuckerman et al. 1991, Acker 1992, Caplan 1993, Fox Keller 1995). More recently, a new argument has been raised that refers to national competitiveness: we need to have more women researchers in order to make sure that the "innovation system" has access to the best talent.

How, then, have women's career prospects changed in Finnish science and research over the past few decades? I will be addressing this question here in the light of the KOTA database that is maintained by the Ministry of Education, studying gender in the Finnish research system and its different disciplines and comparing the situation in Finland with that in other European countries. Among the tools I will be using are two indicators I have extracted from the KOTA database. The first of these I call the *PhD graduation indicator*: this describes the numbers proceeding to take the PhD as a proportion of all graduates completing a higher university degree. In other words, the PhD graduation indicator relates the number of people going on to take their PhD to those completing a first degree, i.e. to the total number of potential PhD candidates, by comparing a certain cohort of PhD graduates with the cohort of those taking their first degree five years previously. The amount of time it takes to complete the PhD varies quite widely in different fields of study, but for the present purposes the interval from first degree to PhD is set at five years, which is the most typical value for the whole dataset. The PhD graduation indicator depends, on the one hand, on the resources available for researcher training and on the number of job vacancies within the research system; and on the other hand, on how much respect the PhD commands in the job market of that particular field. In medicine, for instance, many doctoral theses are motivated by ambitions of promotion within the hospital institution; without a PhD that would be virtually impossible. Likewise, in the humanities and social sciences many PhD graduates have no ambitions of a career in science and research; for some researching a doctoral thesis is more like a pet hobby.

The second indicator I have describes the proportion of women who go on to take the doctorate relative to the corresponding proportion of men. I use this *gender indicator of PhD graduation* to study how evenly PhD graduates are divided by gender by comparing the gender breakdown of PhD graduates with the gender breakdown of those completing first degrees, i.e. by dividing women's PhD graduation indicator by men's PhD graduation indicator. In other words, the indicator value is 1 if the number of women as a proportion of PhD graduates in the age cohort is the same as their number as a proportion of those completing first degrees five years previously. Indicator value 1 describes a situation where women who have completed a first degree are equally keen to continue their studies as men and where the researcher training system is gender-neutral, and further where the job markets are not gendered in such a way as to affect the opportunities of women and men to continue their studies. This indicator provides a useful tool for monitoring changes in the gender balance in postgraduate education: the low (or high) proportion of women among PhD graduates may be due to the field in question being one where the number of women recruited is lower (or higher) than the number of men.

The KOTA database provides gendered data on university degrees from 1989 onwards. For both indicators I have chosen two points of measurement that I will be comparing, i.e. 1996 and 2001.

A closer analysis of women's careers in research would require not only quantitative but also qualitative materials, such as those collected through interviews; this is indeed the direction in which recent academic research on women's position in science and research has been moving (Malina et al. 1999, Husu 2001, Glover 2002). However, even statistical materials can shed important light on the development of women's research careers and provide at least a tentative answer to the question as to whether there are any inherent, structural biases in society, in the science community, in science policy or research funding that prevent or hinder women's entry into and advancement in research careers. The statistical data also throw up interesting challenges for qualitative research.

From equality to competitiveness

A decade ago the main emphasis in the debate on women and research was still firmly on the promotion of gender equality as a European human rights tradition (see e.g. Barr & Birke 1998, Rose 1999, Delamont 2002), although at the same time there was also the goal of making visible women's work and women's action more generally, which tied in closely with the rise of new women's studies in the United States and Europe. Since around the mid-1990s, a new line of argumentation has been emerging alongside the equality discourse which emphasises the more effective use of women's talents in the best interests of the national economy. From this intellectual resources perspective, it is stressed that the social and economic investments made in women's education have not been put to the best possible use, but significant resources of human capital are lying idle. This line of argumentation has it that scientific research is an integral part of the innovation system, and that the efficiency of that system is crucial to economic success, competitiveness and welfare.

The theme of women and research occupies a place of special importance in the current science policy debate, particularly within the context of the EU. It lies at the junction of two major European issues of debate: how to succeed in the face of stiffening global competition, and how to strengthen the foundations of national knowledge and know-how. The communication "Women and science: mobilising women to enrich European research" was the first ever document from the EU Commission that set the explicit target of promoting women's position in European science and research and markedly increasing women's involvement in the fifth framework programme (the general minimum target of 40 per cent). Furthermore the Commission wanted to increase the amount of research undertaken by women, to support research on women and to promote research aimed at improving women's situation (EU 1999). Several projects were launched to get this off the ground, including the report by the European Technology Network on "Science policies in the European Union. Promoting excellence through mainstreaming gender equality" (EU 2000), which has since become a canonical text in this field. In addition civil servants and experts from Member States formed a working group that has since become known as the Helsinki Group (because its founding meeting was held during Finland's EU Presidency).

At its Lisbon Summit in March 2000, the European Union set itself the target of becoming, by 2010, the world's most competitive and dynamic knowledge-based economy. As far as economic growth and innovation are concerned, consensus has it is that the most critical factor is having access to staff with a high level of education. For purposes of promoting the European Research Area (ERA), the Union is committed to increasing the amount of research resources as well as the numbers admitted to researcher training. A further aim is to increase the number of young researchers as well as women researchers. The underrepresentation of women, the Commission says, presents a serious obstacle to the full-scale implementation of the ERA because "this represents an unacceptable and unaffordable waste of human resources -- [and] the underrepresentation of women in science compared with their representation in society induces a distortion between science and society at a moment where it is of utmost importance to increase confidence in science" (EU 2001a, 3). Launched in 2002, the action plan "Science and Society" is in turn an integral part of the ERA strategy and a tool aimed at reinforcing the area, highlighting the promotion of gender equality under a separate item (EU 2001b, EU 2002a, EU 2002b).

The position of women researchers is a cause of growing concern in ongoing efforts to safeguard the diversity and the reproduction of European knowledge and know-how. This applies most particularly to the skills and competencies needed in the information society and to the need to widen the recruitment base to higher education. In Finland, the Science and Technology Policy Council has suggested that for these purposes it is important to get girls to take an interest in mathematical subjects, particularly since girls account for 60 per cent of all senior secondary students in the country but only three in ten of them do the longer maths course, compared to more than five in ten among boys (Science and Technology Policy Council of Finland 2003).

The requirement of competitiveness now extends to the future role of universities as well. In its communication "The role of the universities in the Europe of knowledge", the EU Commission takes a broad view on universities and studies them through the "dynamics of innovation" (EU 2003a). The report addresses questions related to women's careers in research, but pays hardly any attention at all to the problems of the future. One of the future threats is that the research system will become increasingly polarised by gender (EU 2003b), with men being recruited into industrial R&D positions and women into universities. Even now, women are severely underrepresented in private sector R&D – which is understandable in view of the low level of interest women have shown in engineering studies. However private business finances the bulk of research and development work: in the EU the average is 56 per cent, in Finland 70 per cent (EU 2002c).

Higher education, PhD graduation and gender

Higher university degrees

Table 1. Higher university degrees (Master's degrees) by gender in different fields of study in 1989–1991 and 1999–2001 (excluding literature and the arts).

Field of study	Women			Men			Total		
	1989-1991	1999-2001	1991-2001	1989-1991	1999-2001	1991-2001	1989-1991	1999-2001	1991-2001
	no.	no.	change %	no.	no.	change %	no.	no.	change %
Theology	184	271	47	211	174	–18	395	445	13
Humanities	2,678	3,912	46	676	934	38	3,354	4,846	44
Educational sciences	2,434	3,676	51	1,074	733	–32	3,508	4,409	26
Sport sciences	87	115	32	113	106	–6	200	221	11
Social sciences	1,422	2,390	68	924	1,102	19	2,346	3,492	49
Psychology	336	477	42	93	77	–17	429	554	29
Health sciences	421	837	99	20	65	225	441	902	105
Law	571	778	36	663	690	4	1,234	1,468	19
Economics	1,679	2,229	33	1,654	2,098	27	3,333	4,327	30
Natural sciences	1,195	2,099	76	1,292	1,999	55	2,487	4,098	65
Agriculture and forestry	360	473	31	424	370	–13	784	843	8
Engineering	816	1,405	72	3,563	5,340	50	4,379	6,745	54
Medicine	864	702	–19	474	417	–12	1,338	1,119	–16
Dentistry	247	99	–60	97	40	–59	344	139	–60
Veterinary medicine	97	107	10	25	14	–44	122	121	–1
Pharmacy	158	217	37	50	57	14	208	274	32
Total	13,549	19,787	46	11,353	14,216	25	24,902	34,003	37

Source: KOTA database, Ministry of Education.

Women accounted for the majority of all higher university degrees awarded for the first time in 1987. The overall number of university degrees has shown strong growth in 1991–2001, rising by 36.5 per cent. This is largely attributable to the marked increase in the number of degrees completed by women, up by 46 per cent. The trend is explained by the continued growth of university enrolment rather than by any dramatic changes in graduation times or dropout rates, for instance.

In 1990 the number of university students in Finland stood at 112,921, in 2001 the figure was 162,939. Underlying this increase is the growing demand in the information society for people with a higher education: national training programmes have been launched in an effort to meet the shortfall of such people. Indeed IT training has increased markedly since 1986. The clear decrease seen in the number of degrees in medicine and nursing science is explained by the lower enrolment in medical and dental education in the early 1990s, following a government decision in 1994.

The proportion of women students has increased in all fields of study except medicine and dentistry, where women have traditionally accounted for a large proportion of all higher university degrees. In addition, the proportion of women has grown in those fields where the absolute number of degrees completed by men has sharply declined: theology, educational science, psychology, agriculture and forestry, and veterinary medicine. There are many female-dominated fields where the proportion of women has increased from 79 to as high as 97 per cent; these include the humanities, education, psychology, health sciences, veterinary medicine and pharmacy. The classification by fields of study reveals just one “male bastion”, i.e. that of engineering. The proportion of women graduating from engineering faculties remains at a modest 21 per cent, and even within this category distributions are uneven, for instance in the field of chemical technology. Nonetheless the proportion of women in this growth field has continued to increase in pace with their share of new students (19.3% in 1990 and 21.7% in 2002).

The picture that emerges of Finland from international comparisons of education is one of relative gender equality (OECD 2002, Eurostat 2003). In Finland women in the age bracket 25–64 have completed more tertiary degrees (36% women and 29% men) and more higher university degrees than men (16% women and 13% men). Lower degrees also include post-secondary degrees at lower than polytechnic level. Higher degrees, then, consist of higher or lower university degrees as well as polytechnic degrees. Women in Finland account for a larger proportion of tertiary degrees than in any other EU country, and their share of higher degrees is around the average for the European Union. In the EU member states 21 per cent of women have completed a tertiary degree, 15 per cent have completed a higher academic degree.

The number of women as a proportion of university students and graduates has steadily increased both in Finland and elsewhere. In Finland the proportion of women has shown consistent growth since the mid-1970s, both among post-secondary, higher vocational and academic graduates.

In Finland the most popular fields of higher education among women are medicine and nursing science, which in 2000 accounted for one-third of all academic degrees completed by women, and the social sciences, accounting for just over one-quarter; together these two fields of study represented 58 per cent of women’s degrees. The most popular fields of study among Finnish men were engineering (46%) and social sciences (19%).

In the EU countries, too, social sciences (33%) and medicine and nursing science (20%) are the most popular fields of study among women. Among men the most popular fields in the EU are social sciences (30%) and engineering (26%).

The breakdown of women's first degrees at tertiary level by field of study varies widely across the European Union. In Ireland and Italy, for instance, over half of the first degrees taken by women are in the natural sciences, mathematics and data processing. In Belgium, Germany and the Netherlands, the figures for these fields are the lowest, standing at around 30 per cent. Engineering studies are very popular in Portugal, which has the highest figure in the EU at 35 per cent, compared to the lowest in the Netherlands at 13 per cent. In Finland the number of degrees awarded in the natural sciences and engineering as a proportion of all first degrees completed by women is roughly around the average for the EU (EU 2003b, 12–13).

In Finland engineering and the natural sciences accounted for the largest proportion of degrees completed by men in the whole of the European Union, and the number was also one of the highest in the OECD: in 1998 the figure in Finland was 32 per cent and in the OECD 24 per cent (OECD 2002). In Finland women's share of all degrees completed in these fields of study was one of the lowest in the OECD (20.3%), but around the average for the EU (20.4%).

In the light of these statistical sources it would seem that the fields of study favoured in Finland are more clearly gender-differentiated than they are in the EU on average. In spite of all the major problems involved in these kinds of direct statistical comparisons, I would certainly consider this difference significant.

At the same time then as the number of women in Finland who continue to higher education is showing strong growth, there are indications of dual trends among different fields of study: On the one hand, segregation seems to be gathering momentum, i.e. different fields of study are increasingly gendered as "men's and women's" fields. On the other hand, there are indications that more and more women are now entering fields of study that formerly were male-dominated or that used to be more or less gender-neutral. For instance, women today account for the majority (52% in 2002) of all those completing the degree of Master of Laws, whereas in 1975 their share of all these graduates was no more than one-third.

PhD graduates

The number of PhDs awarded in Finland has increased even more than the number of all university degrees. The value of the PhD graduation indicator (the number of PhDs awarded divided by the numbers completing a first degree five years previously) increased from 10.2 to 11.7 per cent, i.e. by 15 per cent during the period under review in 1996–2001. The growth in the number of PhDs ties in with various university and science policy reforms in the 1990s, most notably the increase in public research funding and the conscious emphasis on researcher training (including the launch of the graduate school system), the introduction of management by results in universities and the consequent increase in steering and control. Stiffening competition in the labour market, for instance in public sector research institutes and for positions of expertise,

Table 2. PhDs awarded to men and women in different fields of study in 1989–1991 and 1999–2001 (excluding literature and the arts).

Field of study	Women			Men			Total		
	1989-1991	1999-2001	1991-2001	1989-1991	1999-2001	1991-2001	1989-1991	1999-2001	1991-2001
	no.	no.	change %	no.	no.	change %	no.	no.	change %
Theology	5	17	240	27	46	70	32	63	97
Humanities	54	160	196	69	162	135	123	322	162
Educational sciences	19	122	542	23	72	213	42	194	362
Sport sciences	4	4	0	0	13	–	4	17	325
Social sciences	26	123	373	77	144	87	103	267	159
Psychology	14	26	86	15	18	20	29	44	52
Health sciences	17	89	424	2	10	400	19	99	421
Law	4	10	150	13	28	115	17	38	124
Economics	13	59	354	32	124	288	45	183	307
Natural sciences	108	308	185	258	441	71	366	749	105
Agriculture and forestry	20	63	215	42	78	86	62	141	127
Engineering	31	110	255	190	460	142	221	570	158
Medicine	142	434	206	272	324	19	414	758	83
Dentistry	8	33	313	9	8	–11	17	41	141
Veterinary medicine	6	13	117	7	5	–29	13	18	38
Pharmacy	13	28	115	16	16	0	29	44	52
Total	484	1,599	230	1,052	1,949	85	1,536	3,548	131

Source: KOTA database, Ministry of Education.

and the slowdown of growth and recruitment in the private sector have increased the supply of people with an academic education (Asplund 2000, Sitra 2000).

Women proceed to take the PhD far less often than men: for women the value of the PhD graduation indicator in 2001 was 9.3 per cent, while the corresponding figure for men was 14.8 per cent. Nonetheless women are rapidly catching up.

The gender indicator of PhD graduation provides another interesting angle on how PhD graduates are divided by gender by relating the gender distribution of PhD graduates to the gender distribution of those completing a first degree. In this analysis PhD graduation among women increased by 17 per cent to 63 per cent over the five-year period from 1995 to 2000. In 2000–2002, women accounted for 46 per cent of all PhD graduates. This is a marked change indeed when we bear in mind the low proportion of women over the past decades: in the 1940s through to the 1970s, women accounted for no more than an average 13 per cent of all PhD graduates. It was not until the 1990s that the number of women as a proportion of PhD graduates began to increase (Husso 2002, Table 1).

Since the fraction of women taking the PhD is smaller than the fraction taking first degrees, we do not find female-dominated fields at the PhD level to the same extent as in the analysis of first degrees. The only fields where women account for more than 80 per cent are health sciences and dentistry. Indeed the most interesting point here

Table 3. PhD graduation indicator[a] by field of study and gender in Finland in 1996 and 2001.

Field of study	Women		Men		Total	
	Ind1996[b]	Ind2001[c]	Ind1996[b]	Ind2001[c]	Ind1996[b]	Ind2001[c]
	%	%	%	%	%	%
Theology	3	7	14	22	9	14
Humanities	4	5	18	19	7	8
Educational sciences	3	4	5	8	3	5
Sport sciences	6	4	7	10	7	7
Social sciences	5	7	14	13	8	9
Psychology	4	7	29	20	10	10
Health sciences	9	12	55	45	11	13
Law	1	2	3	5	2	3
Economics	2	3	4	7	3	5
Natural sciences	17	18	28	27	23	23
Agriculture and forestry	8	12	14	17	11	15
Engineering	8	9	10	10	9	10
Medicine	36	49	60	66	45	55
Dentistry	8	13	22	9	12	12
Veterinary medicine	4	12	20	26	7	15
Pharmacy	15	17	22	40	16	21
Average	7	9	14	15	10	12

[a] The PhD graduation indicator describes the percentage of graduates in different fields of study who have taken the doctorate during the selected year, i.e. the indicator relates the number of PhD graduates to the number who have taken a first university degree. In the original material the trends for 1991–2001 are examined as three-year sliding averages.

[b] Ind1996 = PhDs awarded in 1996 relative to higher university degrees in 1991.

[c] Ind2001 = PhDs awarded in 2001 relative to higher university degrees in 1996.

Source: KOTA database, Ministry of Education.

is to identify the fields in which women's PhD graduation, i.e. the value of the PhD graduation indicator compared to men is the highest.

The only field of study where women proceed more often than men to take the doctorate, is that of dentistry. It is surprising to see that in the field of engineering, where women are clearly underrepresented, they nonetheless proceed to take the PhD almost equally often as men when compared to their share of all Master of Science in Technology and Master of Science in Architecture degrees. In other natural sciences and disciplines applying natural science, women have been relatively keen to continue to postgraduate studies. By contrast in the fields I have called female-dominated (the humanities, education, psychology, health science, veterinary medicine and pharmacy), women's PhD activity is remarkably low or at least lower than average. It seems then that even in female-dominated fields of study, women are more inclined than men to orientate to such jobs where it is harder to continue with one's studies while working and where a PhD is not considered a special asset. In female-dominated fields women account for a larger than average share of teaching staff responsible for supervision, so one might assume that in these fields women would be encouraged to continue with their postgraduate studies and recruited into research teams at least to the same extent as men.

Table 4. Gender indicator of PhD graduation[a] by field of study in Finland in 1996 and 2001.

Field of study	W share of higher univ degrees 1995–1997 %	W share of doctorates 1999–2001 %	M share of higher univ degrees 1995–1997 %	M share of doctorates 1999–2001 %	W PhD grad ind 1996[b]	W PhD grad ind 2001[c]
Theology	52	27	48	72	0.24	0.34
Humanities	79	50	21	52	0.21	0.26
Educational sciences	79	63	21	40	0.54	0.44
Sport sciences	45	24	55	67	0.81	0.37
Social sciences	63	46	37	55	0.33	0.51
Psychology	81	59	19	44	0.14	0.34
Health sciences	97	90	3	11	0.16	0.26
Law	52	26	48	72	0.46	0.32
Economics	51	32	49	66	0.41	0.46
Natural sciences	51	41	49	61	0.63	0.68
Agriculture and forestry	52	45	48	54	0.61	0.73
Engineering	21	19	79	82	0.80	0.92
Medicine	64	57	36	43	0.61	0.74
Dentistry	75	80	25	28	0.36	1.40
Veterinary medicine	85	72	15	35	0.21	0.47
Pharmacy	81	64	19	44	0.66	0.42
Average	57	45	43	56	0.54	0.63

[a] The gender indicator of PhD graduation describes how evenly the genders are represented among PhD graduates by relating the gender breakdown of PhD graduates to the gender breakdown of first university degree graduates, i.e. by dividing women's PhD graduation indicator by the corresponding indicator for men. The indicator value is 1 if the fraction of women among PhD graduates in the age cohort is the same as their fraction among those completing a first university degree five years previously. The figures for higher university degrees and doctorates are three-year sliding averages.

[b] Women's PhD graduation indicator is compared to the corresponding indicator for men (PhDs 1996 / higher university degrees 1991).

[c] Women's PhD graduation indicator is compared to the corresponding indicator for men (PhDs 2001 / higher university degrees 1996).

Source: KOTA database, Ministry of Education.

The classification by fields of study includes three minor "occupational" fields where PhD graduation has been markedly lower (3–5%) than in other fields of study: education, law, and economics and business administration. No doubt a more detailed classification would reveal other similar fields as well (see Räty 1991). Education is a female-dominated field, but in the two other fields the gender breakdown in first degrees completed has been more or less balanced.

The other extreme is represented by medicine: here the value of the PhD graduation indicator for women is 49 per cent and for men as high as 66 per cent. It is clear that in this field, first degrees merely serve to guarantee entry into the occupation; career advancement, at least in the central university sector, invariably requires a PhD. In spite of the high proportion of medical students who proceed to postgraduate studies, women's PhD graduation rate (74%) relative to men is only slightly higher than average. The decision to lower the numbers enrolled into medical education will probably reduce the number of PhDs completed in this field, but it is unlikely we will see any change in the rate of PhD graduation. In the field of dentistry women have the highest PhD graduation indicator (140%).

The high value of the PhD graduation indicator in the natural sciences (among men 27 per cent and among women 18 per cent, even though large numbers of students are recruited into the school system and industry) is probably indicative first and foremost of the value of the PhD in the expert labour market (the public sector with research institutes etc.). Perhaps another explanation is that a substantial proportion of PhDs researched at graduate schools is in the field of the natural sciences and engineering. For instance, during the first four-year term of graduate schools in 1995–1999, almost half (46%) of all graduates represented these fields (Ministry of Education 2000).

The number of PhDs awarded in the Nordic countries each year has almost doubled during the 1990s. In 2001 women accounted for around 40 per cent of all PhDs, more than 1.5 times more than in 1990. Finland (this comparison excludes Iceland on account of its small numbers) recorded the highest proportion for women in 2001, when the figure stood at 45 per cent. The proportion of women PhDs was much higher than in the other Nordic countries, particularly in the fields of medicine and nursing science as well in the social sciences (Nordbal 2003).

Table 5. Distribution of women PhD graduates by broad field of study in the EU countries in 2000 (per cent).

Country	Natural sciences %	Engineering %	Medicine and health %	Educational sciences %	Humanities %	Agriculture & veterinary %	Social sciences %	Others %	Total %
Austria	20.1	10.0	3.1	10.2	15.4	6.3	33.8	1.1	100
Belgium	46.2	5.9	20.3	0.5	10.3	5.1	11.5	0.3	100
Denmark	18.2	11.7	34.2	0.0	14.8	11.1	9.7	0.3	100
Finland	15.7	8.3	25.8	11.7	14.0	2.4	20.5	1.7	100
France	44.2	5.7	7.4	1.4	21.6	0.3	18.9	0.5	100
Germany	21.7	3.0	43.1	2.0	11.8	5.1	12.6	0.7	100
Ireland	49.6	5.9	11.4	0.8	19.9	1.3	11.0	0.0	100
Italy	19.1	13.4	27.1	0.0	17.1	6.3	17.0	0.0	100
Netherlands	15.8	7.3	33.3	0.0	10.5	8.2	24.9	0.0	100
Portugal	21.2	10.6	7.4	6.9	12.3	2.4	31.4	7.7	100
Spain	29.3	3.6	22.9	4.5	13.7	4.0	20.3	1.8	100
Sweden	21.2	16.5	36.1	3.9	7.1	3.8	11.2	0.2	100
United Kingdom	35.9	8.1	19.3	4.7	14.3	2.9	14.2	0.6	100
EU 15	28.1	6.5	26.9	3.0	14.3	4.0	16.4	0.9	100

EU 15: Estimate, excluding Greece and Luxembourg. Data for Belgium (Flemish and French) combined.
Data for Denmark, France and Italy from 1999.

Source: EU 2003b (Eurostat, New Cronos database).

Relative to population, Finland had the EU's second highest number of new PhDs in 2000 after Sweden (EU 2002c). In all EU countries women accounted for 39 per cent of PhDs awarded. In Finland, Germany, the Netherlands and Sweden, women PhDs showed a stronger orientation to medicine and nursing science than in the other EU countries. In Finland women's share of all PhDs completed in the natural sciences was the lowest in the EU countries, whereas the figure for technical and scientific fields was higher than the average for the EU (EU 2003b).

Women and men in Finland do not differ significantly in terms of the age at which they take their PhDs. In 2001, the average age of PhD graduation was 38 years; for women the figure was 38.7 years, for men 37.4 years (Nordbal 2003). Similar results came out of analyses conducted at the Academy of Finland using Statistics Finland materials on age of graduation among those taking the PhD in 1987–1998 (Academy of Finland 2000, Appendix Tables 4e–f). On the one hand the fraction of PhD graduates aged under 30 has increased in both men and women, but on the other hand the fraction of those graduating at 45 or over has also grown. The age of graduation among women has clearly come down: in 1987–1989 the age group 30–34 accounted for 20 per cent of the total, in 1996–1998 for almost 30 per cent. In men the age at PhD graduation has remained almost unchanged throughout the period under review (with around 30% of male PhD graduates representing the age group 30–34). In other words, the majority of women and men PhD graduates now represent the same age group.

Women in universities and as beneficiaries of research funding

Universities

The number of university teaching and research posts has increased by over one-third during the past ten years. This is primarily explained by the sharp increase in the number of university personnel who are paid from outside sources. In 1990–2002, the fraction of women among university office holders has increased quite noticeably from 32 per cent to 45 per cent. When the proportion of women professors (21.2% in 2002) is compared to the proportion of women taking the PhD ten years previously (31% in 1992), we find a ”loss” of 11 percentage points. The situation has deteriorated to some extent compared to the previous decade (women accounted for 13.1% of all professors in 1990, and for 20% of PhD graduates in 1980).

In the natural sciences and engineering no more than eight per cent of all professors in Finland are women, and this figure has not grown at all over the past ten years. The share of women is highest among professors in the humanities (31%) and the social sciences (23%) as well as in medicine and nursing science (21%) (Statistics Finland 2000).

In relative terms the number of women is highest in multidisciplinary universities: Helsinki, Turku, Tampere, Kuopio and Lapland, where women account for over one-half of all staff in R&D positions. Women account for no more than one-fifth of staff in universities of technology and in schools of commerce and business administration, with the exception of the Turku School of Economics and Business Administration where 36 per cent of all professors are women (KOTA 2003). In 2001 women accounted for 44 per cent of all research staff in the university sector.

There is no marked gender difference in the age of professors. The main determinant is the general age structure among university office holders in the discipline, i.e. in engineering the professors are the youngest and in the humanities the oldest. (Statistics Finland 2000).

A recent survey of public sector salaries and wages revealed that women professors' monthly earnings are 335 euros less than the earnings of male professors (Statistics Finland 2002). The results of an inquiry by the Finnish Union of University Professors points in the same direction: their figures indicated a monthly wage gap of 258 euros in favour of men. The differences are explained by the breakdown of men and women between different disciplines, by differences in the rate of separate remunerations and by the higher proportion of women than men in the A26 wage band (Acatiimi 2003).

In the European Union, some 11 per cent of all professors in 1999 were women. The latest figures for EU member states indicate some improvement in the situation, with the proportion of women rising to 15 per cent in 2000. However, the figures still vary widely, from six per cent in the Netherlands to 19 per cent in Finland and Portugal (Eurostat 2002, EU 2003c, EU 2003d, latest comparable data for the EU member states for 2000, data for Portugal from 1999).

The share of women among senior university researchers is increasing, but slowly, especially in view of women's increasing numbers in researcher training. One reason lies in the relatively slow turnover of professors: annually the turnover rate is no more than around five per cent. However, that figure is set rise quite substantially in the near future as the babyboom generation begins to approach retirement age. Recent studies have shown that the practice of appointing professors by invitation and/or the increase in the number of fixed-term professorships have had an adverse impact on the recruitment of women. Less professors are now appointed by invitation than before, but especially in engineering faculties it is still quite common (Yliopistotieto 2001, see also Academy of Finland 1998). The system has been said to favour personal relationships and the tailoring of professorships according to suitable candidates. It also waives the requirement of gender equity legislation that the merits of all applicants to the same post shall be compared. Overall the invitational system does nothing to dismantle prevailing traditions, such as the dominant position of men in senior university posts (Academy of Finland 1998, Husu 2001).

Academy of Finland

Academy of Finland research posts and positions as well as research funding are important academic career avenues. Women's position in research funding has improved, for during the period from 1997 to 2002 the number of women appointed to different Academy research posts has clearly exceeded their proportion among the applicants (Academy of Finland 2003a). At year-end 2002, 51 per cent of postdoctoral researchers, 33 per cent of Academy Research Fellows and 29 per cent of Academy Professors were women.

The period after PhD graduation, during which one gains the qualifications required for a career in research, is crucially important to the future of that career. For more than ten years now the number of women among researchers in charge of Academy projects, as well as their number among applicants for project funding, has remained at well below one-third (this is based on figures for Academy funding open for general application). In the case of research programmes, which represent one of the most important forms of targeted Academy funding, women account for around 25 per cent of researchers in charge (Hakala et al. 2003, Academy of Finland 2003b). In both types of funding the number of women in senior positions is slightly higher than their fraction among university professors. In 2000–2002, projects with a woman in charge had two-thirds women researchers; in projects with men in charge, men and women researchers were more or less evenly represented. Research projects run by women were primarily in such fields where women have the strongest representation among university researchers.

The Finnish centre of excellence programme involves 26 units appointed for the period from 2000 to 2005 and a further 16 units appointed for the period from 2002 to 2007. Among these 42 units, 16 per cent are under female management, and women account for 18 per cent of group leaders. The proportion of women among unit directors is slightly higher in the 2000–2005 centre of excellence programme (19%) than in the 2002–2007 programme (13%) (Academy of Finland 2003c). Biosciences have a very strong presence in the first of these programmes, and in these fields women account for a considerable proportion of new PhD graduates. In both programmes the number of women as a proportion of directors and group leaders is relatively small when compared with the fraction of women among professors in the natural sciences (21%) and even engineering (9%), or with the fraction of women among Academy Professors (29%).

When the proportion of women among recipients of Academy research funding is compared with the number of women professors, it is no exaggeration to say that women fare very well indeed in the competition for research funding. This was also the conclusion of a recent evaluation commissioned by the Academy of women's studies (Academy of Finland 2002). The result is quite logical in view of how the academic career usually unfolds: active researchers who have not managed to secure a professorship will continue their research with a view to gaining additional qualifications. On the other hand, given the small proportion of women who are in charge of centres of excellence in research, there is perhaps reason to ask whether the selective policy of research funding and the allocation of most funds to large successful research teams (which are usually run by men), merely shifts the problem of women's underrepresentation among funding applicants to a new level. Even if the number of women scholars holding research posts could be increased, a significant part of research funds are channelled through such procedures in which women represent the minority among applicants as well.

Some case studies have been done to address the problems relating to women's recruitment into postgraduate training and selection into research (e.g. Cockburn 1987 and 1990, Conefrey 1997, Hopkins 1999, see also the Academy's equality inquiry among research institutes and centres of excellence published in 1998). One of the structural imbalances within the science community, it is argued, is represented by the scientific laboratory which is said to constitute a men's world whose culture and discursive practices appear to many women students as cold and even hostile (Conefrey 1997, Ylijoki 1998). Another important issue is the everyday reality of the science community that is enveloped in an atmosphere of stiffening competition and total dedication to research. Cockburn goes so far as to argue that women do not always feel at home in the world of science and research and its hierarchic career structures. On average, there is no doubt that it is extremely difficult to fit together the requirements of a family life, i.e. having children and providing care, with long working hours; and in practice this still remains much harder for women than for men (see e.g. the results of the Finnish equality barometer for 1998, 2001: Melkas 1998, 2001).

Is the position of women in science and research improving?

It was not until the 1990s that the proportion of women proceeding to the take the doctorate began to show more marked growth in Finland. This is probably not so much due to the rising number of women in gatekeeper or other top positions in science and research, but rather to the significant increase in researcher training and to the professionalisation of that training, and further to a conscious effort to give women the same chance as men. There is no question that we will continue to see all relevant indicators of women's position in science and research continue to strengthen in the future.

When women's rate of PhD graduation is compared to the rate for men, we find fewer female-dominated fields at the PhD level than in the case of first degrees. Surprisingly, women proceed to the doctorate in engineering sciences almost as often as men when compared to their share of first degrees completed in engineering. However, in fields where the proportion of women among those completing first degrees is very high, women's rate of PhD graduation is markedly lower than that of men. Indeed it seems that in fields of study that have highly efficient mechanisms of postgraduate training, women proceed to take the doctorate almost as often as men.

The KOTA database is drawn up on the basis of data for individual fields of study, and this is the most detailed centralised source available on specific disciplines. However, for the purposes of this review I did look more closely at a few fields of study (basing my choices on data from previous decades; see Räty 1991) in the light of data obtained from different universities. The key questions relating to the development of women's research careers were clearly crystallised in the disciplines of engineering, mathematics and history. As only a small number of women with a first degree are recruited into engineering studies, their success in the world of science shows no decisive difference compared to men. Although half of all those taking the Master's degree in mathematics are women, their share among PhD graduates remains very small. History is a humanities field with large numbers of women students and a growing proportion of women among those taking a first degree and even the doctorate, but exceptionally few women are recruited to professorships. Does the male predominance among science gatekeepers and professors suffice to explain the small number of women? Both in mathematics and history, most women who take the Master's degree are looking forward to become teachers. If the purpose is to increase the number of women researchers, the very minimum requirement is that women who have taken a first degree are encouraged to continue their studies.

One factor that complicates women's entry into and advancement in research is the set of values that prevails in the science community: this is a world that very much emphasises youth and efficiency. Do the small differences in terms of how family life is prioritised in the fiercely competitive world of science lead to decisive differences between competent people? Even though we might not even want to have a situation where the numbers of women and men are exactly the same, it is important and indeed necessary for reasons of gender equality and maintaining and raising the quality standards of research that all obstacles in researcher training as well as in the science community are recognised and ultimately removed.

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The impact of social research

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"…almost all evaluation of socio-economic effects is actually evaluation of economic effects…. Equally, most efforts in impact evaluation focus on 'hard' science and technology, leaving the social sciences and humanities largely unexplored." (Arnold 2001, 26.)

This piece of writing begins where Erik Arnold ends. Although policymakers today are firm believers in research, it is clear to be seen that their belief only extends to certain kinds of research. Mainstream politics and administration are positively in love with research that produces marketable innovations and that promotes economic growth. The utility of social and cultural research, on the other hand, needs to be separately proved and demonstrated.

I shall begin by considering how social research can have an impact upon society. Who needs social research, how and where are its impacts seen? I then proceed to discuss the measurement of impacts. My main focus is on social research, but much of what I say also applies to cultural research, and more broadly to the letters and arts.

Good times

The emphasis in western politics today on economic and technological issues goes to show that ours is an exceptional era. The political preoccupation with the economy and with technology suggests implicitly that in all other respects, our society and its institutions are in perfect order. Thus, quite an astonishing degree of social stability and confidence in public and private institutions has been achieved. Ironically: history really has ended when the only noteworthy social issue is the accumulation of wealth and when the completion of markets as a result of globalisation is considered an adequate response to that issue.

Unfortunately (or fortunately), though, it seems that history is not entirely complete and ready. September 2001 provided a cruel lesson that the road to globalisation is littered with seemingly unresolvable political and cultural conflicts, at the same time as modern technology is making violence so easy that even the best security systems cannot prevent it. The fanciful notion of the end of history does not stand up to the international test. There are hardly very many people in Africa or South America who can share the experience of stability and confidence in social institutions, and most women in the world still have an uphill battle to fight in order to secure their basic human rights.

Even here in Finland, at the very core of stability, we can hardly describe ours as a model country of sustainable social development. There is a growing sense of insecurity in many areas of society: the number of child welfare cases is continuing to rise, the substance abuse problem is spreading, organised crime increasing, the prison population growing, and there is more permanent poverty than before. In addition to these social problems, we have a host of structural problems to contend with, such as unemployment and labour market instability. And what is even more serious: the low birth rate and the ageing of the population mean that the very process of demographic reproduction is called into question. At stake is nothing less than the continuity of our culture and society.

The history of the western world attests to the excellence of the market as a steering instrument. However, the market is not in a position to secure the continuity of culture and society because it does not produce the most important production force of all, i.e. people. Neither does the state produce or raise children. Both the market and the state are dependent on what individuals decide to do, on their informal solutions (Jessop 2002, 10–54). The continuity of society is based upon different processes and principles being mixed and matched in a way that is beyond the control of any centre or system. This is why plain continuity presents such a lasting challenge for research.

The three dimensions of governance

One of the key tasks for social research is to secure the continuity of society's basic functions. Baltic history 1940–1990 provides an excellent lesson on the significance of governance – on just how much can be lost and how quickly it all happens when society is no longer in control of itself. Societies that in many ways were so similar to Finland fell into economic and social decline at the same time as their neighbour in the north proceeded to develop into a Scandinavian welfare state. The effects of totalitarianism, corruption and the collapse of social morality will continue to be felt in the Baltic states long after their revolutions.

The failure of the Soviet system was fundamentally due to a lack of commitment and courage to study one's own society and the human individual as a social agent. The power elite did not want to engage in serious debate on the systems' and processes' weaknesses and shortcomings, never mind listen to any criticisms. There was no real interest in understanding foreign cultures, no real effort to create the conditions for international trade. In spite of its high standards of scientific research and in spite of the political commitment to developing technology and the economy, the system collapsed.

The first dimension of governance is to establish the expertise required by the continuity of society in political decision-making and administration. The idea of an innovation system can be applied not only to technology. Societies are immensely complex systems whose elements and processes are tied together through several different interdependencies. These interdependencies and different possibilities of alliance will only increase with globalisation, and societies will have to make existential choices (see e.g. Jessop 2002).

In order that we can understand how societies and their subsystems work and in order that we can make changes that have more benefits than drawbacks, we need to research these societies and the relationships between their subsystems. Social research is one of the main tools for purposes of training political and administrative experts who are capable of analysing social phenomena from different vantage-points and testing ideas without conducting experiments with human subjects. Not only the standard of research but also its coverage is important here (Sipilä 1998): it is important that phenomena are studied regardless of their associations with theoretically interesting, international research (Allardt 1999, 36). The university has a crucial role to play in building links between research and expertise. In Scandinavia and Europe more generally, the link between the public sector and the academic world works unusually well.

The second dimension of governance is the production of civic understanding. In democracy, the goals of society are set and determined by the individual citizen – the essence of political activity lies in the experience and understanding of that citizen. People certainly have got their basics right: research results have indicated time and again that the things which matter most to people are such simple and great matters as birth and death, love and caring, friendship and solidarity, health and wisdom, peace and security. However, in this complex world none of these ideals can be translated into serious political objectives unless people are able to acquire information, to think independently and to justify their arguments to one another. Access to research that is independent of those in power is crucially important to the development of perceptive, critical, communicating individuals.

I am not sure whether it is proper today in a discussion of the impact of science and research to make any mention of classical discourses on the value of knowing and understanding or to their positive contribution to the development of human personality (Symes et al. 1999, 427–428). Somehow I sense that in this day and age, it is more appropriate to highlight the way that social research among ordinary citizens also produces a pure and genuine pleasure of discovery. Oili-Helena Ylijoki (2002, 60) made the exciting finding that social science students derived the meaning and motivation for their studies not from the prospects of future employment, but rather from what they were studying and from the time they spent as students: "social science students lived in the present tense".

The third dimension of governance consists in creating an acceptable social order by means of thorough-going dialogue and debate. Politics plays a decisive role in determining the future of citizens, especially during hard times, when not only political leaders and experts but citizens need to show a great deal of wisdom and moral maturity. In this situation it is important to understand how different activities tie in with one another, what kinds of ideas, identities and interests different population groups share in common, how things are done elsewhere and why. Society needs a sustainable social order, and that cannot be established without living politics and culture. In the absence of such a social order, society will not be able to concentrate on any long-term development effort even within the economic realm.

A reminder is in order about the role of social research in maintaining the democratic system. "At least in the twentieth century we have seen that wherever democracy has been curtailed and an authoritarian regime installed in power, teaching and research in the social sciences have immediately been suspended at universities and research institutes", Erik Allardt (1999, 44–45) points out. No one can surely forget the role of the free media in this connection. Journalism alone is not enough, though. To do more than just present mundane observations and populist criticism, journalists need to have access to the descriptions, concepts and analyses produced in a long-term research effort.

The specific nature of impact in the letters and arts

It is well known that the social sciences and the natural sciences have different strengths. Bent Flyvbjerg (2001, 25–65) describes the difference by pointing out that the natural sciences aim to explain phenomena by presenting accurate, universal, systematic, abstract and predictive theories. The social sciences, by contrast, have the special task of addressing such questions as 1) where are we heading, 2) is that desirable and 3) what should be done? Finally, we also need to ask: to whom does this apply and who stands to benefit?

In order that it can shape its own future, society needs an endless string of innovations so that its different subsystems (e.g. technology, economy, administration, education, politics) can keep up with the changes taking place in other subsystems. Just as the diffusion of technological innovations, the diffusion of social innovations is based primarily on borrowing. Borrowing has long historical roots, for instance European princes borrowed poor relief innovations from one another as early as the Middle Ages. However, it is much harder to borrow and apply social innovations in another society than it is to borrow technological innovations.

The specificity of information about society does not lie in its contextuality. We find the exact same element of contextuality in the natural sciences: for example, the trajectory of a cannon ball will vary with changes in air pressure, humidity, temperature or gravity. Some people suffer side effects from a certain medical drug, others do not. Context is always anchored to time and place. However, the contextuality of cultural phenomena is particularly problematic from the point of view of generalisability in that even the elements that the context includes are hard to define. They change together with people and cultures. For instance, the criteria we apply in Finland today to assess the social or public good are very different from what they were in the depths of recession.

The difficulty of grasping the context comes from the fact that research on society and culture is concerned with phenomena governed by human consciousness. A brief example: Let us assume that Lisa says something to Matt and that Matt, in response, does something. From this we cannot, however, draw the inference that the same sentence always elicits the same response. If one or the other of the two persons were different or if the scene took place at a different time or in a different environment, it would be bold to assume that the sentence would elicit the same response. Besides, Matt himself may decide to respond this way on some occasions and that way on others.

The capacity of our object of study for independent reflection and decision-making and the variability of the context obviously make it much harder for us to find laws and to use them to steer the process of change. In principle we should not look upon this difficulty as a problem, but rather as the essence of human richness and the democratic way of life: it is precisely the impossibility of centralised control that protects people against abuse and totalitarian systems.

The difficulty of finding laws and the difficulty of control does not mean that social processes are random. Human activity, especially in groups and organisations, is highly predictable, even if it may not be possible exhaustively to determine the motives of individual decisions. Another source of stability is that changes in societies and cultures usually are slow processes: from the situation today we can pretty reliably predict the situation of the immediate future. In principle, forecasting social processes shares much in common with forecasting the weather – even in the sense that storms that move rapidly from one country to another may suddenly also develop in societies.

It is a notoriously difficult business to ascertain the impacts of social research, mainly because those impacts are usually of an indirect nature and are largely mediated by publicity. It is very rarely we can record instances of such direct influences whereby President Urho Kekkonen, upon reading Erik Allardt's theory of the pressure of conformity and Antti Eskola's analysis of social conflicts, decided to do something that had a lasting impact on Finnish political history. In most cases social research will bring to light new aspects of the state of society (most typically problems), provide the people debating the problem with new concepts and draw attention to connections between phenomena that are impossible for the lay observer to see. Active opinion leaders take onboard the results of research from the public realm and live amongst them like fish in water. Yet it is still possible that they are just as unaware of the backgrounds of the ideas they have picked up as fish are unaware of the chemical composition of water.

Measuring impact

Measurement of the impacts of social research is complicated by two main factors: first, the indirect nature of those impacts and second, the pronounced contextuality of research.

It is of course difficult to measure indirect impacts, but not impossible. Much of what could have been done has still not been tried. Just as the standard of national technological research can be assessed using such indirect macro-level indicators as the volume of hi-tech industry as a proportion of total manufacturing and its exports, the same approach can be applied to social research. If public administration is uncorrupted and if citizens are happy with the police, the army, the school system, health care and social security, then the fundamental purposes of social research have largely been met.

Contextuality is, even in principle, a more difficult issue for the measurement of impact. Social research is profoundly contextual because it is not only its data that are contextual, but also its theoretical and methodological perspectives. There are numerous different theoretical and methodological schools, and there is no need nor indeed any point in trying to eradicate their differences: they reflect the different views of different communities, institutions and political trends, and so they should. As a result, views vary on what counts as good and relevant research. But that is not all; the contextuality of research also extends to the composition of the audience. A lucid theory and an advanced methodology do not yet suffice as criteria for good research, but the relevance of research must always and in each case also be considered from the point of view of the community for whom the report has been written.

The contextuality of research does not detract from its international value, on the contrary: different contexts create a useful setting for comparisons that support analyses of the permanence and variability of phenomena. Internationalism is in itself a source of inspiration, but it can also be a problem for a small country like Finland where it may even affect the conditions for carving out a career in research (Hakala 2002, 25–29). Cultural imperialism is rife in the study of culture and society, and the researcher whose work is focused on a small country is by default little more than an interesting curiosity. Researchers who want to gain a more visible presence on the major arenas of their speciality will often have to turn their attentions away from studying their own society.

All this complicates the international evaluation of research and undermines its consistency. Research into society does not take internationalism for granted in the same way as the study of semi-conductors, for instance (see Hakala 2002, 24), but it is burdened by problems related to the contextuality of research and to differences in the premises of evaluation. It is sometimes difficult to appreciate the relevance of a certain line of research from outside the community concerned, and reviewers following different paradigms often disagree in their views of what is good and important research. People from different countries will often disagree in their assessments as well, and therefore centres of excellence that all agree are so valuable and important are never found in social research.

I have argued above that it is first and foremost the object of study itself that needs research into society, i.e. the citizens and the rulers of the society whose cultural and historical context the researcher understands. Research is always conducted not only for other researchers and for the bodies funding the research, but also for ordinary citizens. For this reason the results of research must also be reported to ordinary people in a way that they can readily understand, via forums that they ordinarily follow.

The impacts of social research can of course be measured in terms of the relative prestige of publication venues and international impact figures. Often it also is useful to have international panels to conduct evaluations. However, if all evaluation is based upon these means that best lend themselves to the natural sciences, that is bound to yield to a very narrow understanding of the impacts of social research and render useless a crucial function of social research. We must not allow the methods of evaluation to begin to steer the development of science and research and force certain areas of study to assume forms that are out of character with the genre.

Domestic impact indicators are needed for purposes of assessing research in culture and society. A domestic citation index would be a small but important step in this direction. Writing for popular publications and media participation more generally are an integral and important part of the domestic impact of research. In the letters and arts, this must be recognised as a genuine asset. Assessments of effectiveness must also understand that social research requires different forms of publication than the natural sciences. Context-sensitive research that needs to justify its approaches will often have to present a lot of text before it can proceed to deal with its research data. This is why books and extensive articles in edited volumes are a much more useful form of publication in social research than is generally the case in the natural sciences.

To conclude this analysis, though, the point that needs to be stressed is that social research does not constitute a single, homogenous world. That its objects are capable of independent reflection and that its inquiries are intensely contextual, do not apply to the same extent to all lines of research. Good examples of exceptions include methodological research as well as studies that apply specialised quantitative methods, such as demographic research. Economics is sometimes mentioned as an example of a social science that comes close to the natural sciences and provides explanations of the "second degree". In this case economic constructs that people have created are taken as given facts that can be studied independently of the context (Flyvbjerg 2001, 43–46).

Social science as a methodological tool

In the discussion above I have mainly concentrated on the genre of social research that is geared to supporting the continuity of society. However, social sciences are often used for more instrumental purposes as well, in which case the researcher serves the subsystems of society (market economy, health care) in close collaboration with scholars specialising in such areas as trade and commerce, technology or the health sciences, for instance. Contract research is surprisingly common in the social sciences. Other disciplines need the strong traditions of these sciences above all in analysing and contextualising human behaviour and opinions.

Indeed research on culture and society can be used for instance in addressing questions related to the use of commodities: are innovations considered to have use value, how can people be encouraged to buy different products, how are they used, how do people perceive their use, why are they not used and what do people do with them when they no longer need them? Research that crosses the boundaries of the natural sciences becomes all the more relevant the more complex the technical systems become and the more often they require bringing together technical tools and services.

The impact of this kind of research is seen in demand levels; in the extent to which social scientists are integrated into research teams dominated by other disciplines, in the volume of commissioned research. Impact assessment in this field is facilitated by the fact that market organisations and health care organisations, for instance, are surprisingly similar across different countries. Indeed good research in these fields often gets published on international fora. This is clearly seen when we look at the special role that Finnish health sociologists occupy in international citation indices when compared to other sociologists.

In conclusion

Information has only limited significance as a societal objective. The more the flood of information in the world has grown, the more acute has become the shortage of understanding, sound argumentation, sharp thinking. We cannot expect a great future only to grow out of good research in different fields; we also need to know how to make good use of that research. We need to assess where a particular piece of research has significance, where it is applicable and relevant. For purposes of practical application, we must know how to piece together the endless fragments of results from separate studies. And what is most important, but also most difficult of all, we must all have the wisdom to sift through the research results according to their human use value. A substantial part of our lives remains beyond the understanding produced by the market and the natural sciences.

The fundamental reason for doing social and cultural research is that people would not be available for projects that might harm themselves or other people who are important to them – so that they could defend their interests in the long run, against all kinds of organised power. But that is not all – research has a dual function – research in these fields is also done for the reason that if the rulers want to rule well and righteously, they need to have access to the knowledge and understanding that that requires. At best, research into culture and society is an angry war against stupidity.

So what exactly should be done? It is time now to take seriously research published on domestic scientific fora at least in the letters and arts and to develop appropriate citation indices. Impact factors should also be determined for domestic scientific journals.

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The social impact of research and knowledge application as seen from the vantage point of centres of excellence

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1 The impact of research and the roles of centres of excellence

The impact of science and research is a cultural characteristic that ties in closely with the objectives of research. Generally, science is about producing new understanding and information. This, however, is too simplistic a vantage point for purposes of unravelling the role and impact of science in modern society. A distinction has been proposed between three types of research according to its basic interests: technical or natural scientific, hermeneutic and critical (see Habermas 2002). Research grounded in different kinds of interests is related to the society around in different ways. The social impacts of science appear at different levels of reality and the mechanisms of those impacts vary. These differences mean that the results of research have different roles in society. Research into the structure of the atomic nucleus has different effects from studies of Judean-Christian texts. The predominant impact paradigm has been concerned with the control of nature by means of technology.

Large numbers of centre of excellence programmes are currently underway all over the world, with widely differing concerns and orientations. All these programmes have at least some science and technology policy objectives, aiming to promote various goals by improving knowledge and know-how. Most of them have the aim of boosting national competitiveness by strengthening the basic structures of knowledge and know-how. Internationally, the field is diverse, and some of the programmes attach more importance to the element of new know-how rather than that of knowledge (see Malkamäki et al. 2001). One of the distinctive features of the Finnish centre of excellence programme is that it is emphatically oriented to high-quality basic research, including technological research. The main objective of the programme is to raise the standard of research work in different disciplines and to reach the cutting edge of international science.

The disciplines represented in the Academy's programme reflect the changes that were seen in the allocation of science funding during the 1990s. Over the past decade investment in the natural sciences and medicine has increased by some ten percentage points. Compared to the other Nordic countries as well as Germany, Japan and the United States, this has been quite a exceptional turn (OECD 1997, OECD 2001). The humanities and social sciences have been underrepresented in the Finnish centre of excellence programme, partly because of their preoccupation with questions of national importance.

Contents

2 Defining the social impact of research

Sociologists first began to talk about the transformation of industrial societies into information societies in the 1970s (Bell 1974). Since then, information has continued to become more and more important in society as well as in the discussions and debates on the development of the economy and welfare in modern societies. This change has also prompted a reassessment of the role of academic research and universities. In Finland the development has culminated in proposals by the Ministry of Education that universities be assigned a third function: that of exercising a social impact (Opetusministeriö 2002).

The social impact of scientific research can be taken to refer to the ways in which research work and its results change a certain social practice, ways of thinking or ways of doing things. Changes in social practices are always reciprocal (Giddens 1984). This applies to the social impact of research: it consists in interaction. Social impacts are created when *knowledge and know-how are integrated*, through a process of change, as part of a new way of thinking, a new practice or product. Reciprocity and the emphasis on practice changes are crucial in the analysis of the impacts of science. Those impacts are created in networks of new knowledge production and application. Social practices are transformed by interpretations and artefacts developed in practical contexts (cf. Tuomi 2002). The diversity of impacts can best be understood from the vantage point of the diversity of reality and the diversity of research interests. Understanding, criticism and reality control have different impacts on social processes.

The linear model of innovation has dominated thinking about the social impacts of science, soon after the Second World War at least until the late 1960s (Guston 1999). It was assumed that new information generated in basic research is the ultimate reason among other things for impacts appearing in the shape of technological innovations. Research into science and innovations has shown, however, that this relationship is not quite as straightforward as that. True, science has shaped and changed practices, but on the other hand practical problems have also influenced the development of basic research (e.g. Stokes 1997). Even when changes grow out of science and research, the rest of society needs to be receptive enough so that the results of science can be transferred into practice (see Boaz & Hayden 2002). In the absence of good practical receptors, even the best scientific ideas will not lead to practical change. It is this that lies behind the new emphasis upon the impact function: a new understanding of how the social impacts of science and research evolve. Those impacts do not develop in and of themselves, but as a result of active interaction.

Table 1 helps to understand the diversity of the social impacts of science and research. The impact of academic research unfolds in a process of interaction among different key sectors of society.

The table does not propose to be exhaustive, but simply provides a few examples of the factors on which scientific research can have an impact in society. The social impacts of science and research appear at several different levels. Research cultures and their views and ways of going about things, shape and influence society as new competence holders move to the service of other sectors in society. New scientific innovations serve as

Table 1. Sectors of science impacts in society.

	Knowledge producers	Knowledge users
University sector	– academic basic research – oriented basic research	Scientific teaching – practical training for research and development (training for researchers and experts)
Other public sector	Sectoral research – oriented basic research – applied knowledge production – product and process development	Public administration and services – developing knowledge base for political processes – interpretation of laws and agreements – public economy – public radio and television
Business and industry	– applied R&D in businesses, product and process development – critical journalism	– users of knowledge-intensive intermediate and final products – media
Third sector	– critical social debate	Civic organisations, everyday actors – civic discussion and debate – change of everyday consciousness and local cultures

the platform for the development of new modes of action and new technologies. Science institutions, universities and research institutes are an integral part of the innovation system whose relations of interaction and modes of action for their part influence the opportunities for exploiting research results.

Scope of the survey

Modern science covers virtually every aspect of human life. In ontological terms it covers multiple different levels, from the basic structures of the physical world to cultural artefacts. Science, as a societal institution, is committed to values and activities that are considered important in modern society, such as advancing human understanding, developing world-views and national identities, understanding the relationship between humans and the animate nature, promoting welfare, developing technology and economic activities. Indeed, broadly understood, the impact of science refers to the way that research promotes these important values.

The 26 units appointed to the national centre of excellence programme in 2000–2005 represent a broad spectrum of academic disciplines. Most of them are university research units, but a couple of units based at research institutes are also included. The programme comprises units from the fields of physics, chemistry, the biosciences, ecology, medicine, neuroresearch, engineering and cultural and social research. Given the breadth of its coverage, the programme can also be expected to have wide-ranging social impacts. The discussion below weighs the social impact of Finnish centres of excellence in research in relation to the values outlined above. The analysis is based on interviews conducted with the directors of centres of excellence during the spring and summer of 2002. One of the themes covered in these interviews was the applicability of research knowledge and cooperation with end-users of that knowledge.

The analysis is qualitative in nature. Its aim is to identify different types of social impact and to describe the ways in which research units have sought to increase the social impact of the work they do. This, it is hoped, should help to broaden and diversify the somewhat narrow perspective that currently prevails in the discussion on social impacts. According to Erik Arnold, evaluations of socio-economic effects have tended largely to focus on economic effects and on "hard" science and technology (Arnold 2001). Such a limited view on the social impacts of science does little justice to the many different ways in which research exercises its influence in society.[1]

3 Types of social impact

3.1 The cultural and social impact of research – changes in culture, working life and education

Cultural impact refers to the development of new interpretations and understanding about everyday activities. Socio-cultural impacts find expression among other things in changes in values, ways of thinking, norm systems, institutions and ideo-political structures in societies. These constitute the core of social innovations. Social innovations are reforms related to the above changes that can be established as social practice.

Academia has been a major force of social impact in Finland ever since the country gained independence in 1917. Many of the names and figures who have shaped Finnish culture and ways of thinking have been learned men of the university (Ihamuotila 2002). Prominent opinion leaders in society have often had a background in cultural and social research. According to Erik Allardt, the university intelligentsia continues to take an active part in the debate on social justice and on the development of culture and enlightenment, drawing upon the skills of grounded argumentation. Natural scientists, Allardt goes on, have been less interested than their colleagues in culture and society to participate, even though there have been plenty of topical issues where their high-level contribution would have been appreciated. Indeed many of the burning problems for all humanity are such that natural scientists could give an immensely valuable contribution to critical debate.

The most immediate cultural and social impacts can be expected of centres of excellence that focus in their research on culture and society. In these fields it is often hard to draw a firm boundary line between research knowledge and its social impacts, and the way in which researchers see this relationship depends upon the epistemic views they have adopted. Indeed, many consider the whole distinction between basic scientific research and applied studies as artificial. Professor of the Year 2003, Simo Knuuttila echoes an opinion that is quite widely held among researchers in this field: "Everything we write in the Finnish language has social impact." Professor Knuuttila wants to promote a culture of knowledge, to challenge self-evident truths and to clarify thinking. The maintenance of a culture of knowledge, social skills and moral consciousness is easily

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[1] The training of experts is not covered in this discussion, in spite of its importance as a form of social impact. In Finland, the importance attached to this training function is clearly reflected in the provisions of the university act according to which higher education based on free research is the primary function of universities. Furthermore, one of the key measures of university performance is the level of doctoral output.

considered a matter of course. On the other hand, it is easy to see that if these structures have collapsed, none of this is easy to create. Professor Knuuttila also points out that the social impact of the humanities has received only scant attention because it is hard to find appropriate economic indicators (Helsingin Sanomat 11, Jan 2003). Although some aspects of reality cannot be quantified, that does not make them unreal. Perhaps the provocative views of Professor Knuuttila need some toning down: Every text or every speech that persuades people to question matters of course and to think or behave in a new way, has a cultural impact.

The Centre of Excellence Programme 2000–2005 includes five units that represent the human and cultural sciences: the Research Unit on the Formation of Early Jewish and Christian Ideology under the direction of Heikki Räisänen; Ancient and Medieval Greek Documents, Archives and Libraries under Jaakko Frösen; the Research Unit for Variation and Change in English under Terttu Nevalainen, formerly Matti Rissanen; the Center for Activity Theory and Developmental Work Research under Yrjö Engeström; and The Human Development and Its Risk Factors Centre under Lea Pulkkinen. Research at these units covers all knowledge interests, although the main emphasis is upon hermeneutic and critical interests of research.

The historico-critical Bible research represented by Professor Heikki Räisänen and antiquity research represented by Professor Jaakko Frösen are both concerned with the deep structures of Finnish and Western culture. Historico-critical research is ideo-critical, it calls into question and historicises the Judean-Christian beliefs embedded in the deep structure of culture. Research influences the debate on values through its critical evaluation of tradition. The involvement of scientists in the debate on Christian beliefs helps to make this a less dogmatic affair; the recent debate on new legislation that paved the way to same-gender partnerships provides a useful illustration. Finnish translations of recently unearthed texts have given the general public direct access to formerly unknown scriptures on the early formation of Judean and Christian tradition.

The study of antiquity is aimed at preserving our shared cultural heritage. Part of this work involves producing objects of permanent value that will be kept and displayed at museums for future generations. Information has been made available to the general public in various different ways. Some projects have been in the position to organise trips. The Petra exhibition that was staged in 2002 together with the Amos Anderson museum was largely based on research conducted by the unit under Jaakko Frösen, its expertise and the unit's close contacts with museums in the Middle East. Historical discoveries can sometimes be quite touching even for people living in the modern world. "All research in the humanities involves a human element: people's joys and sorrows tend to remain the same even though the technology around may change" (Frösen). The exhibition used various means to bring to life the everyday world of people in antiquity, from displays of archaeological finds and photographic exhibitions of the research area to modern multimedia. In this day and age when various shallow visions of the end of history seem to have quite a considerable following, a closer understanding of the man of antiquity helps us to gain a clearer picture of the historical nature of the problems we are facing in the world today. Antiquity research on the Middle East might also be able to bring closer the parties to today's ongoing conflict by drawing attention to the common cultural roots of the different population groups in this area.

Understandably, social impact is not among the priority concerns in the humanities research conducted at the Research Unit for Variation and Change in English under Professor Terttu Nevalainen – although the unit is extremely active in training English language experts, i.e. new teachers. The approaches developed at the unit also have an impact on the development of the language of communication. In the future, the IT tools developed for research purposes will prove useful in the production of new dictionaries.

The impacts of the three units discussed above are all focused on language and the ideological world. By contrast the work that is done at the Human Development and Its Risk Factors Centre and at the Center for Activity Theory and Developmental Work Research has more immediate impacts on social action. Researchers at these units are concerned with important processes of interaction and institutions, working life and education.

At the Center for Activity Theory and Developmental Work Research, the social impact of research is built into the research process itself. The theoretical problems addressed in research are closely integrated with the processes of change in the organisations with which the centre is collaborating or that they are studying. These changes are not made up, but implemented in "experimental" projects. Research materials and results are fed back into the target organisations for further deliberation. These projects that focus on practical changes in organisations also produce materials for further theoretical analysis of the problems concerned. Long-standing cooperation with the target organisations provides a sound foundation for continuous development both in the realm of research and practice. Indeed the unit has extensive links of cooperation with various organisations in working life. The unit also has a separate steering group with experts representing different areas working together to identify current and relevant research questions.

The difference between the units working under Professor Engeström and Professor Pulkkinen well illustrates the diversity of human research. The approach of action research and its relationship to knowledge may be described as oriented basic research: it explores the practical problems of organisations and on the basis of its findings seeks to resolve those problems. In this approach, practical impact is intrinsic to the methodology of research.

Human Development and Its Risk Factors represents a more objectivist approach that is closer akin to the natural sciences. In Stokes' (1997) terminology, this line of work may be described as academic basic research. It has spanned a very long period of time; the subjects have by now been followed for decades. The objectivist approach leads to a different relationship to practice: research projects and practical development projects are more clearly demarcated from one another. The unit's social impact is well characterised by the same arguments that were used by the European Federation of Psychologists' Associations upon announcing its decision to award the Aristotle Prize 2003 to Professor Lea Pulkkinen. Most importantly, reference was made to her life-long research on questions of personality and social psychology which bring science and profession together in a unique way. Another factor mentioned by the selection committee was the active involvement of Professor Pulkkinen in practical and political discussion, decision-making and educational reforms as well as in the development of new practices for supporting children in daycare and at school. According to Professor Pulkkinen, “institutions of applied research and science communication need to be developed with a view to bringing academic research closer to the world of practice and to facilitating the transfer of scientific results into practice.”

3.2 Interactions between culture and nature – the impacts of ecology on administration and politics

Ecology is a natural science that through its object of study ties in closely with societal phenomena. Ecology is concerned to study the animate nature, the adaptation of organisms to their environment: it lies in-between the physical world and the world of consciousness and culture. Ecologists approach nature in terms of ecosystems constituted of animate and inanimate nature. These natural systems are to an ever greater extent influenced by human activity. Ecology helps people to understand the impacts of their actions upon the natural environment. The social impact of ecology is thus of an inverted sort: the discipline helps people become aware of the impact that their actions have had and are continuing to have upon the environment. A positive type of impact is that this information can be used to control and remove the adverse effects that human activity causes to natural systems. In other words, people can use ecological knowledge to achieve their goals, without causing harm to the natural environment. Natural scientific and critical knowledge interests are most typically combined in applied ecology.

The Academy’s centre of excellence programme includes three units in the field of ecology, viz. the Metapopulation Research Group at the University of Helsinki, the Evolutionary Ecology Research Unit at the University of Jyväskylä and the Forest Ecology and Management Research Unit at the University of Joensuu.

The relationship between research at ecology units and practice is well captured in the statement by Professor Ilkka Hanski, who points out that “in keeping with the nature of our unit we continue to engage in basic research, but the dividing line between what is basic research and what is applied research is no longer as clearcut as it used to be”. The relationship between basic research and applied knowledge production is differently weighted in different ecology units. The Metapopulation Research Group is concerned to study changes in the living environment, often the fragmentation of living environments. Drawing upon their research findings, biologists can offer sound assessments of what they believe has happened. The increasing significance of applied knowledge is seen in the fact that the unit is nowadays funded by both the Ministry of the Environment and the Ministry of Agriculture and Forestry.

As well as engaging in basic research, the Evolutionary Ecology Research Unit runs applied projects in the biology of nature conservation: these, according to Rauno Alatalo, are concerned with the impacts of changes upon natural restoration. For example, the unit has joined forces with the Ministry of Agriculture and Forestry to study the use of controlled forest fires in the protection of endangered species; and with the Central Finland Regional Environment Centre to support a project aimed at obtaining new conservation habitats for the whitebacked woodpecker. There have been at least two kinds of problems in practical cooperation. First of all, the information produced in research has no immediate economic value, nor do end-users and political decision-makers like it. Secondly, people at the application end of the chain expect simply to be handed ready-made information packages rather than being prepared to spend time and effort to find out about the complex problems of restoration. Application requires effective knowledge management and a sense of proportion, and that in turn can only be achieved through in-depth understanding.

Forest management, drawing upon the support of forestry research, has always been an important part of the national economy in Finland. The Forest Ecology and Management Research Unit led by Seppo Kellomäki, shows a stronger orientation to practical application than the former two centres of excellence. Basic and applied research is carried out within the same projects. One of the areas requiring basic research is that of modelling. As well as providing access to timber, the integration of the ecological perspective with forest use would help to conserve carbon and nutrient reserves. EU projects are focused on themes that are important to the EU. Involvement in a number of such projects has been an important way for the unit to increase the impacts of its work. Questions of restoration are also on the research agenda at the Forest Ecology and Management Research Unit, which in this area works closely with the Finnish Forest and Park Service, the forest industry and the Ministry of Agriculture and Forestry. The development of forest management methods, such as controlled forest fires, has benefited numerous endangered species, and some projects have found species that it was thought had already been lost. Cooperation with end-users is important for purposes of identifying research needs and fresh perspectives: practice throws questions at researchers that they do not necessarily have to consider at all in the context of academic work.

The Forest Ecology and Management Research Unit has close contacts with applied research institutes, the Finnish Environment Institute, the Forest Research Institute, Agrifood Finland and regional environment centres. Research cooperation with these institutes is designed first and foremost to support agriculture and forestry as well as game management. For Metsäteho, a private company providing R&D services related to wood procurement and wood production, the unit has produced research models for purposes of determining the impacts of forest management on the nitrogen and carbon cycle and optimising forest use.

Other ways in which ecology can have a practical impact is through the training of experts who are capable of practical application; participation in committees concerned with environmental protection; consultation; and different kinds of science popularisation.

3.3 Promoting human welfare through research – how basic research can help to improve people's health

Human welfare can be defined from the vantage point of need satisfaction: people need to have that whose absence causes them to feel unwell (von Wright 1985). People feel well in so far as they can satisfy their essential needs and achieve the goals they have set for themselves. Research can promote the welfare of individuals or larger groups of people. Welfare or well-being is a highly complex, multilayered concept. The promotion of welfare may concern factors that have to do with people's standard of living and quality of life, or factors that are often described as individual self-realisation.[2] Finnish indicators of sustainable development regard acting capacity as an even more important measure of quality of life than health. The social impact of the research units discussed above might also be considered in the broader context of welfare: in the last instance the impact they are seeking to exercise is aimed at promoting people's social and individual welfare. Most typically, the promotion of welfare or well-being is associated with health research. There are two main reasons for this. First, health is considered an important value whose promotion is considered desirable and worthy of public support. Welfare thus becomes identified with health. Secondly, health research does not involve the same kind of conflicts of interest as research into poverty, for example. Health is unequivocally considered to promote human welfare and well-being. Although poverty is widely regarded as deplorable, there are still political ideologies that consciously de-emphasise the adverse effects of poverty on welfare.

Six research units in the Academy's centre of excellence programme have included health promotion among their long-term goals: the Cancer Biology Research Programme under the direction of Professor Kari Alitalo, the Finnish Disease Genes Research Unit headed by Professor Leena Peltonen-Palotie, the Cell Traffic Research Unit headed by Professor Sirpa Jalkanen, the Collagen Research Unit headed by Professor Taina Pihlajaniemi, the Molecular Neurobiology Programme headed by Professor Heikki Rauvala, and the Biomaterials Research Group headed by Professor Pertti Törmälä are all concerned to study problems that in one way or another are associated with health promotion. All units recognise the practical significance of the research they are doing, but they differ in terms of how far they allow that to influence and steer their work. In all cases that work may best be described as oriented or use-inspired basic research, grounded as it is in a more or less clear understanding of its beneficial health effects. But even though it is use-inspired, this is still basic research: research problems are formulated with a view to gaining a deeper understanding of biological processes and mechanisms. Any practical benefits that come out of the research are a bonus, it is not specifically geared to producing such benefits. The unit working under the direction of Professor Törmälä differs from all others in that it is specifically aimed at practical application. In terms of its knowledge interests, the research at these units leans towards the natural sciences and engineering.

There are two critical conditions that any research aimed at promoting health and welfare needs to meet in order to have a practical impact, that is to have good clinical cooperation or to work closely with companies engaged in the development of pharmaceutical and health technologies. Without such cooperation, the impacts of basic research are bound to remain insignificant, or at the very least these impacts will be spread out over a much longer time span.

Scientists in Finland are in a unique position internationally in that national *legislation* allows them to use existing patient materials for research purposes. In the United States, for instance, legislation prohibits the use of such patient materials and registers.

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[2] Erik Allardt's studies on the dimensions of welfare in the early 1970s remain a useful source on the empirical breadth of welfare

Furthermore, patients in Finland have strong faith in the integrity of scientists and generally take a positive attitude towards the use of patient data for purposes of health promotion. A good, *confidential relationship* with patients is crucial to the success of clinical research. One of the factors that has certainly contributed to public confidence is the Nordic health care system which emphasises the importance of joint responsibility and the common good: people believe that by consenting to release information, they will be doing what is in the best interests of everyone, including themselves. The more closely private interests are involved in health research, the more critical is the factor of public confidence and access to information. Good *collaboration* between academic research and clinical research has been the third success factor in Finnish health research: close cooperation engenders fruitful dialogue between basic research and clinical studies.

In oriented basic research, ideas and initiatives for research flow from basic research towards clinical research and the other way round. For instance, computation models that are used in the analysis of gene profiles that lie behind asthma or hyperlipidaemias, have immediate clinical application as well. On the other hand, many specific projects in disease genes have grown out of the clinician's curiosity. In the field of graft technology, surgical know-how is an important part of the development of new materials and technologies. Innovations inspired by basic research typically lead to new practices of care and treatment that are based upon new technologies; it is very rarely that they affect existing treatments. Clinical cooperation among different units covers a broad range: disease-related genetic heritage, cancer diseases, cartilage and bone diseases, muscle and heart diseases and various grafts are among the areas where there is ongoing cooperation, or where such cooperation is expected soon to start up. Neurological diseases come close to the scope of the neuroscience unit, but as yet there is no direct clinical cooperation in this field.

Another important channel for welfare effects is collaboration with the private business sector, both existing firms and new spin-offs. In their collaboration with business enterprises, research units are keen on to emphasise the importance of maintaining a clear division of labour. It is also important to recognise that research units and business companies have different interests, which in turn means that the people working in the two sectors need different skills and competencies. Scientists believe it makes most sense for them to concentrate on what they do best, i.e. research. They are keen to set themselves apart from product development in the business sector. Fee-based research services for the development of new gene tests, for instance, are not considered part of the duties of centres of excellence. Legislation, standardisation and testing related to pharmaceutical development do not fit in with the profile of units aiming at new knowledge innovations: this requires the right kind of people with the right kind of expertise. Scientists feel that their own know-how and expertise is wasted in standardisation work, on the other hand they feel that the translation of innovations into commercial products requires a different kind of expertise that requires a special commitment.

It is crucially important for fruitful cooperation that the business partners have a high level of know-how and expertise: they must understand and appreciate what research is about and closely follow the latest trends in research so they can identify its true application potential. Indeed several units have close contacts with business partners who are doing just that: constantly monitoring the research that is done at the centres of excellence and trying to see which parts of that work carry the potential of useful application and patenting. These parts they will then use in the development of new drugs, tests, implants and other applications.

Some lines of work at the centres of excellence have led to the establishment of spin-off companies with which the centres continue to work closely. The most recent example is a business called Geneos, a company with a staff of three who are working to develop diagnostic methods for asthma and certain other genetic lung diseases and, in the longer term, receptor-targeted drugs aimed at preventing the onset of those diseases. For purposes of patenting their research results, the centres have also used the services of Licentia Ltd., a joint venture of the University of Helsinki and Helsinki University of Technology that is aimed at the commercial application of university research.

All the units described here feel that the research they are doing has direct relevance to the promotion of human health. They have different emphases on the two criteria mentioned above, and they also differ in terms of the way that the social impacts of their research are created. On the one hand this has to do with how much weight the centres of excellence place upon clinical cooperation, and on the other hand with how closely they structure their research around the problems of the discipline. Clinical cooperation is important to all units with the exception of molecular neurobiology, which also stresses the importance of orienting to problems identified within the discipline. Professor Törmälä's unit shows the strongest practical orientation and commitment to clinical cooperation.

3.4 Technological impact of research – human curiosity and practical problem-solving

Technological impacts are most typically associated with research in the natural sciences and engineering. The model of linear innovation impacts in research derives from the relationship between these two fields of study: knowledge produced by physical research allows for better technological control of the material reality. Although this is a mechanistic and simplistic image, it describes the situation in the practical development of high technology. Technology is a tool used for purposes of controlling reality, and the development of generic technologies requires an ever deeper understanding of the workings of nature.

The social impacts of most centres of excellence appointed for the 2000–2005 term are primarily of a technological nature. Three of these units: the Research Group for Computational Material Physics, the Low Temperature Laboratory at Helsinki University of Technology and the Research Unit for Nuclear and Material Physics at the University of Jyväskylä Department of Physics, are primarily engaged in basic physics research. Basic biology research is carried out by the Helsinki Bioenergetics Research Group, the Structural Virology Research Group, and the Plant Molecular Biology and Forest Trees Biotechnology Research Unit. The first of these groups has interfaces primarily with basic physics research rather than applied fields; the latter two believe that knowledge application has growing significance and devote much of their attention to looking into the potential applications of basic research results. The Process Chemistry Research Group at Åbo Akademi University brings together theoretical and technical know-how in chemistry. The Neural Networks Research Unit, the Signal Processing Research Group and the Institute of Hydraulics and Automation are engaged in different fields of technological research. The Industrial Biotechnology Group at VTT Finland shows the strongest orientation to practical application among these centres of excellence.

All physics research groups are keen to stress that the work they do represents basic research. The main focus is upon problems that stem from the field of research; practical application is not overlooked but it does not determine where the spotlight is turned. Nonetheless all the units have cooperation that is geared to creating new applications, although that cooperation assumes very different forms. In their collaborative projects the research units focus most of their attention on basic research. Some of the outputs from basic research such as computation software and patents have had more or less immediate industrial application.

One important channel of social impact is to allow people who are involved in practical application to attend project steering groups and project meetings. Many of the issues raised as discussed at these meetings are of immediate interest to end-users as well. Impacts here depend not so much upon publications as upon informal contacts. These units have worked closely with many hi-tech companies, in some instances they have even arranged joint scientific seminars.

Spin-off companies have emerged from two different centres. The best known of these is a company that spun off from the Low Temperature Laboratory to develop MEG equipment: employing a staff of 25, the company was later taken over by an American outfit. At the spin-off stage there was very close collaboration between the research team and the centre of excellence, in fact a couple of product development engineers for the company were employed at the centre. The know-how that was built up in the course of developing MRI equipment led to the start-up of a medium-sized industrial company that by now has also been taken over by the foreign competitor. At Jyväskylä, a spin-off company has been created around thermometers that can be used for measurements at nanolevel. There is broad cooperation among others with the paper industry, space industry, electronics industry and the pharmaceutical sector.

For physics units then, cooperation with the business sector presents no problem. In their joint projects the research units are well able to maintain their own research profile within the confines of the prevailing division of labour. However, the risks are certainly appreciated and there is ongoing debate on how the centres of excellence could bolster their impact without losing their scientific integrity. Collaboration between the Low Temperature Laboratory at Helsinki University of Technology and VTT Finland provides a good model of cooperation.

According to Professor Mikko Paalanen, Director of the Low Temperature Laboratory, it is important for any university-based research group to follow its own indigenous research ideas; it needs to have its own research identity. That identity is thrown into serious jeopardy if the research group begins to ask topics from outsiders. By doing research commissioned by clients, the centre will lose its way and the development of research will come to a grinding halt. The basic research unit is separated from Finnish industry by quite some distance. VTT Finland specialises in industrial cooperation and has had impressive success for instance in the development of brain research equipment. In these prototype projects VTT has been involved in developing new products for business companies, including sensors and examination rooms for brain imaging equipment. It is difficult for researchers to know exactly what kind of equipment consumers need. There has to be some division of labour in this regard as well. Basic researchers cannot do everything themselves, but they need a partner with whom they can exchange ideas in a fruitful dialogue.

> “If we come up with something new in our basic nanoelectronics research, it is their job to look at potential applications in industrial instruments: they will know whether these low temperature detectors can be used in industry. I’m sure this is the right way to go for both us, we don’t have to try to get into industry, VTT will tell us straight out what will work and what won’t. [They are] a really sophisticated lot. Sweden doesn’t have anything comparable to the VTT, Germany has the Fraunhofer Institute. On the other hand this helps us to cut the number of unnecessary applied projects.” (Professor Paalanen)

Basic biosciences research shares some of the same problems of technological impact as basic physics research: these problems have to do with how the knowledge gleaned from basic research is put to use, with maintaining the scientific integrity of research. For basic biology research, an additional challenge is that it ties in so closely with medicine. All medical research is driven by the practical goal of finding a cure for human diseases. This, however, is the point where the world-views of natural scientists and medical scientists diverge: “For the natural scientist, man is one creature among others. Medicine, for the natural scientist, always appears as an application of biology”, Dennis Bamford says. According to Professor Bamford, the task of application must be delegated to other, business actors. This is not something the research unit should do, even though it can offer its help. You need to have separate people to work on development. The research unit headed by Professor Bamford have patented some of their findings that have prompted the creation of a spin-off company specialising in RNA technology based on viral research. The purpose is to combine enzymes that can be used in RNA manipulation, to find combinations that have potential application. The company would need an extra injection of personnel and funding resources in order to gain added impact. There is a shortage of venture capitalists.

The use and manipulation of the structure of animate creatures brings ethical questions to the surface. Scientists in the United States, for instance, have greater latitude than their European colleagues to develop and use genetically modified or GM plants: researchers here are more constrained in the development, patenting and application of new technologies. Nonetheless patents have been awarded, some have even been sold to other countries. Researchers at the Plant Molecular Biology Research Unit consider it a real risk that new knowledge originating in Europe escapes in the form of patents to such countries as the United States or China, which have less restrictive applications policies. There is, however, business cooperation in the Nordic countries as well as in the context of EU projects that is promoting the use of genetic information. Cooperation on the domestic scene is very much hampered by the scarcity of business partners as large numbers of companies have closed down. The forest industry keeps a close eye on progress, but does not get directly involved in research projects. Some expert consultancy is provided in the public sector in environmental and GM issues.

For units engaged in what may be described as *basic technological research,* business cooperation assumes a rather different form. Here, technological impact is an in-built part of research: every project always starts out from the question of what practical use this research will have. A key criterion of research is whether it will have practical benefit, whether it will bring improvement to whatever the study is about. This means there is always a yardstick even for theoretical research. The themes of research are chosen on the basis of practical problems; in many cases there is some industrial or social motive for research. Models that do not to contribute to improved technical control of phenomena are not considered important, nor are the results of such development efforts usually even published. According to Professor Mikko Hupa, their research does not uncover new laws of nature, but very often it will be concerned to unravel complex phenomena that are closely interwoven with one another. *Research helps to establish better control over those phenomena.* Such is the technical complexity of these problems that even the industrial competitors may be involved in the same project. Solutions to those problems will pave the way to development, which together with commercial application is an arena for open competition among business companies.

Research units are generally very careful to maintain a strict boundary line between their own research and practical application. They very rarely engage in commercial research. A distinction is typically made between *prototype* and product development: research units operate in an area that borders on application, just outside the realm of corporate product development. Research units are concerned to develop universal technological solutions on the basis of which companies can proceed to create new products and services. Proper product development is very rare; that is considered the exclusive domain of companies. Most companies, too, prefer to work on product development on their own, although they do to some extent commission work to research groups. Generally speaking, research units will decide upon their involvement in projects on the basis of whether or not they expect to benefit in the form of increased knowledge and know-how. Professor Matti Vilenius from the Institute of Hydraulics and Automation at Tampere University of Technology has this description of the objective of basic technological research:

> "We try to build our tools of basic research in such a way that they can be used to resolve practical problems. As far as the relationship between research and practice is concerned, you could say that research provides the tools with which engineers can then set out to design new machines. Research in itself may be quite strictly practice-driven, but all the time we are now moving in a direction where theoretical development is pretty important because experimentation alone will not get you very far … what you are really aiming for are solutions that have broad application across many individual cases. For instance, the excavator boom and the harvester boom are both booms. You need to have basic tools that you can use to resolve problems on both." (Professor Vilenius)

Control technology has by now reached such a high standard of sophistication that the problems in boom technology are approaching the problems of controlling physical movement. Technological research is approaching physical research.

Another reason why research units are keen to maintain a clear distinction between industrial cooperation and unit research has to do with the use (and possible misuse) of labour. Cooperation between academic research and industry in Finland is still very much in its infancy and therefore there has not yet been much debate on unwanted side effects concerning cooperation. Finnish universities of technology have a clear and straightforward position on any instances of malpractice that may distort competition: teaching and research staff who are paid from the public purse shall not be hired on business projects in which the professors in charge have a vested interest.

Research units are also somewhat dubious about corporate projects that involve some aspect of confidentiality, which means that not all results can be released in the public domain. There is a conflict of interests here between the research principle of transparency and openness, on the one hand, and the principle of corporate ownership of private information, on the other. As a rule the problem has been more or less successfully contained. Research units have realised the importance of making clear their interests to publish as early on in the project as possible. Very often the majority of research findings (some estimates put the figure at 80%) are such that there are no obstacles to publication. Many projects have their own steering group that will give permission for researchers to release their results. Some research groups have industrial partners who are themselves competent researchers, and they will write up the research together. The information that needs to be patented or that otherwise is obviously beneficial to the business partner concerned, will become the intellectual property of that business. Ownership rights will also depend on the company's financial contribution to the project. One of the ways in which companies restrict the use of the information and technology produced is to prohibit their use in projects involving rival firms.

On the other hand, industry too is often reluctant to disclose strategically important information. Where the boundary line is drawn in different projects will largely depend upon the partner's competencies and abilities in product development. At some stage, the business partner will want to take charge of product development. These joint projects are very useful for research groups because they provide an insight into the practical problems in the field concerned and support the development of new research projects. It is precisely in technological R&D projects that the benefits of reciprocal information exchange are most clearly apparent.

Technology transfer in joint projects with industry takes place in various ways. Industry representatives will often be involved in project or programme *steering groups*, in which case the relevant information is transferred through meetings and informal discussions. VTT Biotechnology has its own formal body, the so-called *industry forum* which involves 16 Finnish companies. The forum has its background in a national basic research programme in biotechnology. Research results are reported and discussed at seminars. If the discussions at these seminars do not lead anywhere, the centre of excellence will contact industry directly and try to find out whether the results should be patented and if so, whether companies are prepared to use the patents.

If the business partner has a sufficiently high level of scientific expertise in-house, it may in one shape or another take part in the *implementation* of the project. In this case there will be close and regular interaction between the two parties. This is an extremely efficient way of organising the transfer of both general information and information that is particularly useful to the company concerned. Joint projects with industry often involve young *students* who upon graduation move to work elsewhere within the industry. This channel of personal technology transfer is important for these young people's job careers and is of great interest to students who in technological fields are often very practically minded. In many cases the research unit's contacts with industry are based upon this horizontal movement in the job market. *Research reports* are of course one channel through which information is transferred, but their practical impact is limited.

There are a couple of units that, unusually, have their own commercial production. The Research Unit for Nuclear and Material Physics at the University of Jyväskylä Department of Physics produces radioisotopes for the pharmaceutical industry, and the Industrial Biotechnology Group at VTT Finland produces enzymes and microbes for small and medium size enterprises. This is motivated, on the one hand, by interests of maximising the capacity utilisation of highly expensive equipment. On the other hand, the level of sophistication in small and medium size enterprises is not yet high enough so that they could manage without the services of the Biotechnology Group.

The natural sciences and engineering units that are involved in the centre of excellence programme can be divided into two main groups on the basis of their impact mechanisms and structures of cooperation. Units engaged in basic natural sciences research have a less immediate relationship to application and to end-users than do units engaged in basic technology research. Their research is more far removed from the practical problems of industry, and indeed it is often necessary to have some kind of *intermediary* to link together the work that is done in research units and the interests of industry. For units engaged in basic technological research, practical application is a built-in motive. They can work directly with industry; if they have a problem, that is more likely to be not too distant a relationship, but too close a relationship with industry. In some cases industrial projects may prove to be too heavy a drain on the unit's resources, throwing in jeopardy the reproduction of the unit's know-how assets. To some extent this may even affect the extent to which units want to advertise the industrial cooperation they are doing and its economic value.

3.5 The economic impact of research – from investments to derivatives

In the discussion above we have at many points briefly touched upon the economic impacts of research. Economic impact refers to such factors that promote economic activity within society. The most typical examples of the economic impacts of research are commercialised product or process innovations, or spin-off companies based on new knowledge. Other examples of economic impact include the development of public finances, the development of work cultures and organisations or the development of character structures and an attitude climate that fit in with the modern economy.

Economic and technological impacts are often closely related: new technology is developed specifically with a view to producing economic impacts. Indeed 15 of the Academy's centres of excellence have cooperation with the private business sector. Apart from engineering, there is business cooperation also in the natural sciences as well as medicine. Even a couple of units in cultural and social research have cooperation with the business sector, most notably in the development of working life.

Different forms of science impacts are reciprocally dependent on each other. For instance, economic activity promotes welfare and vice versa. A high level of know-how and intellectual capital supports the creation of economic value, but on the other hand economic prosperity is a condition for the development of knowledge-based society.

It is important to make a distinction between *direct and indirect* economic impacts. Many centres of excellence are engaged in basic scientific research in their respective fields. The economic impact of their work is more often of an indirect rather than a direct nature, if the latter is taken to mean outputs that can be measured in terms of monetary value. The impact of basic research is also broad in scope rather than being specifically localised. Sometimes, scientific innovations related to the deep structures of knowledge can give rise to whole new fields of technology.

Research in culture and society is rarely aimed at direct economic impacts. All centres of excellence, however, have indirect effects, for instance via their impacts on reforming culture or changing structures of social action. The economic impacts of research in culture and society can be usefully compared to energy: the energy consumption of a manufacturing unit cannot be immediately seen in the final product, but without that energy input, there would be no product. It is easy to understand the economic impacts of the work of English language researchers by imagining a situation where universities would offer no programmes in English. In all international exchange today, English is a major lingua franca. The high standard of teaching at primary and secondary level relies largely upon the work of English language researchers. Furthermore, English has absolutely crucial significance to the competitiveness of the national economy. The role of cultural critique is apparent if we compare societies that support open discussion and debate with those that represents fundamentalist religions. A democratic culture of open discussion and debate is a crucial precondition for the working of modern economy – and has become even more so with the informationalisation of the economy and the increasing flexibility of production. Knowledge of foreign and past cultures supports the development of the tourism industry, and the Petra exhibition that is now touring the world provides an example of a joint project between researchers and museum people that has economic impacts.

The investigative development of organisations in working life is ultimately aimed at rationalisation. These changes lead typically both to the growth of welfare and to increased organisational efficiency, which in turn pave the way to improved economic cost-effectiveness. It is also impossible for the modern economy to survive without the support of educational institutions. Many of the key problems in the economy today are of a social rather than economic nature; the only reason they do not show up in economists' forecasts and recommendations is that it is virtually impossible to fit their underlying reasons into economic models.

The economic impacts of ecological research are both direct and indirect. Improved forest management methods have direct economic effects through higher levels of forest yield. The situation is very much complicated by the integration of sustainable development objectives with forest use, but this has now become a global boundary condition for forest economy. Forestry has to take into account the continuing growth of environmental requirements. Environmental control has increased significantly since the Rio Earth Summit, and environmentally friendly production methods are bound to gain increasing significance as a competition factor in business and industry. Ecological research provides invaluable clues on how all these different objectives can be rationally fitted together: on how much the natural environment can tolerate, on how to choose the most appropriate measures of control, on how to adjust production methods.

The economic impacts of health promoting research find expression in two main ways. On the one hand, clinical cooperation related to health research supports the development of increasingly effective treatments and practices. On the other hand, research produces patentable information, new drugs and spin-off companies. The Academy's centres of excellence have produced and patented, among other things, information related to diagnostic tests, cancer, muscle and nervous diseases as well as various biodegradable grafts. Some of the results are turning in a profit right now, others will yield a profit some time in the future.

Even within the field of technological development, the economic impacts of the Academy's centres of excellence are usually of an indirect nature: most of the work they do is effectively groundwork for industrial product development. It is only rarely that they are directly involved in work that would lead to a commercial product. This is due to the different nature of research and product development: research is aimed at producing new information about the natural environment and society and generic technologies, product development in turn is the business of producing marketable products. The requirements of objectivity and accuracy that academic research takes for granted, are easily seen as additional cost factors in commercial product development. In the development of generic technologies, by contrast, the theoretical foundations, parameters and data of the models employed are all expected to meet these requirements: these are crucial so that the models can provide a reliable simulation of reality. The success of commercial innovations is not determined only by the technological superiority of new products; indeed this is not necessarily even the primary determinant of success. More important factors than technological sophistication include the needs of end-users, their impressions as well as the price of products. The best technology can lose out to less sophisticated technology if its use is not supported by the interests of the producers and end-users.

All centres of excellence are clearly aware that there are certain bounds they cannot overstep without jeopardising their main function: the creation of new knowledge and generic technologies. However, it is at this very interface that the centres operate, as is indicated by the growth of some spin-off companies, the patenting of results that have economic potential, relatively extensive business cooperation and in technology units even some measure of involvement in product development projects.

Contents

4 The diversity of the social impacts of research in centres of excellence

The discussion above has looked at the social impacts of research units involved in the national centre of excellence programme 2000–2005 by highlighting some of the typical impacts of different fields of research and different lines of inquiry. The purpose has been to draw a general picture of the different types of impact exercised by science and research. This picture still simplifies reality, but it certainly affords a more in-depth view than the one provided by the current discussion where the focus is very much on technological and economic impacts. If we could go deeper still, we should be able to demonstrate that the impacts of centres of excellence in different fields are by no means confined to the main effects we have raised here on the basis of a relatively narrow dataset. Similar effects that we have now seen for instance in connection with cultural and social research would show up in other fields of recearch and vice versa.

The Academy's centres of excellence cover most of the broad field of science and their primary knowledge interests vary widely. The same goes for their social impact: it comes in various different shapes and sizes and covers a broad spectrum. This is the most important conclusion that can be drawn about the impact of centres of excellence; it would be counterproductive to narrow the focus and concentrate on certain aspects of that impact only. Research has a broad impact, ranging from the critical evaluation and reorientation of basic cultural factors through to the production of direct economic benefits. In pluralistic society, social impacts are reciprocal, and through feedback mechanisms they also accumulate. For instance, basic research on culture rarely has immediate economic impacts. But just as the results of basic research in mathematics can surprisingly produce far-ranging technological applications, so basic research in culture can prove to have significant economic impacts. An in-depth understanding of Chinese and Asian cultures, for instance, would today be immensely valuable for the international success of Finnish industry. In this specific historical situation, cultural understanding and commodity aesthetics have emerged as important economic competition factors.

Social homogeneity is typically associated with past societies and totalitarian systems. Modern society is certainly not immune to the threat of homogenisation. Strong, autonomous and diversified science provides an important safeguard against such a threat. In order to produce broad-ranging cultural impacts, scientific research itself needs to be broad-ranging. It is impossible to imagine a sound modern society that does not recognise its basic values, work to improve its methods of raising children, develop its organisations, and appreciate the conditions for environmentally sustainable development. These impacts often unfold in qualitative development projects in which knowledge produced in research plays a crucial part.

The impact of science and research consists in interaction. Some centres of excellence have developed established forms of collaboration that strengthen the impacts of research without compromising the integrity of basic research. For example, the cooperation of the Low Temperature Laboratory at Helsinki University of Technology with VTT Finland and the cooperation of the Collagen Research Unit at the University of Oulu with FibroGen, both seem useful ways of promoting the dissemination of basic

■ Table 2. Examples of the social impacts of research at the Finnish centres of excellence.

Impact type	Examples of impacts
Socio-cultural	– unravelling the deep structures of culture – maintaining the continuity of culture – preserving cultural artefacts – knowledge of foreign languages – developing communications culture – developing organisational structures – promoting museums, exhibitions and tourism – advancing the knowledge and understanding of practical actors in work organisations – providing better conditions for personal growth and social development
Impact on administration and politics (e.g. ecological research)	– critical assessment of existing practices – controlling interaction between humans and nature on a critical basis – protecting habitats and species diversity – environmental restoration projects – promoting exploitation and conservation of the natural environment at the same time
Impact on welfare and health	– promoting and deepening the use of clinical information – active business cooperation – developing test methods – pharmaceutical development – knowledge and know–how leading to spin–offs
Technological impacts	– developing generic technologies (controlling complex phenomena) – models, programs, patents, prototypes – knowledge and know–how leading to spin–offs – close cooperation with applied research – cooperation in industrial forum – knowledge transfer to industry in project steering groups, at seminars and through informal contacts – cooperation, transfer of knowledge and know–how in project implementation
Economic impacts	– developing the cultural competencies required by global business – developing the operation and efficiency of organisations – promoting economically sustainable management and use of the environment – developing more effective treatment methods, materials and tests – developing service businesses – commercialised product and process innovations – fee–based products – new spin–off companies

research results in society. In both cases the key thing is that responsibility for industrial application lies with the party that in the last instance has an interest in that application. End-users have both a high level of scientific know-how, a knowledge of potential applications and close contacts with business and industry. This means that researchers can concentrate on what they do best and on how they feel they can contribute most to what is best for society as a whole. These kinds of arrangements where end-users have enough expertise and competence to assess the practical applicability of research are of immense value to strengthening the social impact of research. In this regard there is still much room for improvement in Finnish industry. As for the economic and technological impacts of research, one problem that remains is the question of initial capital: more funds need to be made available to actors and institutions that are primarily interested in putting to use the knowledge produced in research.

There is also need for institutional solutions that would put cooperation with public administration on a longer term foundation and at the same time strengthen the impacts of information. Research programmes have provided some help in this respect, but one has to ask whether this kind of cooperation really is close and effective enough. Researchers often feel that the information they produce has less practical impact on administration and politics than they would like to see it have. Increased impact would also require a better ability to receive and to put to use the information generated in research in different fields of administration.

Acknowledgements. I am grateful to Erik Allardt, Reijo Miettinen and Anneli Pauli for their comments.

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Hanski Ilkka	20	Mar	2002
Hupa Mikko	7	Aug	2002
Jalkanen Sirpa	5	Aug	2002
Kellomäki Seppo	28	Mar	2002
Nieminen Risto	29	Aug	2002
Oja Erkki	11	Apr	2002
Paalanen Mikko	2	Sept	2002
Palva Tapio	30	May	2002
Peltonen-Palotie Leena	10	Jun	2002
Pihlajaniemi Taina	9	Aug	2002
Pulkkinen Lea	1	Feb	2002
Rauvala Heikki	14	May	2002
Rissanen Matti	26	Feb	2002
Räisänen Heikki	12	Feb	2002
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Contents

BIOSCIENCES AND ENVIRONMENTAL RESEARCH

ACADEMY OF FINLAND

RESEARCH COUNCIL FOR BIOSCIENCES AND ENVIRONMENT

Contents

Contents

The quality and social impact of biosciences and environmental research

Introduction

The twenty-first century has been dubbed the century of the biosciences. Indeed researchers in this field have been making significant progress, opening up new domains of development. Work has now been completed to map the genome of humans and many simpler organisms, gene transfers have become a commonplace in research, and researchers studying the conjoint effects of hereditary and environmental factors have made a quantum leap in their explorations. Research in the biosciences helps us to understand the evolution of organisms and paves the way to new innovations for greater human well-being.

It is very rarely that advances in science come about through studies on a problem formulated within any one discipline. The development of different fields of research is shaped and influenced by the practical problems that people face in their everyday life. Among the problems on which biosciences and environmental research are seeking to increase our understanding, and for the resolution of which they are seeking to develop new technologies, are the various processes of global change, the progressive loss of biodiversity and other factors that affect the physical well-being of different organisms. Some have suggested that research and technology in the biosector have the potential of growing into a new knowledge-based economy comparable to the ICTs sector (Life Sciences and Biotechnology 2002).

The research in this field is problem-oriented and multidisciplinary: there are close links of cooperation with the natural sciences, engineering and medical research. Materials research, computer design and software development are all turning now to biological processes in search of models, and the development of new medical drugs and health technologies also requires a firm foundation in biosciences. The more scientists learn about natural processes, the less meaningful are the boundary-lines between disciplines. Right now biosciences and environmental research are making phenomenal progress. Expectations are accordingly high, both in the world of science and in society at large.

With all the new instruments that are now available to researchers for intervening in life itself, there has been growing public concern and debate on research ethics and the use of research knowledge. Stem cell research, human cloning and the use of animals for research all require a clear set of rules and guidelines as to what is acceptable in scientific research. The threat of bioterrorism also presents a new challenge to science's traditional principles of transparency and openness: how can those principles be safeguarded at the same time as the abuse of research results is prevented?

A recent international evaluation of biotechnology concluded that Finland has invested heavily in the development of biosciences research (Biotechnology in Finland 2002). During the 1990s, the Ministry of Education supported this sector with grants worth around 100 million euros. In addition, a total of some 60 million euros were channelled to the sector through Academy of Finland research programmes in the latter half of the decade. Environmental research has not enjoyed quite the same support.

Biosciences and environmental research are conducted in virtually all universities around the country as well as in sectoral research institutes, which means that they are regionally representative. The main research clusters are to be found in the Helsinki region as well as in Joensuu, Jyväskylä, Kuopio, Oulu, Tampere and Turku. All these universities have strong research both in the biosciences and in the field of ecology. The University of Tampere and the Finnish Environment Institute specialise in environmental social research. In many places these research clusters have inspired the start-up of various centres of expertise and business ventures, which are having ever great regional significance.

1 The quality and internationalism of research

The key criterion in the evaluation of research is its scientific innovativeness, its capability to promote development within the discipline itself. Innovative research depends upon a number of different factors: it needs to show creativity in formulating its problems, to apply advanced methods and methodologies and to produce reliable results. Creative ideas are one necessary but not a sufficient condition for innovative research. Creativity is not the outcome of what a creative individual has done, but the outcome of interaction between the cultural field and the individual (Csikzentmihalyi 1990). It is easier to assess innovation in the domain of science and research than it is in many other cultural domains because the results have to be credible. The commitment to objectivity makes it easier to reach agreement on what is considered progress in research.

The quality of research is most typically measured on the basis of publishing – although since the 1990s increasing attention has also been paid to other aspects of research. International comparisons of the quality of research continue to rely primarily on comparisons of different publications. The two key measures of quality evaluation are impact factors and citation indices. Both describe the quality of research, albeit from different angles. As far as the scientific weight and significance of research results are concerned, citations are a more relevant measure of the publication’s quality than the impact factor. The impact factor, for its part, provides a better indication of the size of the potential audience, i.e. it describes the exposure that the work enjoys and the esteem of the researchers concerned. Citation indices and impact factors cannot be directly compared across different fields of research.

The quality of a scientific article: does the journal’s impact factor provide a relevant measure of the significance of research?

Professor Mikko Nikinmaa, University of Turku

In recent years the impact factor (IF) of different publications, as determined by the Institute for Scientific Information, has become perhaps the most important criterion in assessing the quality of scientific research. So pervasive is IF thinking today that researchers may say their work is highly rated because their production has a high impact score (number of publications multiplied by the publications’ IF). This is rather curious if we pause to think for a while what exactly the IF describes: the ratio of the citations received by articles published in the journal over the past two years to the number of articles published in the journal during the same period (the journal's IF2002 = [citations in 2002 to the articles published in the journal in 2001 and 2000/the total number of articles published in the journal in 2001 and 2002]). In other words, the score does not take into account those articles that have been published in the journal more than two years ago. However, in the natural sciences at least very few articles become outdated in such a short space of time.

The fact of the matter is that the IF does not pay very much attention at all to the significance of individual articles to the development of the discipline concerned. This is better illustrated by the number of citations received by the article (beyond the time frame used in calculating the IF). If the IF were to provide an accurate description of the significance of scientific work, then we should see a clear positive correlation between the IF of the journals in which researchers publish their work and the number of citations received by their articles. To establish whether this is the case, I collected a sample of prominent Finnish natural scientists and studied the total number of citations received by their production. A statistical analysis revealed no significant correlation between the total number of citations and the journal's IF. Since the number of citations and the journal's IF did not seem to correlate, I proceeded to look at the journals in which certain Finnish researchers had published their most important pieces of work. This analysis was confined to articles that had been cited more than one hundred times – which means that the bulk of all researchers' production is excluded from the analysis. In this group of researchers by far the largest part of their most important work has been published in series with an IF of 0–3. On neither of these criteria, then, did the journal's IF have any influence on how the article was cited. Indeed it is obvious that readers read and quote articles that are relevant to their own work, without paying too much attention to the IF of the journal in which they are published.

With the continuing growth of electronic publishing and the increasing use of electronic libraries I am sure that the content of scientific papers will come to matter more and the IF of the publication channel come to matter less. Perhaps over the next few years the IF will revert to the role for which it was originally designed, i.e. to describe how closely a series is followed and how much it is used in the short term. Used in this way, the IF is a valuable tool for the researcher, providing useful guidance in the search for the most appropriate channel for publishing a certain piece of work. What the IF does not necessarily do is describe the quality of a publication or its significance to the discipline as a whole.

2 The quality and state of biosciences and environmental research at the start of the 2000s

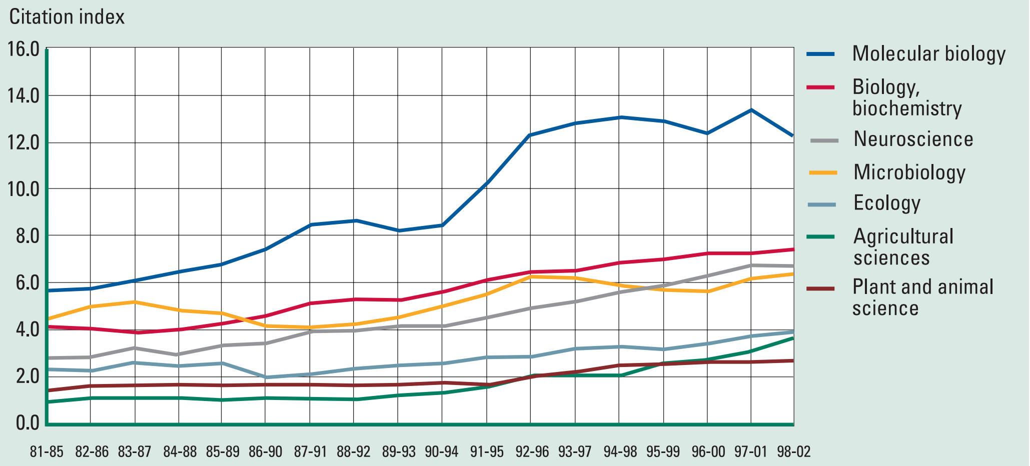
2.1 Increasing trends of internationalisation in publishing

Finnish biosciences and environmental research have shown increasing trends of internationalisation during the 1990s. Citations to articles published by Finnish researchers in international series have increased in all fields of research (see Figure 1).

Finnish researchers have long been competing for international exposure in the fields of molecular biology, biochemistry and biology. Molecular biology and genetics showed strong growth in the early 1990s, but the trends then plateaued towards the end of the decade. The strong growth during the early part of the decade is explained by methodological innovations in molecular genetics that allowed for much faster identification of disease genes. Researchers in Finland took good advantage of the opportunities opened up by the national disease heritage and advances in Finnish clinical genetics to catch up with the international forefront. Although the pace of development has now slowed down somewhat, Finland certainly remains at the cutting edge of science in these fields.

International publishing has been an integral part of microbiology ever since the discipline arrived in Finland. Major European rivals have now emerged to challenge the dominance of US journals. In particular, European journals in microbial ecology

Figure 1. Development of citation indices* in biosciences and environmental research in Finland in 1981–2002.



*Citation index = number of citations / number of publications.

Source: Institute for Scientific Information, NSI 1981-2002 / Standard.

have gained a strong position. International visibility was at very high level in the early 1990s. Growth resumed after a short quieter period, and it seems that this trend is continuing in the early part of the twenty-first century.

Publishing in Finnish neuroscience is beginning to narrow down the lead to the top nations in the world. In the 1980s Finland still lagged some way behind these major science powers, but during the 1990s the citation indices of publications by Finnish neuroscientists reached the same level as those of their Japanese and French colleagues.

Ecology is traditionally a strong discipline in Finland, but it was not until the late 1970s and especially the 1980s that internationalisation truly got under way: that trend continued to gather momentum towards the end of the 1990s. Finnish research has enjoyed international success especially in the fields of evolutionary ecology, behavioural ecology and population ecology. Sweden has seen very similar trends in development. One of the key factors contributing to the internationalisation of Finnish ecology has been that from very early on, environmental research in the Nordic countries adopted English as its universal language.

Forestry research showed a strong international orientation as early as the 1980s, although it was not until the 1990s that it made its international breakthrough. Scientific evaluations commissioned by the Academy in Finland in forestry research and closely related disciplines highlighted the importance of an active policy of internationalisation. This coincided with a new young, more internationally-minded generation of researchers coming of age.

Researcher training in plant biology received special support in the 1990s, which helped to create stronger research teams and to increase international publishing and citation numbers especially in the latter half of the 1990s. Publication and citation indices have also increased in the animal sciences. There is a stronger drive now to publish in high-profile series, and the quality of publications has also risen.

Agricultural and food sciences have also shown a strong trend towards internationalisation over the past 15 years. In fact, the international publication and citation figures (relative to population numbers) for these disciplines are now among the highest in the world, a huge change compared to the situation in the 1980s. Indeed in the latter half of the 1990s these disciplines showed much stronger development in Finland than in most other EU countries, the United States and Canada. This is largely attributable to increased European cooperation as well as a growing commitment at research institutes to gain greater international exposure for their research.

Comparisons of international publishing in environmental social sciences are unable to shed light on trends of internationalisation in this field of research. Although work in this field generally is characterised by a strong international orientation, publishing traditions are different from those in the natural sciences. Publishing here is often in the form of monographs and contributions to national discussions and debates. Closer collaboration with natural-scientific environmental research and biosciences would no doubt serve to harmonise publishing structures, which in turn would add to the international exposure of publications in these fields.

The recent trends in international publishing are explained by the continuing expansion of the research system and increasing competition. In 2001, some two-thirds of all research-years spent in biosciences and environmental research at universities were funded from outside sources.[1] The tendencies of internationalisation are at least partly explained by the structural changes in the research system, the establishment of graduate schools and other steps to improve and intensify researcher training. The Finnish research system continues to rely heavily on the contribution of doctoral candidates. In 2001 the number of PhDs graduating from universities was around 140 per cent higher than at the beginning of the 1990s. In the biosciences and environmental research, growth has been even faster.[2] The number of articles published in international journals has increased at almost the same rate. Most doctoral theses are based on series of articles published in international journals, with a separate synthesis produced to summarise the work. The structural changes are also seen in the slower growth of citation indices compared to publication volumes: work published with a view to gaining research merits is important for the individual researcher's career, but less so for the development of science. In biosciences and environmental research, most scholars publish what is regarded as their most significant pieces of work towards the later stages of their career.

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[1] In geography external funding accounted for less than one-half of the total (SVT, 2001:4).

[2] The number of doctoral degrees increased from 1994 to 2001 by 72 per cent, in biosciences and environmental research by 77 per cent.

Table 1. Publishing in biosciences and environmental research by field of research in Finland and selected OECD countries in 1988–2002 (number of publications per 10,000 population).

	Molecular biology and genetics			Biology and biochemistry			Microbiology			Plant and animal science		
	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002
Finland	1.2	1.8	2.3	3.7	4.8	6.0	1.1	1.4	1.6	2.9	4.1	5.0
France	0.9	1.3	1.4	2.7	3.0	3.1	0.7	1.0	1.1	1.6	1.9	2.0
Germany	0.9	1.1	1.3	2.4	2.4	2.7	0.8	0.8	1.0	2.1	1.8	2.0
Japan	0.4	0.7	0.9	2.1	2.3	2.4	0.5	0.6	0.6	1.0	1.2	1.3
Sweden	1.7	2.2	2.6	7.1	7.8	8.4	1.7	1.7	2.0	3.6	4.5	5.2
United Kingdom	1.2	1.8	2.0	3.8	4.5	4.4	1.4	1.5	1.5	2.7	3.2	3.4
United States	1.3	1.8	1.9	4.1	4.0	3.8	1.1	1.0	1.0	2.9	2.7	2.5

	Neuroscience			Ecology and environmental sciences			Agricultural sciences		
	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002
Finland	2.0	3.1	3.7	1.2	2.1	3.3	1.3	1.4	1.8
France	1.0	1.2	1.4	0.3	0.5	0.7	0.5	0.6	0.8
Germany	0.8	1.1	1.6	0.5	0.5	0.7	0.8	0.7	0.7
Japan	0.6	0.9	1.0	0.2	0.2	0.3	0.7	0.7	0.7
Sweden	3.6	4.2	4.5	1.9	2.5	3.2	1.0	1.1	1.3
United Kingdom	1.8	2.1	2.5	0.7	1.1	1.5	0.9	1.0	1.0
United States	2.0	2.2	2.2	1.1	1.2	1.3	0.9	0.8	0.8

Source: Institute for Scientific Information, NSI 1981–2002 / Standard.

Table 2. Citation indices* in biosciences and environmental research in Finland and selected OECD countries in 1988–2002.

	Molecular biology and genetics			Biology and biochemistry			Microbiology			Plant and animal science		
	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002
Finland	8.7	12.8	12.2	5.3	6.5	7.5	4.2	6.2	6.4	1.6	2.2	2.7
France	9.7	11.3	12.3	4.9	5.9	6.9	5.2	6.0	7.0	1.7	2.4	3.5
Germany	11.7	12.5	13.5	5.8	7.2	8.3	5.1	6.1	7.4	1.8	2.6	3.4
Japan	6.6	8.5	10.8	5.0	5.4	6.1	3.7	4.2	4.5	1.5	1.9	2.5
Sweden	8.0	10.7	11.8	6.3	6.9	7.7	5.3	6.9	7.0	2.7	3.1	3.6
United Kingdom	11.6	14.4	15.0	6.2	7.2	8.4	5.4	6.4	7.6	2.5	3.2	4.1
United States	14.4	17.1	17.3	8.2	9.4	9.9	8.1	8.1	9.2	2.2	2.9	3.4

	Neuroscience			Ecology and environmental sciences			Agricultural sciences		
	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002
Finland	4.0	5.2	6.7	2.3	3.2	3.9	1.0	2.0	3.7
France	4.7	5.9	6.8	1.6	2.4	3.6	1.6	2.2	2.7
Germany	5.5	7.0	7.8	1.8	2.6	3.6	1.1	1.5	2.2
Japan	4.0	4.7	5.4	1.4	1.9	2.3	1.5	1.7	2.0
Sweden	6.0	6.8	7.6	3.0	3.5	4.3	2.4	2.5	3.0
United Kingdom	6.0	7.1	8.7	2.1	2.9	4.2	1.8	2.4	3.2
United States	6.5	8.3	9.5	2.4	3.1	3.8	1.8	2.3	2.7

* Citation index = number of citations / number of publications.

Source: Institute for Scientific Information, NSI 1981–2002 / Standard.

2.2 The state of biosciences and environmental research at the start of the 2000s – the qualitative strengths of research and the main targets for development

2.2.1 Biochemistry, cell and molecular biology, genetics

In the late 1990s, investment in the biosciences was at a much higher level than in many other fields of research. Universities and biocentres benefited among other things from biotechnology funding. Following the biotechnology review in the mid-1990s, the Academy of Finland began to allocate special funding to these disciplines, for instance through research programmes (Genome Research Programme, Research Programme for Molecular Epidemiology and Molecular Evolution, Structural Biology Research Programme, Cell Biology Research Programme). As a result of these targeted funding programmes, biosciences in Finland have shown strong growth, and the standard of research and teaching in the field is extremely high (Biotechnology in Finland 2002).

In recent years Finnish research in structural biology has been advancing in leaps and jumps. The use of biophysical methods in research has increased and the standard of work improved. These advances in structural biology and other biosciences have also paved the way to the next step in research, i.e. to studying larger complexes of biomolecules. Funding has now been made available to this field of systems biology through a dedicated research programme, giving scientists in this field a stronger footing in the international competition.

Although Finland has quite an impressive record in neurobiological research, there has been no basic training specially devoted to this area. Elsewhere, neuroscience represents a unified field of research, in Finland there is still a marked lack of coherence. Neuroscience researchers have now begun to network during the past couple of years, witness the work at graduate schools and the launch of a new research institute.

With the strong influx of new students, the availability of training programmes in the biosciences has also been increased. The upcoming reform of university training programmes (3 + 2 years) may further increase the range of programmes available at Finnish universities, with plans in the pipeline to set up dedicated Master’s programmes. Development efforts along these lines are crucially important so that the future demand for qualified people can be met not only in research but also in the business sector and society at large. Researcher training in biosciences is well organised in traditional research groups as well as in a number of graduate schools. A significant fraction of students who complete a first degree continue to the postgraduate stage. As yet there is no long-term evidence on the employment prospects of PhD graduates, but at least for the time being it seems the situation is good. However, from an employment point of view it is essential that the bioindustry continues to enjoy strong growth and development.

2.2.2 Microbiology

The review of the state and quality of Finnish science and research in 1997 concluded that the main strengths of microbiology lie in its teaching and research traditions as well as in the large number of professorships. In 2003 two Academy Professorships are held by microbiologists, both of whom are also in charge of centres of excellence in research. The Microbes and Man Research Programme was launched in 2003. Graduating microbiologists have had no difficulty finding work, and the range of positions occupied by people with a researcher training in microbiology is wide and diverse.

One of the field's weaknesses, according to the 1997 review, was that the quality of work may have suffered at the expense of the quantity of publications. Quality evaluation is rather difficult in this field because there is no suitable microbiological series with a very high impact factor. This is apparent from the positive reception received by the new journal of Environmental Microbiology and from its high IF from the very outset. Another weakness identified in 1997 was that there were some areas in the important field of environmental microbiology that fell short of international standards. In 2003 environmental microbiology enjoys a relatively strong position. For instance, the Applied Microbiology Research Unit that was appointed a centre of excellence in research for 2002–2007, represents the field of environmental microbiology.

By now scientists have sequenced the complete genomes of more than one hundred prokaryotes, providing a strong foundation for functional genome research. The situation is very different for eukaryotic microbes: to date the full genomes of no more than two yeasts have been published. The information that scientists are now gathering is hugely important in that it allows for the use of microbial cells in the production of enzymes and bioactive compounds with medicinal effects. Various new chip technologies have greatly facilitated the study of complex interactions and signal transmission between microbes as well as between microbes and higher organisms: this is expected to yield crucial information on the role of these interactions for instance in gene regulation as well as in the development of drugs, probiots and functional foods. New methods in molecular biology have paved the way to exploring completely novel areas because there are many microbes that cannot be grown in laboratory conditions. The microbiology of the soil and the intestinal system are two examples of fields where microbial ecology is looking forward to significant new breakthroughs.

One threat that remains on the horizon in 2003 is the limited number of new student places at universities, which means that the number of students who can take up a career in research in this field is obviously more limited than in more popular fields such as molecular biology. There is a shortage of posts for senior researchers. In Finland microbiology is a female-dominated field, and that may be reflected in difficulties of landing new research posts and positions: the stage of gaining the qualifications of researcher and setting up one's own research group often coincide with the stage of life when women start a family.

2.2.3 Neuroscience

The discipline of neuroscience is characterised by a transdisciplinary approach aimed at understanding the development and function of the nervous system from the molecular and cell level through to the system level. Traditionally, research in neuroscience has been done as part of other fields of research. None of the universities in Finland offer students the option of majoring in neuroscience to the Master's level. This is noteworthy because especially in the United States, neuroscience began to evolve into an independent discipline as far back as 20–30 years ago. The transdisciplinary approach in neuroscience has produced several major breakthroughs, and in the United States and Japan, for instance, recent investments in the natural sciences have been precisely for purposes of setting up neuroscience departments and research programmes. The University of Helsinki has now launched an independent Neuroscience Center to produce multidisciplinary, high-standard research and training in this field.

Brain imaging and related cognitive research is one of the main strengths of Finnish neuroscience. The application of computational methods to brain research is another area where Finnish research has enjoyed much international exposure. It is an obvious weakness that research which makes use of imaging methods is scattered across several different research institutes. This is a line of work that uses expensive equipment, but its contacts with other strands of neuroscience research are too loose and sporadic.

Molecular genetics concerned with human diseases is one of the strongest areas of biomedical research in Finland. Its main focus is upon nervous diseases. The one weakness in this field is that it remains very much detached from the rest of neuroscience.

A major weakness and threat for molecular neuroscience is the lack of adequate facilities for housing test animals, which primarily affects the work that is being done with transgenic mice. In modern neuroscience, transgenic methods form a bridge between molecular research and the behavioural level. For this reason alone the use of animal models is crucially important to behavioural research.

One of the strongest lines of work in Finnish neuroscience is represented by electrophysiological research. Research that combines electrophysiology and molecular biology is another strength area. A major weakness in electrophysiology, as in neurophysiology more generally, is that it lacks in breadth: there are no more than a handful of laboratories in the country, and even they do not have enough equipment. For example, modern imaging technology at cell level combined with electrophysiological research is a powerful tool in nervous system signalling and plasticity research, but scientists in Finland do not have access to the necessary technology.

2.2.4 Ecology, forestry, plant and animal science

Following the 1997 review which singled out the main shortcomings of Finnish biosciences and environmental research, the Research Council began to support the convergence of basic and applied research through targeted funding as well as research programmes. The Finnish Biodiversity Research Programme FIBRE, the Finnish Global Change Research Programme FIGARE, the Sustainable Use of Natural Resources Research Programme SUNARE and the Baltic Sea Research Programme BIREME have all emphasised ecological research applications. On the other hand, the Cell Biology Research Programme and Life 2000 programme have supported cell and molecular biology research on plants and animals.

Finnish research has achieved international success most particularly in the fields of evolutionary ecology, behavioural ecology and population ecology. The methods of molecular biology have opened up new horizons for ecological research and at once thrown up new challenges for the training of ecologists. The Academy's research programmes have for their part helped to strengthen the links between basic research in ecology and applied studies in environmental ecology and conservation biology. With the growth of postgraduate training in ecological disciplines there has also been a marked increase in the number of PhDs seeking employment outside the university sector. This presents a challenge not only to postgraduate training, but also to recruitment policies at research institutes and to their networking with universities.

Forestry emerged with flying colours from a recent scientific evaluation of the University of Helsinki, and the Faculty of Forestry at the University of Joensuu has been appointed a centre of excellence in teaching. In addition, both universities have a centre of excellence in forestry. Research programmes in the forestry sector have produced a number of experts in new areas of forestry research, including wood material science (Wood Wisdom) and biodiversity (FIBRE). On the other hand, researcher training ought to have been more closely adjusted to demand: as it is there has been too much postgraduate training in the field of forest ecology, and too little in the fields of forest economy and forest policy. The investments made by the business sector in research concerned with forest economy remain quite modest, while quite considerable sums have been poured into wood processing.

Research in functional cell biology (systems biology) has inspired closer cooperation between plant genetics and plant physiology. Research in systems biology is a great breaker of barriers between different fields of research in that the development of genomic and proteomic technologies and the application of research results require extensive cooperation between biologists, bioinformaticians, mathematicians and technology experts. Active researcher training in the 1990s has helped to strengthen research teams in the field of plant biology (plant molecular biology and plant biotechnology), and graduating PhDs have been in a position to set up their own research groups. PhD employment outside the university sector has been reasonably good.

Animal sciences have not yet established the same kind of unified, methodologically transdisciplinary research tradition as the field of plant biology, partly perhaps because research programmes in the field have been heavily focused on humans and health, while physiological research concerned with the interaction between animals and their environment has received less attention. It is possible that the invisibility of physiological animal research science is due to a genuine disappearance of disciplinary boundaries, although it may have more to do with the fact that animal physiology has not yet taken full advantage of the new research methods developed by cell and molecular biology. Stronger physiological research concerned with the environment and natural resources would support not only basic research in animal physiology, but also closely related applied environmental sciences. This also goes for plant ecophysiological research, which has recently been overshadowed by research in molecular biology.

One of the most serious problems in the field of plant and animal science is the decline of taxonomy and systematics as well as the dwindling knowledge base and expertise on the domestic species. These areas need to be strengthened with a view to supporting biodiversity studies and environmental research.

2.2.5 Agricultural sciences

Agricultural sciences is a heterogeneous discipline that covers a wide range of fields from plant breeding to agricultural economy. These different sectors vary widely in terms of their internationalisation. In fields of research most closely related to basic biology, such as plant breeding, there is quite extensive international cooperation and publishing. On the other hand, opportunities for international contacts and exchange have not necessarily been the same for the agroeconomic research conducted at MTT Agrifood Research Finland, for instance, which the Ministry of Agriculture and Forestry wants to contribute to the development of Finnish agricultural policy.

Nonetheless international cooperation has increased in agricultural sciences, too. One of the major factors has been the active participation in EU framework programmes by Finnish researchers. In order to succeed with their applications Finnish researchers have had to publish actively on international fora, which in turn has increased European cooperation and influenced publishing.

As was pointed out in the 1997 review, the main strengths of Finnish agricultural sciences lie in the purity of the raw materials and produce as well as in the country's sound research infrastructure. The Ministry of Agriculture and Forestry has recently launched a research programme on organic production, Luomu 2003–2006, which is also looking into ways in which the national strengths can be put to the best possible use. Research organisations have been merged in line with the recommendations issued, which should promote multidisciplinary research. The most notable change in this respect has been the merging of the Agricultural Economics Research Institute and the Agricultural Research Centre into Agrifood Research Finland. There is still scope for improving researcher training. Agrifood Research Finland and universities have closer cooperation than before.

Finnish agriculture and the countryside at large are closely dependent on EU agricultural policy, and will become even more so with enlargement of the EU. This presents a host of new challenges for agricultural research: we now need to establish and take full competitive advantage of the pure produce of Finnish agriculture. On the other hand, there is also need for multidisciplinary research into the conditions for sustainable development in rural areas, with agricultural sciences working closely with environmental social sciences and forestry, for example. The situation is largely the same across Europe, but there has not been much progress with this kind of research. Indeed Finnish research is well-placed to take up a prominent role in this sector, not least by virtue of the various research programmes that the Academy of Finland has set up (SUNARE, FIBRE etc.) and that have provided a strong foundation for multidisciplinary research into natural resources and the environment.

2.2.6 Geography

Geography differs from all other natural sciences in that it combines knowledge of natural systems with knowledge of the regional structure of human systems. Within the discipline itself this is widely acknowledged as one of its main strengths. There are countries where natural and human geography have been allowed to drift apart, but the results have not been very encouraging – quite the contrary. In these countries geography's identity has become rather splintered, and the discipline lacks the sort of weight and influence it has in social discussions and debates in Finland. It therefore remains an important priority in the future to preserve and strengthen the unity and coherence of geography in Finland.

The quality of research has continued to improve. Research projects have shown great innovativeness throughout. It is particularly pleasing to see that professors and other senior scholars are still keen to contribute to national discussions that serve the needs and interests of business and planning processes as well as the development of teaching.

The main areas of priority in geography have remained effectively unchanged since the 1997 review. The only noteworthy change is geoinformatics. In the past couple of years great effort has been invested in the development of this new discipline, witness the decision in 2001 to set up four new fixed-term professorships. Geoinformatics is an umbrella concept that includes geographical information systems (GIS), remote sensing, spatial computation, mobile positioning systems and spatial statistics. The field has shown strong development both in Finland and elsewhere, and its future prospects appear good. For geography it is important that efforts are continued to develop geoinformatics in both basic and applied research.

2.2.7 Social-scientific environmental research

Social-scientific environmental research is a field that typically lies at the interface of disciplines hosted by different Academy Research Councils. It takes a problem-oriented approach to the relationship between humans and nature. The field is far more sociologically and politologically minded, and it also places more emphasis on environmental philosophy than the Academy's definition of the discipline – environmental policy, environmental economy and environmental law – gives to understand. The most established of the different fields of research, in terms of teaching and research posts, is environmental law. The new professorships in environmental policy have also helped to strengthen the status of the discipline. Teaching and research in environmental management have also been strengthened partly in connection with economics, partly at the interface of different disciplines at several universities and research institutes.

Founded in 2002, the graduate school in social-scientific environmental research represents a major new force in the field that significantly adds to its resources. The graduate school has helped to increase collaboration among different research institutes. It is also noteworthy that environmental economists and environmental lawyers are closely anchored to their respective disciplines and their graduate schools and are therefore not as closely involved in the work of the graduate schools in social-scientific environmental research.

It is unclear in the present situation what kind of *science policy means* would provide the fastest and most efficient way to raise the quality of different lines of social-scientific environmental research. The modern remedies of interdisciplinarity as well as international networking have been amongst those suggested. They have certainly helped, although progress has been relatively slow. Multidisciplinary research programmes have also given added weight to social-scientific environmental research and helped to raise its quality. Without research programmes the field would undoubtedly be even more fragmented than it is and less aware of the opportunities provided by multidisciplinary cooperation. One of the difficulties is that basic research in the social sciences on the relationship between humans and nature is still too weak, both conceptually and methodologically, to provide any significant direction to the work done in related fields. This applies most particularly to research in environmental policy, which has traditionally been under heavy pressure from various directions to network.

Quality standards in social-scientific environmental research in Finland are at more or less the same level as in the corresponding fields of social science in general. However, this special field of expertise at the interface between different disciplines has higher ambitions, and high expectations are also pinned on the young researchers who have been recruited into the field in large numbers. The field is more international than before and its research work has a sounder foundation than before, but it is still under pressure to raise the quality of that work.

Research and researcher training in environmental planning is a problematic area that is not yet recognised as part of social-scientific environmental research. However, recent new legislation (e.g. the Act on Procedures for Environmental Impact Assessment, Nature Conservation Act, Land Use and Building Act) has greatly increased the need for multidisciplinary knowledge about the physical environment.

3 The social impact of research in biosciences and environmental research

3.1 Why evaluate the social impact of biosciences and environmental research?

After World War II the general thinking was that all future innovations would be based upon the knowledge foundation created by basic research. Applied research and product development were expected to pick up and, in their own time, turn that knowledge into practical benefits. Half a century on, Finland has become increasingly convinced that science and research should also be expected to show clear social impacts.

Biosciences and environmental research are distinguished from the basic natural sciences by their firmer problem orientation. In the first review of the state and quality of Finnish science in 1997, the Academy's Research Council for the Environment and Natural Resources based its assessment on a distinctly problem-oriented approach. The main problems related to the state of the environment derive from functions in society that have changed the boundary conditions for the operation of natural systems. This has generated high expectations of the ability of environmental knowledge to help resolve problems. There are high expectations, too, of development in agriculture and forestry and of the development of new health-related methods. In 1997 the Research Council cautioned against expecting benefits for business alone. In its review the Council stressed that research also influences society by creating an atmosphere of curiosity and innovative thinking by training experts and by producing solutions that contribute to people's well-being.

3.2 In what does the social impact of science and research consist? – Relevance, interaction, change

The relevance of research refers to its ability to work towards the attainment of a given set of social objectives related to the subject-matter at hand. The impact of research, then, means that research or its results can change a given practice or way of thinking in society. Changes in social practices are always interactive. Social impacts are produced when knowledge and know-how are established in the process of change as part of a new way of thinking, a new way of acting or doing things or a new product.[3] The impacts of science are created in the networks of producing and using new knowledge. Practices in society are changed by interpretations developed in practical contexts. Multilateralism and the emphasis on changes in practices are central to the analysis of the impacts of science and research. The social impacts of scientific research mean that in the interaction between the research sector and other sectors in society, new interpretations and actions are created that shape and influence existing practices.

The social impacts of research must not be confined to the traditional notion of innovations, to new products or services sold in the marketplace or improvements in production processes. The concept of impact, especially in environmental sciences, is much broader than that of innovation. Environmental research has had an important role in drafting and implementing international conventions and legislation, for instance. The training of experts that is done in connection with research and the production of silent knowledge are the most significant mechanisms through which research exerts incremental impacts. Most of the impacts of research come in the form of gradual improvements in different processes. The full impact of the investments made in science and research are not seen in society until decades later. This can be speeded up by better and more readily intelligible communication of the results beyond the scientific community.

3.3 Different types of impact of biosciences and environmental research

To get a clearer idea of where and in what kinds of practices social impacts may be expected, the Research Council for Biosciences and Environment asked the opinion of a sample of researchers: How did they see the practical impacts of their work?[4] In their

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[3] Tuomi (2002) has developed a concept of innovations as a user-led process of redefining practices. Technological artefacts are an integral part of the new innovative practice, but these artefacts are not, as such, innovations; it is only once they have been taken into use in some socially determined and reformed practice that they become innovations. The same train of thought applies to the social impacts of research.

[4] The researchers were instructed to describe the impacts of their scientific research not within the confines of their current research project, but more broadly in terms of their work as researchers. It was stressed that there was no standard format for the descriptions: the respondents were encouraged to write their accounts in their own words, stressing those aspects that they thought had social impacts. The letters of request were sent out in June 2002 to 58 researchers who in spring 1997 had received general-purpose Academy grants. After one reminder, responses were received from 31 researchers, giving a response rate of 53 per cent. The clear majority of Academy-funded researchers feel that their work has some social impact. The material collected provides a useful overview of the different types of those impacts and a rough estimate of their prevalence.

responses we can identify a few typical social contexts and practices in which research has an impact. The discussion below summarises these researchers' accounts into eight main types of impact. It is very rarely that research is considered to have just one type of impact; usually it will be described as having multiple layers of parallel impacts. It is for this same reason that it is hard to predict, in advance, what kinds of impacts a certain piece of research is going to have.

3.3.1 Training for experts

The most common type of impact attributed to scientific research is in the training of **new experts** and researchers. This represents an important pathway for the transmission of research knowledge from the academic world to the society around. Some two-thirds of researchers in biosciences and environmental research consider this an integral part of their work. Some respondents make a distinction between the training of experts and the training of PhDs – a distinction, of course, that is usually made in other sectors of society, such as public administration or business and industry. Coordinators of major research programmes over the past few years regarded the training of experts as a major impact of these programmes, in addition to network building and the production of "silent knowledge".[5]

3.3.2 Economic and technological impacts

Recent discussion on the social impacts of science and research has been dominated by two types of impact: economic and technological. Indeed work in the biosciences and environmental research often has various **economic** impacts. Over half of the researchers in these fields say that the work they do has economic impacts; among the examples they mention are spin-off companies, fur farming, the development of resistant plant and animal species, pest control, recycling, and the logistics of timber acquisition and harvesting. The economic impacts of research need to be seen in terms of *indirect* effects that unfold in the longer term and that are supported by broadly-based promotion and development of knowledge and expertise. As well as economic impacts, one in three researchers say the work they do has **technological** impacts. Examples here include patents for medical drug development, the development of new molecules that can be used for saccharide purification, the development of new methods for virus determination, the development of environmentally friendly biotechnologies for mining and quarrying and the development of new equipment for the measurement of greenhouse gases.

The Wood Wisdom programme, for instance, was expected to produce both economic and technological impacts. The content of the programme was influenced both by the targets it was set and on the other hand by the direct involvement of the forest industry in consortia steering groups. Steering groups also serve as an important avenue for channelling the results of research programmes through to end-users. Almost 70 different stakeholder organisations have been involved in the programme, the majority

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[5] For the Research Council's assessment we interviewed the coordinators of the Academy's Biodiversity Research Programme, the Finnish Global Change Research Programme, the Sustainable Use of Natural Resources Research Programme. In addition, the coordinator of the environment cluster's research programme was interviewed.

of which have represented forestry companies. One of the most important impacts of the programme at macro level has been to encourage closer cooperation among different parties and to inspire the creation of new discussion forums and new structures of cooperation.

The economic and technological impacts of research in the biosciences

Professor Jyrki Heino, University of Jyväskylä

High-quality basic research in the biosciences is crucially important to the development of new innovations. As well as encouraging more traditional forms of cooperation between the private business sector and academic research, biocentres have inspired the growth of spin-off companies as university researchers have set out to take commercial advantage of their innovations. In addition, it seems that there is a growing demand in business companies for increasingly qualified people, which has increased the need for doctoral training especially in the biosciences. The rapid increase in the volume of biosciences research in Finland and its improved quality in the late 1990s also provided a boost to development efforts aimed at commercial applications. This was reflected in an increasing number of patents and in a growing movement of researchers from universities and research institutes to the open sector. The rapid growth of businesses in the sector caused a temporary shortage of qualified staff. The funding problems of SMEs using biotechnology have adversely affected their capacity to recruit new people. Employment prospects for researchers with a specialist training in this field are still quite good, even though research groups at universities and research institutes, constrained by the slowdown in research funding, have no longer been in the position to recruit researchers in the same way as before.

Finnish research in the field of biotechnology was evaluated in 2002 and described as internationally competitive. If continued growth can be secured for basic research and researcher training, that should improve prospects for commercial applications in biotechnology research. The development of nanosciences and nanotechnologies also looks set to create new potential for applications in the field of biosciences. This trend in development is bringing the biosciences closer to research in physics and chemistry and opening up new opportunities for the development of entirely new kinds of technologies.

3.3.3 Cultural and political impacts

Cultural impacts refer to the development of new interpretations and understandings of everyday activities. General **cultural** impacts are more or less equally common as economic impacts. One of the examples mentioned by the researchers is provided by positive public opinion towards the protection of the Saimaa Seal and growing public awareness of the possibility to control detrimental microbes without the use of pesticides. Among the channels of cultural impacts identified by the researchers, mention may be made of publications in popular media, television and radio appearances and lectures and discussions on ethical questions related to biotechnology. Launched at the initiative of the Government, the Biodiversity Research Programme included an assessment of how the programme has succeeded in promoting cultural impacts. According to the report (National Impact of the Finnish Biodiversity Programme), the programme has increased public awareness in Finland of biodiversity issues and sustainable development. The programme has also opened up new channels of interaction and communication between researchers and end-users. On the other hand, the report makes the critical remark that the knowledge produced in the programme has not reached all key agents, and that many of its results have not filtered through to the general public.

Impacts on **administration and politics** are equally common as technological impacts. Some of the examples mentioned by the researchers include influencing the content of conservation decisions; identifying the “best models” for communication and exchange between land use and nature conservation; providing assistance to administration in testing programmes; supporting work to draft international agreements; promoting the implementation of agreements; and working to develop forecasting models for forest growth. The Biodiversity Research Programme in particular was aimed at supporting the implementation of the UN Biodiversity Convention by producing information about biodiversity to the Finnish authorities.

Research plays a major role in the development of air pollution control

Director General Lea Kauppi, Finnish Environment Institute

Research has played a very prominent role both in Finland and internationally in addressing the problem of acidification and in general in developing air pollution control at different stages of the air pollution control cycle (identifying the problem – understanding the impact mechanisms at play – surveying and assessing the extent and significance of the problem – dose-response studies – developing models for the ecological and economic assessment and comparison of different emission reduction alternatives for use in international negotiations). In the Nordic countries the phenomenon of lake acidification was first identified by Swedish researcher Svante Oden, but Finnish colleagues were not far behind. The issue was first brought to public attention at the Stockholm Environment Conference in 1972. Especially in Sweden and Norway where the problem was even more serious than in Finland, nature conservation organisations were keen to put acidification on the international agenda. In Finland, too, environmental organisations and the green movement ran vigorous campaigns.

In the 1970s and 1980s, researchers were chiefly interested in the ways that airborne contaminants (initially sulphur but later on nitrogen as well) are transported and transformed and how they affect different organisms and ecosystems. On the other hand, they were also keen to establish the geographical extent and severity of the problem. Once they began to understand more about the mechanisms at play, they moved on to dose-response studies. Now, equipped with detailed regional information on dose responses, researchers were able to provide delegations to international emission reduction negotiations with detailed assessments of how different reduction strategies would be reflected in the Finnish environment. From the very outset researchers from different countries have worked quite closely with one another on these issues, which has allowed them to produce harmonised assessments covering the whole of Europe. With economic analyses attached to their calculations, researchers have also been able to say how best to optimise the reductions in emissions.

In this way then research has contributed to promoting human well-being by improving the quality of the living environment – and done so cost-effectively. The development of Finnish clean technologies (e.g. fluidised bed technology) also ties in closely with research in air pollution control.

The focus of research has now shifted to heavy metals and small particles. Most of the work with heavy metals is still at the stage of determining dose responses, in the case of small particles we have only just begun to explore the basic processes. The assessment of health effects has been largely based upon air quality norms, which of course are determined on the basis of international and domestic dose-response studies.

From the outset there has been close dialogue between researchers, NGOs and end-users of research results. One of the reasons no doubt is that in contrast to earlier environmental problems, acidification was clearly an international problem: there was no way this was going to be resolved nationally, let alone locally. On the other hand, the Finnish Research Project on Acidification (HAPRO) provided a solid foundation for Finnish research and educated large numbers of competent researchers. It is not insignificant that ever since this project, there has been close cooperation between universities and sectoral research institutes. As research institutes have had close contact with ministries and delegations to international negotiations, a broad avenue of communication has been opened up from basic research through to end-users.

3.3.4 Nature conservation and environmental rehabilitation

Around one-quarter of the researchers said their work had impacts in the area of nature conservation and environmental rehabilitation. The first type of answer referred to general knowledge and understanding about nature conservation and restoration, such as increasing awareness and knowledge about biodiversity preservation and climate change. There were also references to the rehabilitation of desertified areas and to the biotechnical rehabilitation of polluted areas. Linking ecological knowledge with economically relevant information, such as mowing and grazing, organic farming, and the impacts of reindeer herding on the forest nutrient balance, provide examples of a somewhat different type of impact which combines aspects of ecological and economic sustainability. Nature conservation is an integral part of most research programmes administered by the Research Council for Biosciences and Environment (e.g. FIBRE, FIGARE, SUNARE). The knowledge produced in these programmes should contribute to the end of resolving environmental problems and promoting the sustainable use of natural resources. The Research Council also had an active role in launching the European Biodiversity Platform and in hosting its first meeting in 1999. The Biodiversity Platform supports the objectives of both the European Platform for Biodiversity Research Strategy and the European Research Area by bringing together decision-makers and researchers from different parts of Europe.

The social impacts of research in population ecology

Academy Professor Ilkka Hanski, Academy of Finland

The social impacts of research in population ecology depend upon whether that research is concerned with species that humans generally consider harmful, beneficial or endangered. In the case of harmful and beneficial species society is usually prepared to make informed decisions on the basis of the best knowledge available. Research has clear objectives, and much of the work is done at government research institutes. Ecologists working at research institutes often have close contact with the end-users of research results, which facilitates efficient communication.

The situation is very different in population ecology research on endangered species. From the ecologist's point of view the research problems are exactly the same as in the case of other species: the aim is to establish the causes of population fluctuations and where possible to produce models for predicting those fluctuations. There is also broad public consensus that continuous species endangerment, which also affects biodiversity, is a trend that should be avoided and averted. However, on just about everything else there is profound disagreement.

The authorities in the environment sector have a genuine interest in research knowledge, and the presence in government agencies and research institutes of staff who share the same kind of basic training as researchers makes the use of that knowledge much easier. In political decision-making the positions taken by the Ministry of the Environment reflect the broader values in society, which means that species endangerment receives rather scant attention even on the environmental agenda. The general thinking is that people do not want to pay very much for the preservation of biodiversity, although no doubt the response would largely depend on how the question is asked and on the broader context of social development in which the preservation of biodiversity is considered. One of the goals of voluntary nature conservation organisations is to try and influence people's values in such a way that the preservation of biodiversity would take on greater importance than it has today.

It is not the researcher's job to defend different value perspectives – although surely it is not necessary to deny one's values in the case of issues where there is broad public consensus. Just as medical doctors may express their support for higher standards of medical care, so ecologists may express their support for the preservation of biodiversity. However, the key issue as far as the researcher and the bodies funding research are concerned is how to make sure that the knowledge produced in research gets through to the political decision-makers, intact and undistorted.

In an ideal world, the different parties would first reach agreement on the interpretation and message of a certain piece of research evidence; then, in the political process that follows, they would proceed to agree on the steps that need to be taken in accordance with the prevailing opinion in society. Unfortunately, research on endangered species rarely gets to exercise such an influence in society, but the parties that for economic or other reasons are opposed to conservation are inclined to disregard research evidence on endangered species. Instead, they are keen to highlight the economic and social impacts of conservation. Although both the ecological, economic and social impacts of conservation need to be taken into account in the process of political decision-making, it would benefit the effective utilisation of research knowledge if these factors could first be analysed separately. Ecological research evidence is often challenged on the general grounds that we do yet not know enough about the relevant processes. However, the people who say this very rarely have the basic education to make an independent judgement of the research results they are looking at.

In sum, the greatest difficulty with regard to the social impact of research on endangered species is that the results from this work very rarely get through, undistorted, to inform political decision-making. The situation may be very similar in other fields where research touches upon issues that involve social conflicts of interest. The old biblical adage about how much wisdom induces much grief, finds a new expression here: for what a great paradox it is that it is easier to make decisions on socially complex issues without consulting the best research evidence available.

3.3.5 Well-being and the evaluation of environmental risks

Somewhat less common types of research impacts than those discussed above are the **promotion of well-being** and the **evaluation of environmental risks**. Among the examples in this category are the identification of environmental toxins, the identification of exposure to air pollution, healthy foods, new treatments and the diagnostics of good water quality. Well-being effects seems to be divided into two main categories. The first consists of immediate effects at the individual level: the development of new medical drugs or treatment for seasonal affective disorder are ways of helping an individual with a well-being deficit. The latter examples, then, refer to well-being effects at the level of society. In these cases the impacts have to do with the general standard of welfare and the risks presented to the welfare of whole population or part of the population.

The social impacts of dioxin research

Professor Terttu Vartiainen, University of Kuopio & National Public Health Institute

People in the advanced industrial world have shown a sharply critical reaction against stable organic environmental toxins. Most of the public attention has focused on dioxins, polychlorinated dibenzo-*p*-dioxines and polychlorinated dibenzofurans. In the late 1980s, these were dubbed the "supertoxins", which did little to improve their negative image.

Quite considerable sums have been invested in dioxin research. In Finland, most of the monies have come from the National Public Health Institute's core budget funds as well as the EU's fifth framework programme, the Academy of Finland and various ministries. In addition, the National Food Agency and the Finnish Environment Institute have been involved in supporting the research.

The development of the analytic tools needed in this research was a hugely challenging task. Research has now been able to shed light on the main sources and mechanisms responsible for the emergence of dioxins as well as on purification processes and disease-causing mechanisms. It has produced information on the environment, on nutrition and human exposure, proceeding all the way to epidemiological health follow-ups. Not only the research community but public administration has benefited from the results.

Without the basic research carried out in Finland and the excellent files on concentration levels produced on the strength of this evidence, the EU's specified limits for dioxin concentrations in fish would be at an entirely different level from what they are now. It is too early to tell whether or not the outcomes were favourable, but in any event the impacts of Finnish research were considerable. Finnish delegations to EU meetings were always equipped with up-to-date scientific evidence. Without in-depth research, none of this would have been possible.

No other country in the world has kept its people as well-informed about dioxins as Finland has, even though we are by no means at the greatest risk. The research results have received coverage in the print press dozens of times, television has covered the issue sometimes monthly. In this case the popularisation of science has greatly helped to alleviate people's fears of these faceless, unknown "supertoxins". We are now in a position in Finland to discuss the prevalence and possible adverse health effects of dioxins in a constructive atmosphere, without any panic or prejudice. This was clearly in evidence around a year ago when the EU decided on the maximum permissible levels of dioxins in fat containing food, when Finland and Sweden were exempted for a period of five years. In Sweden, the public discussion that ensued was nothing short of panic-stricken when compared to the matter-of-fact, weighted deliberations in Finland on whether or not the benefits of eating fish are greater than the possible adverse effects of dioxins in fish.

The recommendations issued by the National Food Agency regarding the frequency of eating fish are based almost exclusively on Finnish research results. If we had listened to the advice of foreign research, we would hardly be eating any wild fish at all in Finland today. Without Finnish dioxin research, we would have seen the end of professional fishing some time ago. We would be eating foreign fish, mainly farmed Norwegian salmon.

Research has also helped to persuade fish farmers in Finland about the importance of feeding their fish stock on pure fish oils and fodder. This has at once helped to resolve the problem of both dioxins and heavy metals.

A rare type of impact that stands apart from all others is the promotion of **development cooperation**. There are three references in the interview material to this type of social impact that has direct relevance to the Johannesburg Declaration and Action Plan. Information on the use and rehabilitation of rain forests has a direct impact on the economy and environmental protection of developing countries. For instance, information on the ecological value and productive potential of regions has influenced decisions on the protection of Peruvian rain forests. Cooperation with local authorities and research institutes has led to the establishment of several new conservation areas in ecologically unique areas. On the other hand, rain forests have not been cleared in regions where research has shown that the soil would yield insignificant crops if the land were cultivated. Training for researchers and experts from the developing countries promotes the transfer of knowledge and technologies to the Third World.

4 How should the quality and impacts of research be promoted in biosciences and environmental research?

The Research Council's recommendations and development proposals

Basic education at universities is organised around established disciplines. In the future too, this education will provide the foundation for scientific postgraduate training and for the training of the qualified staff required by business companies in the environmental and biosector. For reasons of continuity, then, it is essential that steps are taken in all fields to maintain an adequate level of student intake at universities. In some fields, such as microbiology, that level is already low.

Most of the advances in biosciences and environmental research happen at the interfaces of established fields of research. Continued research funding shall be made available to these border zones that are most likely to produce significant new scientific discoveries and breakthroughs. One of the problems is the shortage of posts for senior researchers. Steps are needed to make it easier for advancing scholars to set up their own research groups.

Special funding for biosciences has been crucial to developing the infrastructure of biocentres and to the formation of research clusters and networks. Nonetheless the infrastructure in the field remains far from complete, nor do researchers always have access to all the technology they would need, or to the best technologies available. As the number of research groups has continued to rise, competition for research appropriations – which were no longer rising at the start of the 2000s – has become much fiercer. Indeed it is important that there is continued and even increased direct public support for the development of research in the biosciences. The discipline of neuroscience that showed strong growth throughout the 1990s needs to be further strengthened by allocating more funding to the area through a research programme.

Biological research has moved on to the post-genomic era. The set-up of technologies related to genomics/proteomics/metabolomics requires considerable resources. For instance, the ongoing national organisation of research in plant genomics is set to improve the use of resources and increase international cooperation for instance with corresponding organisations within the European Research Area.

Researchers in the fields of ecology and forestry emphasise global environmental issues that cut across the boundaries of several different disciplines. In the case of forestry, these issues include forests in climate policy, sustainable forest economy and the role of forest economy in combating poverty. Sociological questions related to forest economy have so far received insufficient attention when considered against development needs.

Society has access to various economic, legal and informational steering mechanisms it can use to promote socially, economically and ecologically sustainable development. The key challenge for social-scientific environmental research is to increase our understanding of how different steering mechanisms, individually and collectively, produce intended and unintended outcomes. This requires that social-sientific environmental research is closely integrated with other lines of environmental research – although at the same time it is important that steps are taken to safeguard its autonomous development from its own scientific premises.

Applied environmental research and informed political decision-making as well as environmental policy measures based on that research require a close understanding of the distinctive northern features of Finland's natural environment. In its capacity as an agency dedicated to supporting basic research, the Academy of Finland must make sure that adequate support is made available to research that is aimed at gaining a more in-depth understanding of the biological factors that have an impact on species diversity, distribution and adaptation. In particular, funding should be made available to research in the fields of modern systematics, taxonomy and ecophysiology.

Geoinformatics has got off to an excellent start and its continuity must be safeguarded. Geoinformatics supports all disciplines that need positioning information and its development will support for more effective utilisation of that information. Environmental monitoring and the development of planning systems will also rely to an increasing extent on geoinformatics.

Agricultural research needs to establish and take competitive advantage of the pure produce of Finnish agriculture. In addition, there is a growing need in this field for multidisciplinary research that explores the conditions for sustainable development in rural areas. The integration of agricultural sciences with other disciplines, including social-scientific environmental research and forestry, is crucial to this effort.

The most important way in which the social impacts of biosciences and environmental research can be promoted is through an in-depth understanding of the meaning of interaction. Social impacts are created if and only if there is the right kind of division of labour between different sectors of society and if the individual actors involved have the necessary expertise and commitment to try and resolve misunderstandings that are due to divergent interests. Intensive postgraduate training in the field has produced a large number of experts who, if they work in the right direction, can promote the adoption and application of new information in different sectors of society. The innovation policy pursued over the past years has provided a solid foundation for socio-economic actions based on the utilisation of knowledge and know-how. What is called for now in different sectors of society is an investment in the skills and competencies that are needed to put the existing and the emerging knowledge and know-how to the best possible use.

The cultural and political impacts of research can be supported and promoted through improved science communication. The goal of communications policy is to develop the dialogue between researchers, political decision-makers and individual citizens and to make sure that the voices of different actors are heard in the policy-making process. The involvement of individual citizens and voluntary organisations in the discussions and debates on the ethics of biosciences and environmental policy helps to remove prejudice and to strengthen the value foundation of the information society. Open dialogue also helps the parties involved to understand one another and increases the political impacts of science. It is important therefore that researchers are given every possible opportunity to take part in this kind of dialogue.

Both the private and the public sector have promoted the technological and economic exploitation of biosciences. The Ministry of Education, the Academy of Finland, the National Technology Agency and private venture capitalists have increased the amount of personnel and economic resources available in this field. SMEs in the biotechnology sector are the most research-intensive in the whole economy. For research and training purposes it is important to look into the reasons why these businesses are having funding problems. The development of products and services that are financially sound and that can make a real difference to people’s well-being is a long process that often takes years. Such a sustained development effort obviously requires secure access to adequate resources.

Biosciences and environmental research can help to gain control over environmental problems by producing information that supports political processes aimed at resolving those problems. The Kyoto Climate Convention, the Biodiversity Convention and the Johannesburg Action Plan are examples of good dialogue between research and politics. Since all environmental problems are in the final analysis caused by human activity, natural sciences alone cannot resolve those problems. It is therefore important to support social-scientific environmental research that adds to our understanding of the connections between social and natural processes. Solutions with a favourable impact on the environment require the right kind of value climate in society as well as a commitment to make the best possible use of the existing knowledge base.

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Contents

Appendix 1. Research Council for Biosciences and Environment in 2001–2003

Chair
Terttu Vartiainen, Professor
National Public Health Institute

Annele Hatakka, Professor
University of Helsinki

Jyrki Heino, Professor
University of Jyväskylä

Lea Kauppi, Director General
Finnish Environment Institute

Markku Löytönen, Professor
University of Helsinki

Pasi Puttonen, Professor
University of Helsinki

Maija Rautamäki, Professor
Helsinki University of Technology

Eevi Rintamäki, Professor
University of Turku

J. Peter Slotte, Professor
Åbo Akademi University

Juha Tuomi, Professor
University of Oulu

Matti Vornanen, Professor
University of Joensuu

Science Adviser Timo Kolu and Director Arja Kallio from the Academy’s Biosciences and Environment Research Unit were involved in preparing the Research Council’s report.

Contents

RESEARCH IN CULTURE AND SOCIETY

ACADEMY OF FINLAND
RESEARCH COUNCIL FOR CULTURE AND SOCIETY

Contents

Contents

1 Introduction

In addition to the more traditional emphasis on internal impacts, there have been increasing calls in recent years that science and research should give equal attention to the social impacts of research. This has its background, on the one hand, in the growing trend towards accountability in services funded from the public purse and, on the other hand, in the national strategy adopted by Finland which stresses the importance of innovativeness and top-level knowledge. The Science and Technology Policy Council of Finland considers social innovations to be equally important engines of socio-economic development as technological innovations. In the humanities and social sciences, increasing the social impact of research is a new challenge the assessment of which is a complex and demanding task indeed.

Various changes in the environment of research combine to have an effect on the state and quality of research. General economic development, solutions adopted in the university system, and the gradual structuring of the European Research Area are examples of such changes. The aim of this report is to review developments over the past few years against earlier evaluations and to open up new perspectives that have been ignored in earlier reviews. The material consists of statistical data from various sources (KOTA database, Statistics Finland), expert evaluations, and self-assessments by researchers of their work and its impacts – a new method that has not been used before. The purpose has been to complement the picture drawn by quantitative indicators with qualitative data. This kind of material helps to uncover such kinds of scientific impact that have been hard to establish on the strength of quantitative indicators alone.

The Finnish science and research landscape has seen a growing tendency for larger research groups to be formed. This has been aimed at increasing the international competitiveness and impact of science. Long-term research in larger groups and networks has increased in the humanities and social sciences, too. Academy funding instruments such as research programmes, centres of excellence and Academy professorships, have played a crucial role in this development. However, it is important to note that research in the humanities and social sciences differs from work in the natural sciences in the sense that individual efforts continue to have a significant impact in these fields.

Research programmes administered by the Research Council for Culture and Society in 2000–2002:
Finnish Companies and the Challenges of Globalisation, LIIKE 2001–2004
Information Research Programme II 1996–2001
Interaction across the Gulf of Bothnia 2000–2003
Life as Learning Research Programme, LEARN 2002–2006
Marginalisation, Inequality and Ethnic Relations in Finland, SYREENI 2000–2003
Media Culture Research Programme, MEDIA 1999–2002
Research Programme for Russia and Eastern Europe 1995–2001
Research Programme for the Economic Crisis of the 1990s, LAMA 1998–2001

Centres of excellence in the disciplines hosted by the Research Council for Culture and Society in 2000–2005:
Ancient and Medieval Greek Documents, Archives and Libraries (University of Helsinki)
Center for Activity Theory and Developmental Work Research (University of Helsinki)
Research Unit for Variation and Change in English (University of Helsinki)
Research Unit on the Formation of Early Jewish and Christian Ideology (University of Helsinki and Åbo Akademi University)
The Human Development and Its Risk Factors Programme (University of Jyväskylä)

Centres of excellence in the disciplines hosted by the Research Council for Culture and Society in 2002–2007:
Helsinki Brain Research Centre (University of Helsinki, Helsinki University of Technology, and Helsinki and Uusimaa hospital district)
History of Mind Research Unit (University of Helsinki and University of Jyväskylä)
Research Unit on Economic Structures and Growth (University of Helsinki)

Academy Professors in disciplines hosted by the Research Council for Culture and Society (1 August 2002):
Hakulinen, Auli, University of Helsinki (linguistics)
Hietala, Marjatta, University of Tampere (history)
Honkapohja, Seppo, University of Helsinki (economics)
Knuuttila, Simo, University of Helsinki (philosophy)
Näätänen, Risto, University of Helsinki (neuropsychology)
Palonen, Kari, University of Jyväskylä (political science)
Räisänen, Heikki, University of Helsinki (biblical exegetics)
Sams, Mikko, Helsinki University of Technology (neuropsychology)
Sepänmaa, Yrjö, University of Joensuu (environmental aesthetics)
Siikala, Anna-Leena, University of Helsinki (folklore)
Vuorela, Ulla, University of Tampere (social anthropology, women's studies)

2 Trends and challenges in recent years

2.1 The growth of multidisciplinarity

The past few years have witnessed a progressive crumbling of boundaries between individual disciplines as well as increasing multidisciplinary cooperation within the field of humanities and social sciences. These trends have invigorated and renewed research in several fields of study. On the other hand, the humanities and social sciences include a number of disciplines that are inseparably linked with the natural sciences (e.g. psychology, archaeology).

The Research Council considers research programmes to be an effective means for promoting high-quality multidisciplinary and interdisciplinary research. Research programmes support both thematic integration and multidisciplinary cooperation, creating an arena that is conducive not only to specialisation but also to exchange and interaction between closely related disciplines. Multidisciplinary research programmes have been geared at producing research results and knowledge that have social relevance. For research in culture and society, programme initiatives jointly sponsored by different research councils have opened up interesting new prospects of cooperation with medicine, the natural sciences and engineering. However, in many cases the most fruitful multidisciplinary projects grow up out of spontaneous contact and longer term cooperation among individual researchers. It would be important to assess the impacts of joint council research programmes on the emergence of research at the interface between different disciplines.

In 2000–2005, the Academy has five centres of excellence in disciplines hosted by the Research Council for Culture and Society. Judging by the interim reports of their international scientific advisory boards, these centres have had excellent success both in creating innovative new research approaches and in training a new generation of researchers. One of the great strengths of centres of excellence in research is their ability to integrate the approaches and methodologies of different disciplines: this has earned them much international recognition. Work produced at these centres is aimed for publication in leading international journals. In their studies of changes in work, organisations and technology, researchers at the Center for Activity Theory and Developmental Work Research have combined the approaches of adult education, psychology, sociology and communication studies, for instance. The centre of excellence that is dedicated to the conservation and interpretation of ancient and medieval Greek documents applies not only the methods of classical philology and archaeology, but also state-of-the-art technological expertise. There are three centres of excellence in disciplines hosted by the Research Council for Culture and Society that started their six-year term (2002–2007) in 2002. One of the units engaged in multidisciplinary research is the History of Mind Research Unit that is concerned with the structure and function of the human mind in the philosophy of different eras. In this work it resorts to the toolboxes of philosophy, theology, history and linguistics.

Multidisciplinary and interdisciplinary research is also supported through Academy professorships. In 2002, the Research Council for Culture and Society had 11 such professorships. Among the Academy Professors who started their term in 2002, Mikko Sams draws upon both psychology and engineering sciences; Marjatta Hietala's work is a combination of history, sociology and urban studies.

One noteworthy trend over the past few years has seen strong multidisciplinary fields gain the status of independent subjects that are taught as part of the university syllabus. Examples are provided by women's studies, future research and cognitive science: all have matured into syllabus subjects in their own right yet still retained their original multidisciplinary nature.

Commissioned by the Ministry of Education, the national evaluation of women's studies and gender research concluded that this multidisciplinary field produces a very high standard of research that is internationally competitive. Unusually, the evaluation also covered the organisation of university education. Overall the evaluation of women's studies went extremely well, and researchers in the field were keen to participate and contribute through self-assessments. Indeed the assessment itself probably had a positive impact on this field. However, the panel concluded in its report that at most universities, women's studies does not yet have a sufficiently sound financial basis, but its future growth and development will require permanent professorships as well as teachers' posts at PhD level.

A new opening that is expected to create added interdisciplinary synergy is the multidisciplinary Helsinki Collegium for Advanced Studies that was launched at the University of Helsinki in 2001. This has increased the visibility of research in the humanities and social sciences and provided a new stronger platform for long-term multidisciplinary cooperation in these fields.

In the humanities, increasing exchange and contact across disciplinary boundaries in arts research has been a growing trend in recent years. In particular, mention should be made of the closer contacts that arts research at science universities has had with philosophy and sociology. Networking with the broad field of cultural studies is another noteworthy trend. The rise of the postcolonial perspective has brought arts research into closer contact with cultural geography and microhistorical research, for example. Multidisciplinary media studies, a field that to an extent is still in the process of taking shape, has developed in close contact with arts universities and arts subjects at science universities. In its multidisciplinary studies of everyday media practices and media users, the Media Culture Research Programme (funded by the Research Council in 1999–2002) produced valuable new information for various sectors of society.

Research at arts universities depends for its progress not only upon interdisciplinarity, but also upon exchange and interaction between research and the arts. In order to promote this novel form of communication, the Research Council together with the Central Arts Council supported in 1999–2001 a total of ten projects from all four arts universities as well as the University of Lapland Faculty of Art and Design. These projects were geared to finding solutions to the practical and methodological problems of arts research and to promoting the integration of science and the arts. The evaluation seminar concluded that the results overall had been encouraging, even though it had not been possible to resolve the questions of integration within the confines of this one-off targeted programme.

Social-scientific environmental research is a new multidisciplinary line of inquiry. One of its growing areas of specialisation is legal environmental research, which combines the approaches of law, social sciences and natural sciences. Social-scientific environmental research is a typical example of a discipline that lies in the middle ground between different Academy research councils. The Research Council for Culture and Society is charged with the task of supporting cultural, sociological and philosophical research that is concerned with the interaction between humans and the natural environment but that does not fit in with the administratively and economically oriented lines of environment research that come under the Research Council for Biosciences and Environment. Many current research problems and projects, such as those concerned with sustainable development, call for the development of multidisciplinary interface programmes between different research councils.

Regional studies is a growing multidisciplinary field of research that applies social and cultural research. Multidisciplinary research with a specific regional focus (e.g. Arctic research, EU research, Russian studies, Chinese studies, African studies) is ongoing at several universities. Often, this line of research has been started in response to challenges thrown up by growing trends of globalisation. The Research Council has been responsible for preparing the Research Programme on Russia that is expected to provide important new directions for regional studies. In general, the local impacts and transformations of globalisation are an important field of study that will require increasing input from research in culture and society.

More research is also needed into the relationship between humans and technology from a humanities and social science vantage-point. In particular, more research is needed in subjects related to gender and technology. This was also mentioned among the recommendations of the international panel who evaluated women's studies and gender research in Finland.

The growth and development of new fields of study requires much flexibility on the part of research funding bodies. The multidisciplinarity of research should also be reflected in practices of evaluation. The Research Council for Culture and Society has sought to pay special attention to reviewing multidisciplinary projects, but this is an area that still calls for a committed development effort. At universities, too, management by results and the methods of evaluation used often stand in the way of research and training projects that cut across faculty boundaries.

2.2 The internationalisation of research

According to the KOTA database, publishing in the humanities and social sciences has increased since 1994–1996, especially on international forums. For example, an increasing fraction of peer-reviewed scientific articles are published in international series. The sharpest increase in the number of articles published in international journals is recorded for theology. The proportion of articles published abroad is highest (at over 80%) in economics and business administration and psychology. There has also been a marked increase in the number of articles published in edited volumes or printed conference publications as well as in the number of monographs.

Table 1. Proportion of articles published abroad by field of study in 1997–1999 and 2000–2002.

Field of study	1997–1999	2000–2002
Theology	29%	41%
Humanities	43%	50%
Art studies*	37%	19%
Educational sciences	50%	56%
Social sciences	45%	51%
Psychology	79%	81%
Law	20%	11%
Economics	78%	83%
Total	52%	56%

*Including art, music and theatre.

Source: KOTA database, Ministry of Education.

Figures compiled by the NSI show that the number of citations received by Finnish publications in the humanities in 1998–2002 is higher than the world average. In the social sciences, the relative citation impact for Finland is close to that average.[1] Data presented in the previous review for 1995–1999 showed that citations to Finnish publications in these fields were still well below the world average. Against this background it is safe to conclude that Finnish research in these disciplines now enjoys stronger international recognition than before. However, the NSI database leans heavily towards the Anglo-American world and does not provide comprehensive coverage of publishing in the humanities and social sciences. In particular, large amounts of research from outside continental Europe and in other than the English language are omitted from NSI statistics. It may be assumed then that Finnish research has greater significance than these figures give to understand.

In its review in 2000, the Research Council recommended that steps be taken to support publishing in foreign languages by allocating more resources to translation and editing services. So stringent are the style and grammar requirements of high-profile international publishers that researchers in the humanities and social sciences need special support in order to make the grade.

Domestic scientific journals and series also play an important role in many disciplines within the humanities and social sciences. Domestic publishing has a major impact on public opinion and the general attitude climate. Good examples of scientific publishing that has a social impact include publications in women's studies, social-scientific environmental research and theology. In public discussions and debates, researchers in the humanities and social sciences can contribute most significantly to the human side, as well as providing a historical perspective and addressing value issues.

The internationalisation of research is a major challenge for funding bodies as well. In the previous review of the state and quality of scientific research in Finland, the Research Council looked ahead at the emerging impacts of globalisation in the humanities and social sciences and concluded that funding bodies need to step up their cooperation both nationally and internationally. This recommendation has been reflected in changing patterns of cooperation in research programmes. New avenues of cooperation have been sought in all research programmes launched in 2002, and the Council now has regular exchange and cooperation with the National Technology Agency, for example. International cooperation is pursued along several different avenues. Life as Learning Research Programme serves as one example of international networking with corresponding research programmes in a number of other countries. Joint international funding is being tried out with the European Science Foundation (ESF) and its member organisations in the field of social sciences. Involvement in the European Social Survey project, for instance, has opened up interesting and important opportunities in comparative research.

Finnish researchers were involved in 42 projects under the Improving Human Potential programme in the EU's fifth research framework programme; this is about

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[1] In the humanities the relative citation impact was 1.37 and in the social sciences 1.01, while the world average is 1. Publishing is discussed in closer detail in the Review's General Section, Chapter 5.1.

one-quarter of all projects funded through the programme. To qualify for funding through the framework programme, research projects are expected to involve elements of cooperation with researchers from different countries as well as across disciplinary boundaries, and further to produce results with practical application. Many comparative research projects related to welfare, the labour markets, training and other fields have benefited from the new opportunities of European networking. Overall the number of Finnish researchers involved in humanities and social science projects appears to be on the increase. Another indication of the growth of European research cooperation and at once of the competitiveness of Finnish research in the humanities is the start-up in 2001 of a multidisciplinary research project in church history. Coordinated by the University of Helsinki, this is the first ever EU-funded research project strictly within the purview of the humanities.

In its previous review in 2000, the Research Council for Culture and Society recommended that more European research funds be allocated to the humanities and social sciences. Indeed these fields have now achieved a stronger position in the EU's sixth research framework programme that was opened at the end of 2002 – although research into themes most directly relevant to these disciplines still accounts for only a small proportion of total programme funding.[2] For the first time now the framework programme includes a separate thematic priority (Citizens and governance in the knowledge-based society) for research oriented to the humanities and social sciences. In June 2002 the Commission invited expressions of interest in which researchers were to propose future research subjects to be included in the sixth framework programme. Judging by the proposals received, there is quite a high level of interest in these themes when compared to the amount of funding earmarked. However, the sixth framework programme also includes new types of project funding that challenge researchers in the humanities and social sciences to set up joint European projects on a major scale. Universities, for their part, need to invest greater effort in developing administrative services that would allow Finnish experts to serve as coordinators for European research projects. The Research Council has supported Finnish participation in framework programmes by granting funds for purposes of preparing applications, mainly to project coordinators.

2.3 Special issues of researcher training

The number of doctoral degrees increased sharply in the 1990s. In 2000–2002, a total of 1,149 PhDs were completed in culture and society disciplines (Figure 1). However, compared to the number of first university degrees the proportion of students proceeding to the doctorate is lower than in other fields. For instance, almost 60 per cent of all higher university degrees completed in 2001 were in the field of culture and society, whereas among PhD graduates the figure was no more than 33 per cent. However, there are marked differences in the PhD graduation rate between individual disciplines. The highest number of postgraduate degrees relative to the number of professors was recorded in philosophy, theology, psychology, social sciences and history; and the lowest in communication and information sciences, law, linguistics and business administration.

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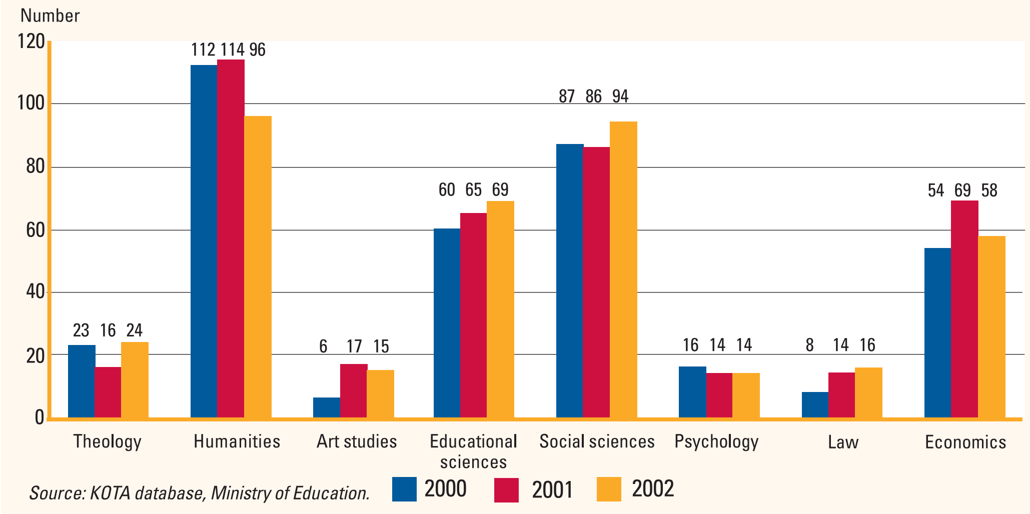
[2] The total budget for the sixth research framework programme in 2002–2006 is 17,500 million euros, with 225 million euros set aside for the Citizens and governance in the knowledge-based society programme.

Women accounted for 47 per cent of all PhDs completed in 2000–2002. By field of study, the proportion of women PhDs was highest in education at over 60 per cent.

Figure 1. PhDs completed in fields of study hosted by the Research Council for Culture and Society in 2000–2002.



Source: KOTA database, Ministry of Education.

As in other fields, graduate schools have become a significant pathway to the doctorate in cultural and social studies. Most disciplines represented by the Research Council have by now their own graduate school. One single statistic suffices to illustrate just how widely scattered these disciplines are: the 346 graduate school places funded by the Ministry of Education as from the beginning of 2003 are divided between 41 graduate schools. These are usually single discipline or multidisciplinary networked schools run jointly by several departments or universities. Examples of single discipline networked schools are provided by national graduate schools in philosophy, education, history, art history, law, theology, literature, economics, economics and business administration, psychology and linguistics. Good examples of the areas of study covered by recently founded multidisciplinary networked schools with a special thematic focus are Russian and East European studies, language technology, American studies, the gender system, social-scientific environmental studies and development studies.

In the interest of balanced scientific and cultural development it is important that all disciplines under the Research Council for Culture and Society should have their own, broadly-based graduate schools that could also accommodate postgraduate students from closely related fields of study. However, it is not possible within the humanities and social sciences to have a graduate school system that caters for postgraduate training needs in each and every discipline. Apart from graduate schools, other important pathways to the PhD have included postgraduate positions at universities and research institutes – although these positions now look set to lose much of their significance with the changes being planned in university systems of teaching and research posts. The Research Council has actively supported researcher training outside the system of graduate schools, for instance through high-quality research projects and support for doctoral studies abroad. It remains an important recommendation that researcher training in the humanities and social sciences should have access to flexible funding options that correspond to the needs of science and society at large. That in turn will require steps to develop improved monitoring mechanisms.

PhD graduates in cultural and social research have had little difficulty finding employment. According to Statistics Finland the jobless rate at year-end 2001 among those graduating in 1998–2001 was less than three per cent for all PhDs except those with a degree in history, archaeology and music. The jobless rate is clearly lower than in 1997 when in the humanities the figure was 5.5 per cent and in the social sciences 2.1 per cent. Most PhDs are engaged in the university sector, but some with a degree in cultural and social research work in the business sector. In the private sector the biggest single employer is publishing. At universities, most new PhD graduates are hired through fixed-term project funding from outside sources.

Research and postgraduate training at arts universities is a special strength of Finland's: this is an area where there is still very limited researcher training in other EU member states. In 1997–1999 a total of 22 PhDs graduated from arts universities, in 2000–2002 the figure rose to 38. Research and postgraduate training at arts universities includes both artistic and scientific components, although the position and interaction between these varies from one university to the next and even between different postgraduate programmes at individual universities.

Postgraduate training at arts universities is organised through graduate schools and with project funding. However, the funding of postgraduate training at arts universities is somewhat more problematic than at science universities in that there is no funding body that is directly responsible for supporting doctoral studies in arts subjects. For reasons of equity alone, however, arts and science universities should have the same kind of access to public funding for postgraduate training.

The employment and placement of PhD graduates is closely monitored in order to keep track of educational needs. The skills and competencies required in a traditional university career will no longer suffice for future PhDs. Therefore steps will be needed to develop and upgrade the doctoral degree in cultural and social research as well, where the most typical career path has been that of a professional researcher within the university system. One area that holds interesting promise for the future is represented by new business concepts emerging at the interface between hard and soft disciplines (e.g. IT and new learning environments, language technology or electronic business).

2.4 Research funding

No research can be competitive and have a real impact unless it has access to adequate funding. According to Statistics Finland figures, research spending in the humanities and social sciences at universities has developed favourably over the past few years. In relative terms the biggest increases in research spending are recorded for art studies, cultural studies, political science and communications studies. Table 2 shows the research spending for the humanities and social sciences in 1997 and 2001 as well as the proportion of core budget funding in 2001. Although funding for research in the humanities and social sciences has continued to increase in recent years, its percentage share of the total volume of university research has declined over the past ten years.

Table 2. Research spending in the humanities and social sciences* in 1997 and 2001 and the proportion of core budget funding in 2001.

Field of research	1997 1,000 €	2001 1,000 €	Percentage share of core budget funding in 2001
Philosophy	2,351	2,984	38
Linguistics	23,677	29,295	76
Art studies	10,318	16,140	68
Theology	4,919	5,435	61
History and archaeology	6,866	9,504	48
Cultural studies	3,389	5,090	54
Humanities total	51,520	68,448	66
Economics	6,016	7,076	55
Business administration, economic geography	25,552	35,998	46
Law	9,799	12,438	67
Social sciences	15,973	19,520	53
Psychology	6,839	7,945	44
Education	26,075	33,185	76
Political science, administrative science	8,059	12,113	49
Communication and information studies	4,606	6,933	51
Statistics	2,856	1,832	63
Social sciences total	105,775	137,040	57

*Including universities and university hospitals, excluding polytechnics.

Source: Statistics Finland.

The proportion of external funding continued to increase in the humanities and social sciences throughout the 1990s, but even so the total volume of such funding remains much lower than in other disciplines. Although universities have managed to attract more external investment now, the bulk of research is still funded from core budget sources. In the humanities core budget funding accounted for 66 per cent and in the social sciences for 57 per cent of research spending in 2001. Therefore the concerns voiced by the Research Council in 2000 with regard to the adequacy of core funding for universities and its importance to maintaining a high level of research, remain as current today as they were then. The key importance of core funding is further accentuated by the slowdown in research funding from the business sector.

The majority of external research funding in the humanities and social sciences comes from the Academy of Finland and other public sources. In history and theology, the Academy of Finland now accounts for more than 70 per cent of all external funding. On the reverse side of the growing proportion of funding from other than core budget sources, departments have had to cover the additional costs incurred from research projects. As from 2001 these have been compensated from an overheads grant included in all Academy funding decisions.

3 Strengths, cooperation and new openings in different fields of research

In its quest for renewal and reform, research in the humanities and social sciences has mainly probed the interfaces between different disciplines and established new contacts of cooperation at home and abroad. As well as showing stronger internationalisation, research in these fields has devoted greater attention to its national impacts and to its relationship with the surrounding society.

Long-standing areas of strength in the field of **philosophy** include logic and its history, the history of philosophy, the philosophy of science and norm theory. New, emerging areas include the philosophy of mind and cognition, practical ethics and other applied philosophy, social philosophy, phenomenology and feminist philosophy.

Finnish philosophy has primarily been grounded in the analytic tradition and showed a strong leaning towards the Anglo-American world. Recently, however, closer contact has also been established with the other Nordic countries and continental Europe. Finnish philosophy has also shown some ambition to break down barriers between philosophical schools and to inspire comparative discussion and debate between different lines of philosophical inquiry.

Philosophy has continued to have quite a prominent role in public and social life. Philosophers are also in demand in the private sector for such jobs as drafting codes of professional ethics, management training as well as various consultancy tasks. Most philosophers, however, work at universities with funding from universities themselves, the Academy of Finland and foundations.

Philosophical research is an inherently international exercise, although it is also considered to have significance to national culture. Philosophical commentary and textbooks therefore also get published in Finnish, as do Finnish translations of classical works.

Among the areas that have shown good success in **historical research** are ideological and cultural history, the history of the Middle Ages and the Early New Age in Finnish and general history, urban history, the history of the family and the history of everyday life, the history of crime, psychohistory and the political history of the Cold War. Antiquities research and social history based on quantitative methods have been losing some ground.

The challenge of international cooperation has been taken seriously not only in general history that has always shown a strong interest in international subjects, but also in domestic history as well as in the historical subjects covered at social science faculties. Nonetheless the subject of Finnish history also emphasises the national significance of this field, on good grounds. Even though research in this field is chiefly concerned with national questions, the number of international publications in history have shown strong growth. International researcher visits, colloquia and networks of cooperation have also increased, as have international comparisons in research.

Both the search for new interfaces between disciplines and multidisciplinary cooperation have increased in historical research. Historians of antiquity and the Middle Ages have traditionally worked closely with linguists and archaeologists; ideological and conceptual historians have often joined forces with philosophers and political scientists; social and economic historians in turn have had close cooperation with social scientists; and for historians of the everyday the most natural choice of partner has been represented by anthropology and ethnology. Reference might also be made to the interest shown by psychohistorians in the psychoanalytic research tradition and to the cooperation of environmental historians with other environmental sciences.

Archaeology is another inherently multidisciplinary science. It has traditionally worked closely with the natural sciences, including geology and paleology. Recently archaeology has been showing some movement away from its traditional natural science orientation towards the humanities, mainly history and linguistics. It is reasonable to suggest that the role of classical archaeology has strengthened.

Research in **education** is divided into several different areas with quite widely divergent interests. There are major research groups and units in the fields of research on learning, training and development in the workplace, teaching technology, educational policy, evaluation and subject didactics. Three of these areas are covered in the Academy's research programme Life as Learning that was launched at the end of 2002: research on learning, training in the workplace and teaching technology.

The organisation of Finnish education research into ever larger projects has helped to give it greater international exposure. However, there are still no more than a handful of researchers (in the fields of workplace development, learning and teaching technology, educational sociology and educational policy) who enjoy international recognition. Multidisciplinary cooperation among different units and more advanced publishing practices would certainly allow the discipline better to meet the needs of society and add to its international visibility. As far as publishing is concerned it is important to make a clearer distinction between publications dedicated to academic discussion and debate and those aimed at practical application.

In education, the past few years have seen quite rapid growth in project funding from outside sources, mainly the Academy of Finland, the EU, the National Board of Education, other government agencies, local governments, foundations and to some extent business companies. There are three graduate schools in this field.

Linguistics has the great advantage that it is intrinsically an international and multidisciplinary field of research. A major force of domestic cooperation in this field is the national graduate school Langnet, which covers both Finnish and Swedish (Finland's two official languages) and foreign languages. Research in this field has been highly rated in several international evaluations.

One shadow hanging over the future of this field is the ever greater predominance of the English language, which has now reached the point where some other languages are reporting problems recruiting new students. The numbers dropping out is another cause of some concern. One of the options universities may well have to consider is a rearrangement of their national division of labour and increased Nordic networking: this might help to safeguard the diversity and high standard of language education and research.

Although most language students are pragmatically oriented to teaching, translation, technical communication and other modern language occupations, there is also growing interest in postgraduate studies. However, the majority of PhD graduates still take up an academic career because neither the school system, public administration nor business and industry seem to be interested in recruiting PhDs. Most of the research funding also comes from the Academy of Finland and various foundations.

Fennistics obviously has research interests all of its own that tie in with Finnish language heritage, but otherwise it is largely preoccupied with the same kind of research questions as foreign language studies more generally. The fact that all these disciplines share the same graduate school has also contributed to increased research cooperation across language boundaries. Theoretical and applied research in language technology both have a prominent role in general linguistics by virtue of the national and Nordic language technology programme. Training and research in the field of logopedics has received a major boost in recent years, and discussions are currently underway on the possibility of expanding research and teaching in this field beyond the universities of Helsinki and Oulu in order to meet the high demand.

As far as methodology is concerned, the most noteworthy trend is surely the growing impact of corpus linguistics: the collection and analysis of domain-specific corpora is central to many Academy-supported projects. There is growing need in comparative corpus research for an extensive and annotated standard corpus of the Finnish language. As well as applying new quantitative methods that are applicable with electronic corpora, researchers are also making increasing use of multidisciplinary qualitative methods.

There is one centre of excellence in the field of linguistics, viz. the Research Unit for Variation and Change in English. The high standard of expertise at this centre should be put to better use so that the whole field of linguistics could benefit.

New emerging lines of inquiry include various socio-linguistic themes, discourse research and pragmatics. Likewise, there has been growing research into the social relevance of language use and themes related to professional language work.

The growth of international cooperation is based upon diverse patterns of exchange and interaction between people who speak different languages. Concealed in these processes are new and important objects of study that researchers have not yet fully appreciated. In general the human ability to translate thoughts into words and to take part in various decision-making and human relations processes is set to become an increasingly important area of multidisciplinary research.

There is more and more cooperation with other closely related disciplines as well. This is crucially important for research into such questions as the relationship between language and culture, the psychological foundations of language learning, the identity and socialisation of immigrants and other bilingual people, speech recognition and automatic language processing more generally.

Cultural research is carried on in numerous fields of humanities research (literary studies and arts research, cultural history, media studies, aesthetics) and in numerous social sciences (such as cultural sociology, environmental aesthetics). In all these fields the scope of research interests has been expanding and work has taken on an increasingly multidisciplinary nature – to such an extent that it is now impossible to categorise research in this field under any one heading.

In the discussion below, cultural research is understood as referring to ethnological and anthropological disciplines, which are taken to represent expertise on popular culture and foreign cultures. Ethnological and anthropological sciences have continued to broaden their scope of interests from their traditional themes towards such issues as the modernisation of culture and post-modernity. In today's world of globalisation and localisation, research into ethnicity has also taken on a new look.

Growth and expansion in these fields, mainly through the adoption of new research themes and fresh theories and methods, have led to increasing diversification and fragmentation with important benefits. Internationalisation and methodological reform have also helped to strengthen one of the core areas of research (classical folklore).

Interdisciplinarity and multidisciplinarity have increased: these fields have more and more cooperation now, both in the context of research projects and postgraduate training, with cultural women's studies, cultural sociology, media studies, textiles, clothing and craft design studies and cultural geography, for example. Interdisciplinarity has been promoted by the adoption of new research interests, a stronger theoretical approach and by the use of new (e.g. visual) materials. The graduate school in this field is shared with ethnological disciplines. In addition, a number of postgraduate students in ethnological and anthropological disciplines are researching their theses at thematic graduate schools.

As cultural research has continued to grow and expand, so it has assumed increasing weight and significance. Researchers and experts are now being trained to produce, analyse, interpret and apply information about cultures. Hence the growing scientific as well as social impact of research.

The main strength of **law** lies in its immediate applicability, i.e. its close links with legislative work, the enactment of laws and legal praxis as well as with discussions on legal policy. In other words, law has close and direct, real-time interaction with society and its development.

Research in law has traditionally consisted mainly of monographs by individual researchers. This has always given the discipline a certain air of cliquishness; its scientific status has never really been challenged. However in this regard, too, the younger generation of researchers is clearly showing signs of greater openness and an eagerness to work more closely especially with other social scientists.

There is a strong and very productive tradition of legal dogmatic research in Finland, but recently growing attention has also been paid to methodological diversity, particularly in doctoral training. Finnish legal scholars compare favourably with colleagues in the other Nordic countries, both in terms of the volume and the quality of their production.

Relevant branches of law have been closely and dynamically involved in ongoing processes of internationalisation, and European law has grown into an independent discipline at universities. Among the most recent newly independent branches of law are women's legal studies, legal linguistics and sports law. In the future regional jurisprudence may well emerge as a topical branch of law in the fields of legal anthropology and legal history, possibly contributing to international comparative law.

Looking ahead to the future, new branches of law may be expected to develop in response to advances in biotechnology and information technology (medical law, media law). Changes in social values, such as those related to the environment, will also require new lines of research and closer cooperation with both natural scientists and humanists.

Psychology departments at Finnish universities are strongly oriented to research. There are several neuropsychological research groups in the country that enjoy international recognition: all of them rely upon multidisciplinary cooperation and state-of-the-art imaging techniques. The most important line of research is that concerned with the neurological foundation of linguistic development.

Significant research has also been done in the fields of developmental psychology, personality and motivation research as well as experimental cognitive research. Postgraduate training in psychology is mainly organised in research groups, although the national graduate school plays a major role as well.

Publishing in psychology is concentrated in international journals, and within the discipline the international visibility of research is monitored by means of citation indices (in the same way as in the natural sciences). This approach to assessing the quality of research that relies upon international feedback certainly provides a useful vantage-point for the further development of research. At the same time, though, it may well narrow the scope of psychological research to such themes that are most likely to get published in journals that are covered in publication databases.

Research in the **social sciences proper** – sociology, social policy, social psychology and social work – shows a high degree of specialisation and internationalisation. Research in these disciplines has been geared to addressing current challenges in the social policy domain. One of the areas that has shown particularly impressive progress is social-scientific women's studies. International publishing has increased to some extent, although there is much variation in the speed of change between different themes and areas of specialisation.

The stable development and regeneration of the social sciences proper has been supported through core funding and multidisciplinary research programmes. The graduate school system, for its part, has contributed to their institutionalisation: continuity here has been represented by schools within specific disciplines, renewal and regeneration in turn by schools dedicated to specific research themes. The Research Council has recently been preparing the Research Programme on Social Capital and Networks of Trust that will be launched in 2004. Apart from the social sciences proper, the programme will involve numerous other fields of cultural and social research as well as health research. The programme is aimed at raising the scientific quality of research in this thematic area, promoting multidisciplinary and international research and at increasing the social and scientific visibility of cultural and social research.

Academy research programmes and graduate schools have contributed significantly to domestic cooperation in the fields of social sciences proper. International networking has been much slower: successes in research cooperation have been more or less sporadic and in many cases based upon international funding programmes. Indeed, a major new challenge for research projects in the social sciences proper is to promote closer international cooperation and networking.

Ever since the early 1980s Finnish social sciences proper have been in a state of methodological transition. On the one hand, both the research techniques and the thinking that lies behind the traditional quantitative methods of empirical research have developed rapidly. On the other hand, considerable effort has been invested in developing qualitative methods. To an extent this work has been quite successful – but primarily in terms of popular and media interest rather than in terms of rigorous scientific progress. In view of the changes brought about by globalisation and Finland's current membership of the European Union, the international impact of Finnish research – for instance in the field of comparative studies in the social sciences proper – remains quite modest.

Arts research is conducted at both science and arts universities. In recent years the field has expanded enormously, and at the same time it has shown strong internationalisation. Special attention has been devoted to developing postgraduate training at arts universities. The major arts subjects at science universities are literature, music and art history.

An important strength of literary studies (and at once a problem) is the division of the discipline between several different strands of research: so widely do the premises of some of these lines of inquiry differ from one another that it will soon be difficult to talk of one coherent discipline of literary studies. These trends have led to theoretical and methodological reform, to deliberations on the distinctive qualities of literary studies and to multidisciplinary networking particularly in the field of cultural studies concerned with gender systems, ethnicities and the environment, for instance. Researchers are moving across the old dividing line between Finnish literature and comparative literature all the time: instead the main focus of research at universities now is upon specific themes, such as lyrics and the institution of literature. Among the disciplines most closely related to literary studies, aesthetics and theatre research have invested heavily in internationalisation. In the field of aesthetics, the strongest lines are represented by environmental aesthetics and phenomenological aesthetics.

Research in music is traditionally concentrated upon the historical and analytical study of art music. In recent years, however, these lines have remained more in the background as several other approaches have emerged that draw upon premises from outside the realm of music research (such as cognitive music research, ethnomusicology, feminist music research and semiotics).

The main strengths of art history have traditionally been in empirical research, but in recent years, with the growth of a more theoretical orientation, some researchers have been calling for a distinction to be made between research in visual cultural and traditional empirical research in fine arts.

Literature and art history both have their own graduate schools, which has been important for doctoral training. In the field of music there are some smaller and more closely profiled graduate schools. Project funding from the Academy of Finland has helped to cover some of the areas that remain outside the scope of these schools.

Research and postgraduate training at arts universities have shown strong growth. Each of the arts universities in the country has its own rather distinctive profile in postgraduate training. A special challenge for postgraduate training at arts universities is presented by the question of how to combine the diverse elements of science and the arts.

Within the field of **economics,** research in different areas of national economics and business administration covers a broad spectrum of issues from the operation of the markets and the public economy through to problems of selection behaviour in private households. The traditions and approaches in different strands of economics and business administration vary widely. In terms of methodology, economics has remained a more coherent field of research than business administration. The need for research and training in these fields has increased as a result of accelerating technological change and the greater knowledge-intensity of the economy.

Economics traditionally has an important role among the social sciences. It also figures prominently in the field of business administration, because it is important for companies to have a clear understanding of their broader operating environment. The discipline has organised cooperation in training and research and it has run a national postgraduate training programme since 1990. The departments of economics within the metropolitan Helsinki area are joining forces to set up a major unit in economics.

Research in these fields has been geared to addressing the challenges thrown up by economic development. Much of the work has been concerned with the recent, exceptionally severe recession in Finland as well as the processes of EU integration and monetary union. New areas of research are represented by the globalisation of the economic environment and advances in information technology. The development of the international economy and new information products have also presented new questions for research on economic structures, growth theory, incentive systems and financing. Analysis of the economic sustainability of the welfare state is an important and topical area of research.

Economists have become more closely involved in debates on economic policy and in various expert positions, which now include the assessment of European economic policy. Empirical research has been strengthened by virtue of new databases and methodological tools. Work by Finnish economists is more and more often published internationally, and they are also in demand for international positions of expertise. Large numbers go abroad to continue their studies after graduation, and many Finnish scholars have been appointed to professorships in other countries.

Business administration is divided into a number of disciplines, the most important of which are management and organisation, accounting and financing, and marketing and international business. Entrepreneurship and logistics have also emerged as independent disciplines. Research traditions in business administration are highly diverse and not necessarily limited to economic issues; to some extent their problem-oriented vantage-points are in fact quite far removed from economics. Research traditions in this field are less established than in economics, but the number of professors and other researchers is much greater. There is a national graduate school in the field that is organised around individual disciplines.

Based upon knowledge and know-how, Finland's development strategy as well as the globalisation of business have created a growing demand for business know-how. The networked structures of efficient production and e-commerce have presented new challenges for research. Deregulation and internationalisation in the financial markets have inspired new research into corporate strategies, financial administration and financing. Another focus of research has been upon entrepreneurship and human resource management.

Postgraduate training has increased in response to the growing demand for PhDs both at universities and in the business sector. Drawing upon external sources of funding, universities in economics and business administration have stepped up their research effort and launched development units to provide an effective university interface vis-à-vis business companies. The Academy of Finland is supporting the research programme for Finnish Companies and the Challenges of Globalisation (LIIKE) that started up in 2001 in order to strengthen research in economics and business administration and to promote business know-how. The two main challenges in this field are to strengthen the research tradition and to promote the internationalisation of research.

The principal **theological** disciplines are biblical exegetics, church history, systematic theology and practical theology with its various branches. The latest newcomer is comparative religion, which has expanded significantly in recent years. The methodology applied in these fields is largely shared in common by such closely related disciplines as classical and Semitic philology, literary studies, philosophy, history, education and psychology.

Theological centres of excellence have close contacts of cooperation with multidisciplinary networks across Europe as well as in the United States. These centres of excellence, the EU project in church history coordinated by the University of Helsinki and ESF networks have significantly contributed to postgraduate training and to methodological development of the field in Finland. There are also several other projects in theology that have close contacts with corresponding projects abroad; most of these are funded by the Academy of Finland.

New methodological openings have been made in studies of religious communities, voluntary work in the third sector, values in education as well as in research into the humanities dimensions of social capital. There is also multidisciplinary research cooperation in the field of modern church art and architecture as well as in Middle East archaeology. The new theological faculty at the University of Joensuu provides a meeting place for western and eastern, i.e. the research tradition of Orthodox theology.

Research in theology should seek to step its involvement in current theological discussions: it needs to contribute more intensively to debates in society on questions of values and morality, to the analysis of the welfare state and to the dialogue between different religions both at home and abroad, especially in EU contexts.

The discipline of **political science** comprises general political science, international politics and administrative science. There are two fields that enjoy international exposure: research into contingency and conceptual changes in politics and research concerned with voting behaviour and voting procedures. Political science and international politics have a joint graduate school.

Traditional research themes in political science include political institutions, power, decision-making and voting behaviour. Empirical research into political behaviour and opinion formation has also been promoted by developing social-scientific data archives. Political science also comprises politological research concerned with political systems other than the state institution.

Research into international relations has dealt with such issues as globalisation, European integration and peace research. Several universities have research units and posts dedicated to European research (Jean Monnet professorships). In 2002 the Academy of Finland commissioned an international evaluation of Finnish research in the field of foreign and security policy. The findings indicated that work in this field covers a wide range of research issues. The main emphasis is upon problems in Finnish foreign policy both in a national and regional and in a European context. Finland's relations with the Baltic states and the Nordic countries and especially with the EU have also received some attention.

The reviewers came to the conclusion that political science in Finland should move away from background analysis and interpretation of current phenomena and devote more attention to comparative international studies. Furthermore, they recommended that research in foreign and security policy adopt a stronger international orientation; that greater effort be invested in developing postgraduate training; that research careers be supported by means of funding instruments; and that international publishing be increased.

Administrative sciences have mainly addressed current development needs in the field of social policy, concentrating on questions of national importance. Crucially, the development of administrative sciences requires a concerted effort to raise the quality of basic research as well as steps to build up an independent theoretical foundation, leaning for instance on the tradition of organisation and governance theories. With the continuing internationalisation of the public sector, there will also be a growing need for internationally qualified experts in public administration. Administrative sciences are set to gain increasing significance with the launch of the EU's Citizens and governance in the knowledge-based society programme under the sixth research framework programme. A new line of work is represented by international comparative research in which Finnish institutions of public administration and their work is compared with corresponding institutions in other countries. The needs for this kind of research will no doubt increase in the future with integration and the growing demands of efficiency in the public sector.

Statistics provides important support to many lines of inquiry in the social sciences. The past few years have seen significant changes in the field of statistics, and new methods have been developed outside the realm of traditional statistics in computer science and mathematics. Biosciences have emerged as an important area of application for statistical methods alongside the social sciences.

The broad field of **communication sciences** is in a constant state of flux. In particular, there has been a sharp increase in the number of disciplines in media studies. A new area of research is represented by everyday media use, for instance.

Diversity is at once the strength and the weakness of modern communication studies. Continued internal dialogue is particularly important as research traditions and concepts are drifting ever further apart. Indeed the main challenge for the future is how to take advantage of the methodological diversity in this field.

Traditional areas of strength in the field of Finnish communications studies include societally-oriented research in journalism and mass communication; research with a humanistic and cultural orientation that has evolved alongside journalism and mass communication (with some measure of overlap); and information studies, which comprises information retrieval and questions of information management. However, the long-standing division of the field between humanities and social sciences oriented research is less pronounced than before. Interdisciplinarity within the field has been strengthened by the national network of cooperation in communication studies, which has included two graduate schools and involved close research collaboration. The units involved specialise in the areas of organisational communication, journalism, audiovisual and visual communication and information sciences.

Communications researchers have been active to network both internationally and across disciplinary boundaries. New areas of research interest include media globalisation and digitalisation. Active participation in social discussions and debates and close contact with people and organisations outside the academic world have been another distinctive characteristic of communication studies.

4 Assessing the impacts of research in the humanities and social sciences

It is particularly important in the field of cultural and social research to explore the various mechanisms through which their impacts are conveyed to the society around. To this end, a survey was organised in which researchers in ongoing Academy research programmes under the Research Council for Culture and Society were asked in their own words to describe the impacts of their scientific work. Together with more traditional sources of information used for this purpose, this material provides useful insights into the many different types of impact that research in the humanities and social sciences can have. However, this dataset does not cover all the disciplines hosted by the Research Council. For reasons that have to do with the way the data were collected, the results cannot be directly generalised to the whole field of research, but they do serve to complement the picture that is obtained from other sources.

The social impact of science and research refers to the influence that their results or the expertise of scientists has upon social and political decision-making processes, upon expert practices or upon public access to information. Some research in the social sciences is directly addressed to practical problems and aimed specifically at supporting informed decision-making. Some researchers, in their own accounts, referred to situations where a research project has directly contributed to changing public services or legislation. This kind of research with immediate impacts on social practices has been conducted in law and the social sciences proper, among others.

However, in most cases the social impacts of research cannot be reduced to the answers provided by one particular study to a given practical problem. Instead, those impacts usually evolve over the longer term, in an incremental process of deepening understanding. This understanding may be filtered through to social practices in various different ways. One of the most important pathways is through initial education at universities: here the new research knowledge is passed on to people who are engaged in that particular field and its academic practices. Another important channel is represented by general interest publications. In the field of cultural and social research at least some research reports can be written in such a way that they are accessible to ordinary readers beyond the research community. The difference between scientific reporting and science popularisation is not as clearcut in these disciplines as it is in the natural sciences. The researchers themselves felt that work they had published for domestic audiences had had an impact on social issues. A third channel of social impact is provided by participation in various working groups or in the writing up of expert opinions. In assessing the impact of their own work, the researchers we consulted had numerous examples of how they had taken part in an expert capacity in drafting new practices or decisions. Some researchers occupied significant positions of expertise in international bodies: in these cases researchers can be said to exercise social impact at an international level.

Part of the general impact of research in culture and society is based upon the personal contribution of researchers, in their capacity as independent and critical commentators, to public discussions and debates. Researchers working in the humanities and arts also have a major role to play in increasing and shaping the cultural consciousness.

Commentators with a background in social scientific research have contributed to democracy by critically weighing the effectiveness and legitimacy of public administration and political decision-making.

Where the social impacts of research are concerned, it is important to bear in mind that those impacts are based not only on the results of work that researchers have done themselves. Researchers and research groups also play a major role in importing international research and scientific discussions into Finnish culture. Through the work they have done, researchers have gained entry into international science communities and networks, and that in turn has given them access to the latest research knowledge, regardless of where it is produced.

Researchers in the field of culture and society could have a greater social impact than they do today. Only some researchers have succeeded in finding various different means and channels of impact; the expertise of large numbers of researchers remains largely underutilised. Researcher training today provides only limited guidance in exercising social impact based on scientific expertise. The systems in place at universities and research institutes for purposes of bringing the latest research knowledge to the attention of social debate and political decision-making, are also inadequate. The same goes for the use of scientific expertise in the media, public administration and political decision-making. The scarcity of people in the media and public administration with a researcher training is one possible explanation.

A high quality of research is obviously crucial for science and research to have a social impact. Assessments of this quality are most typically based upon indices that measure the internal impacts of science. The impacts of an individual researcher working within a given discipline may be either local or global. Local impact refers to the direct measures through which the researcher has influenced her/his immediate scientific community. Judging by the materials collected for our survey, the most important forms of local impact include the training of the next generation of scientists, importing new theoretical and methodological tools into Finnish research and assembling research groups and networks. This category further comprises various functions in science administration which are geared to maintaining and strengthening the infrastructures of science and research. As far as local impacts are concerned, the conclusion seems warranted that Finnish research has become more professional and more organised in the humanities and social sciences. Many researchers involved in Academy research programmes feel that securing the next generation of scientists, sharing know-how, organising research groups and other infrastructure development are all an integral part of the researcher's job.

The global impact of science, then, refers to the connections of the individual researcher's or research group's work with the general development of the discipline concerned. The most important forms of global scientific discussion and debate are represented by scientific publications and congresses. What matters most is the type of forum on which and the frequency with which researchers get to publish their work as well as how other researchers make use of that work. Other important indicators of impact include international invitations to lecture and invitations to various positions of scientific expertise and evaluation. On the basis of general statistical data and the researchers' own descriptions, the evidence is quite clear that publishing by researchers in the humanities and social sciences has increased. The results also indicate that more and more researchers are attending international congresses and aiming to publish in international series.

In some disciplines (such as psychology), there are by now clear indications that researchers are consciously seeking to gain international visibility through high-profile journals and in this way to push up their citation indices. In Finland there are some researchers in the humanities and social sciences who have, as judged by citation impact factors, gained an exceptionally strong international position in their scientific community. However, disciplines within the humanities and social sciences differ quite sharply from one another in this respect. In most disciplines the services that compile citation figures provide very poor coverage of the most important publication channels. In these cases it is impossible to draw reliable conclusions on the basis of the statistics compiled about the global impacts of individual researchers. By contrast the researchers' own descriptions allow us to draw the conclusion that there are in these fields quite a substantial number of researchers now who are regularly invited to lecture at important congresses and whose expertise is widely used in reviewing publications and in different researcher networks.

5 Conclusions and recommendations

This review of the current state of research in the humanities and social sciences has drawn attention to various issues related to the procedures and methods of evaluation itself and to the information made available for evaluation:

- Methods of research evaluation need to be developed in order that a clearer picture can be gained of both the internal scientific impacts of research and above all of the social impacts of research. Traditional methods of evaluation provide only a narrow picture of the impacts of science and research. Improved methods are needed to describe how the outputs and new ways of thinking produced in humanities and social sciences research are conveyed through to practices in society.
- International exposure and impact are crucial considerations in the assessing the quality of scientific work. The sources of information currently available do not provide a sufficiently reliable basis for valid assessments in the field of social scientific and humanities research. There is a need for more comprehensive databases with more balanced geographical coverage of publishing in these fields. The ESF initiative for the development of a new publication and citation database in the humanities should be implemented as soon as possible.

Our review of the internal and social impacts of science and research has also drawn attention to the question of the most appropriate channels of publishing in social and cultural research. Many high-profile groups in different disciplines have already achieved quite a prominent status in the international scientific debate and their publishing is compatible with the best international practice. However, in many fields publishing in humanities and social sciences research does not provide the groups concerned with the kind of international visibility that their research would warrant.

- Continued attention needs to be paid to developing high-quality publishing strategies in the humanities and social sciences. From the earliest stages of researcher training, researchers should learn about international publishing practices and be taught the skills and competencies they need in order to get their high quality work published in esteemed international journals.

- In the human sciences, language requirements are much stricter in international publishing than they are in medicine and the natural sciences. Special measures of support are needed to help researchers in the humanities and social sciences get over the language barrier and meet the rigorous style and grammar requirements of high-profile international publishers.
- In research funding decisions as well as in scheduling research projects, it is important to make sure that enough time and resources are set aside for the careful preparation of manuscripts for articles and books.

It has become clear in this review of social impacts that researchers do not always have the skills and competencies required by science popularisation or other forms of persuasion based on scientific work. Scientific organisations also provide inadequate support for the social impacts of research.

- Researcher training in the fields of cultural and social research should pay closer attention to the different forms and pathways of social impact. Specifically, this means researchers should learn how better to target their publishing; learn the proper skills of scientific publishing; and also learn about the special requirements involved in science popularisation.
- In supporting the efforts of universities to fulfil their new functions in social and regional service, special consideration should be given to the ways in which researchers could bring the latest findings from their own work as well as from their discipline more generally to benefit society as a whole.

In the process of appraising applications for research funding, reviewers time and again discover that there are numerous theoretical schools within the field of cultural and social research that are unaware of the work that is going on elsewhere, or that intentionally refrain from referring to that work even when they are clearly addressing the same or closely related research problem. This narrow-minded focus on one's own line of research may seriously hinder the accumulation of theoretical and empirical knowledge in the human sciences. Feedback from foreign reviewers in particular suggests that Finnish researchers in the field of culture and society are not always able to provide a very impressive account of the methods they have used. This points at problems, on the one hand, in the tradition of writing up research plans and research reports; on the other hand, it also suggests that knowledge and know-how in the field of research methodology are not of a sufficiently high standard.

- In human sciences research special attention ought to be paid to the ways in which the development of science and the accumulation of scientific knowledge can be promoted. A good knowledge of research traditions and ethically sound citation practices is of great importance.
- Many fields of research in culture and society should pay more attention to improving knowledge in research methodology. The aim should be that doctoral students gain an in-depth understanding of the methodology in their own field and also learn about the latest methodological trends internationally.

In recent years the solutions adopted in Finnish research funding have provided a sound basis for intensive researcher training in the context of graduate schools and research projects. The decrease in the amount of funding made available to culture and social research as a proportion of the net total has meant, however, that opportunities for a long-term research effort have not increased to the same extent.

- Where future funding decisions are made it is important to make sure that research in culture and society has access to resources that correspond to its growing challenges.
- For reasons of securing the continued international success of Finnish science and research, and also for reasons of supporting individual research careers, more attention needs to be given to the postdoctoral stage, which is when researchers should work to gain a prominent status in the international science community.

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Interim reports by the scientific advisory boards of centres of excellence in the humanities and social sciences funded by the Academy of Finland in 2000–2005.

Contents

Appendix 1. Research Council for Culture and Society in 2001–2003

Chair
Arto Mustajoki, Professor
University of Helsinki

Kaija Heikkinen, Docent
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Liisi Huhtala, Professor
University of Oulu

Marja Järvelä, Professor
University of Jyväskylä

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Science Adviser Helena Vänskä and Science Adviser Jaana Salmensivu-Anttila from the Academy's Culture and Society Research Unit were involved in preparing the Research Council's report.

Contents

HEALTH RESEARCH

ACADEMY OF FINLAND

RESEARCH COUNCIL FOR HEALTH

Contents

1 Revisiting the 1997 and 2000 reviews: to what extent have the recommendations been met?

In the Academy's review of the state and quality of scientific research in Finland in 2000, the Research Council for Health noted with satisfaction that most of the recommendations put forward in the 1997 review had been met in the three-year interim. Today, the Council is in the position to make the same observation with regard to the review in 2000: most of its recommendations have been picked up and the problems identified in the research system addressed.

In 2000, drawing upon on its review of the state and quality of scientific research in Finland, the Academy of Finland suggested that (1) core budget funding to universities be increased with a view to strengthening the front end of the research and education system. Decisions and steps taken by Parliament and the Ministry of Education have helped to satisfy this recommendation. The decision to add a 12.5 per cent overheads share to all Academy research appropriations has also served to consolidate the financial situation of universities. (2) The second recommendation in 2000 called for increased national and international cooperation among research funding bodies with a view to meeting the shortfall in funding for health research. The Research Council for Health has responded by stepping up its cooperation with hospital districts, national foundations and international bodies. The recommendations aimed at (3) strengthening the clinical research career and increasing clinical research funding have led to the decision to start up a national clinical graduate school and a research programme in health services research. (4) The Council's decision to establish a support centre for register research utilising national registers in the health care sector is also in line with the recommendations of the 2000 review. In its report in 2000 the Council also (5) expressed its concern over the decline of small disciplines. This remains an ongoing concern, in spite of the Council's efforts to strengthen these fields both through additional support for researcher training (veterinary medicine, nursing science and psychiatry), calls for targeted appropriations (pharmaceutical research and development) and through support for the creation of Nordic and European graduate school and researcher networks (e.g. in the fields of dentistry and child psychiatry). The previous review on the state and quality of science and research also emphasised (6) the importance of ethical, social and economic issues. All of these have received closer attention in new research programmes and in the curricula of graduate schools.

2 Assessment of health research funding in 1997 and 2000

As is pointed out in the two previous reviews, figures for research and product development expenditure in medical sciences cannot be obtained directly from Statistics Finland sources. The main difficulty is that research work done at biocentres is classified in these sources under the natural sciences or engineering and technology, even though most of that work is without question health research (biomedicine). Academy expenditure on researcher training abroad and membership fees to international organisations are also excluded from Statistics Finland figures. For these reasons a substantial proportion of funding by the Research Council for Health appears to be channelled to sectors outside the fields of medical and nursing science.

The reader is advised to bear this in mind when studying the figures and summaries attached.

In 1997 the Research Council for Health estimated the total volume of funding for health research at 281 million euros. In 2001, according to Statistics Finland, the figure had risen to 470 million euros (an increase of 67%) mainly as a result of substantial additional investment by the pharmaceutical industry: these figures showed an increase of 190 per cent from 68 million euros in 1997 to 197 million euros in 2001. The corresponding figures in the university sector were 85 and 123 million euros (up by 45%), in university hospitals 64 and 74 million euros (up by 16%) and in research institutes under the Ministry of Social Affairs and Health 62 and 76 million euros (up by 23%). In other words, it is the research and product development investment by the pharmaceutical industry that accounts for most of the strong growth in this field of research, whereas hospitals and research institutes have seen very little real growth.

Table 1 provides a more detailed picture of trends in R&D spending in universities and university hospitals from 1997 to 2001 by sources of funding.

Table 1. R&D in the university sector in 1997 and 2001.*

Source of funding	Medical sciences, € million		Biology and environmental sciences, € million	
	1997	2001	1997	2001
Core budget funding (own funding)	58.2	66.1	25.8	29.4
Academy of Finland	11.3	15.6	13.2	21.8
Other Ministry of Education funding (including graduate schools)	0.6	4.0	0.8	3.3
Ministry of Social Affairs and Health	56.9	55.4	0.2	0.04
National Technology Agency Tekes	3.6	12.4	2.4	6.5
Other ministries (including other Ministry of Trade and Industry funding)	1.4	2.5	1.7	1.7
Municipalities	0.4	1.5	0.6	1.3
Other public funding	1.1	2.5	0.3	0.5
Domestic funds	2.6	8.2	0.5	1.7
Domestic business companies	3.1	9.2	1.7	2.7
Foreign funds	0.6	1.2	0.2	0.1
Foreign business companies	4.3	8.4	0.4	0.4
EU funding	2.7	5.7	2.7	3.1
Other foreign funding	1.4	3.0	0.6	0.5
Universities' own funds	1.5	1.1	0.6	0.5
Universities total	85.3	122.7	51.7	73.6
University hospitals total	64.2	74.1		
Total research expenditure by university sector	149.6	196.8	51.7	73.6

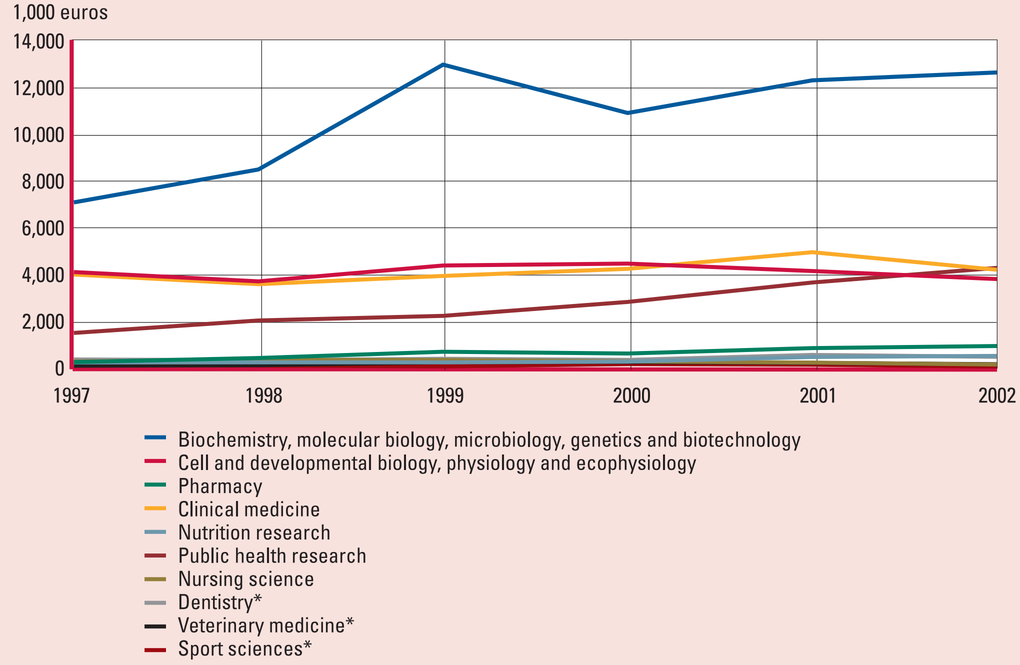
* Research expenditure in medical sciences as well as in biology and environmental sciences by source of funding (million euros).

Source: Statistics Finland 1999 & 2003.

2.1 Research funding by the Research Council for Health in 1995–1999 and 2001–2002

The Research Council for Health is the smallest of the Academy's four research councils, accounting for 18 per cent of the total volume of Academy research funding. In 2001 the Council awarded 35 million euros to support Finnish research in this field, which represents seven per cent of total research expenditure in the medical and nursing sector in 2001. Most of the support for health research goes to biomedicine (cell, molecular and developmental biology and biochemistry; Figure 1).

Figure 1. Academy of Finland funding for health research by field of research (million euros) in 1997–2002.



Source: Focus database 6 June 2003, Academy of Finland. * These trendlines overlap.

In addition to the direct funding decisions made by the Research Council, biomedicine benefits from funding through research programmes and centres of excellence programmes: all funding decisions for the latter are made by separate subcommittees. However, if we compare the average proportions of applications that are approved in different fields of research, there is not very much difference between these figures (Figure 2).

There is more year-on-year variation in smaller fields of research. The Research Council for Health has been more or less even-handed in its treatment of applications from different fields of research: the large differences in funding volumes merely reflect differential success rates and to some extent differences in the average size of projects. On the other hand, a growing proportion of research projects today are multidisciplinary ventures, which means it is impossible to slot them under any single heading.

Figure 2. Number of funding decisions by the Research Council for Health relative to number of applications, percentage shares in different fields of research in 2000–2002. Figures in parentheses indicate totals for three-year period.

Source: Focus database 6 June 2003, Academy of Finland.

3 Assessing the quality of research

3.1 Biomedicine

While work continues to sequence the genomes of an ever-growing number of organisms, biomedicine is proceeding in its research to the post-genomic stage: to a broader analysis of interactions between organisms, cells, cell organells and macromolecules, to a study of complete metabolic pathways and to the application of the evidence amassed for purposes of unravelling disease processes and developing new pharmaceuticals and therapies. At the same time the biomedical paradigm is transforming from hypothesis-driven research to discovery-driven research and moving towards more integrative approaches. In addition, the study of diseases is turning its attention to interactions between hereditary factors, the environment and lifestyle. Bioinformatics, the discipline of science that specialises in the compilation of databases and in the computer-aided analysis of research data, has become one of the fastest-growing areas of research in the biosciences. In the wake of these trends, biocentres have emerged as important multidisciplinary research environments for high-quality research and highly specialised support services (e.g. genotyping, microchip analysis, proteomics, structural research and imaging). Biocentres also play a major role in postgraduate training and in the development of new innovations.

The recent international evaluation of the impact of public research funding on Finnish biotechnology (Biotechnology in Finland... 2002) took a broad view on the discipline and defined it as comprising the bulk of basic life science research as well as its applications. According to the evaluation report the marked increase in research funding over the past 15 years has produced impressive progress in the biosector. Finland has several national centres of excellence that are at the very cutting edge of international research. The evaluation report also pointed out that Finland's biocentres have played a major role in raising the quality standards of research as well as in pulling down barriers between different disciplines and between bodies outside the university sector. In particular, the panel of experts was impressed by the long-term and consistent efforts and investments by the Ministry of Education, the Academy of Finland, the National Technology Agency and the National Public Health Institute to strengthen the facilities and resources for biotechnology research in keeping with the policy decisions of the Science and Technology Policy Council of Finland. Finland's research and technology programmes received strong recognition in the evaluation, as did the support provided by the Academy of Finland for national infrastructures. The Academy of Finland has also made determined efforts to step up its international cooperation in research funding. All in all the evaluation concluded that the steps taken in Finland have strengthened the national research and innovation system, contributing to the country's success in several international comparisons.

Targets for development

Major new investments are going to be needed in research equipment if biomedicine is to remain at the cutting edge of research. In recent years these needs have been met by setting up centralised service units (core facilities) at biocentres with special biotechnology funding from the Ministry of Education: these steps have helped to provide biomedicine with research facilities and resources of an international standard. Since the development of research equipment is set to continue apace, it is crucial that continued support is made available for these investments. At the same time it is important to provide adequate support to research groups working outside biocentres, centres of excellence and research programmes. Furthermore, funds are needed to cover the salary costs of highly trained experts at central service units. These experts do not necessarily have their own research profile, and therefore they are not in a position to benefit from the Academy's current funding instruments. Biocentres ought to further step up their cooperation. Model organisms ought to be added to the Finnish research palette as soon as their genomes are sequenced, and greater attention should be paid to the cross-use and comparison of different model organisms. Further effort should also be invested in the development of transgenic mice technology. The development of know-how in bioinformatics is considered a special priority.

3.2 Clinical research

Finland has a high standard of health care and the medical profession has traditionally been actively involved in research. However, most of this research is a sideline to full-time clinical duties and therefore remains on a rather modest scale; lack of time and scarce resources have effectively prevented a more professional approach. Indeed in this situation a clinical research career is not necessarily the most attractive proposition for young medical doctors: already they are under considerable pressures of workload in health care, specialisation requires several years of intensive study and in many cases it is at this same stage of life that people begin to have a family. Yet the health care system needs to be backed up by high-level clinical research in order that it can continue to provide a high-quality service. Evidence-based medicine has clearly highlighted the importance of well-designed and well-implemented clinical research. High-quality clinical research also requires training. The recent launch of the National Graduate School for Clinical Research provides a solid foundation for the systematic development of clinical researcher training.

The Finnish health care system has established a firm and reliable foundation for clinical research in medicine. Increasing cooperation and networking between clinical research, basic biomedical research and epidemiological research has helped to further raise the quality of work in these fields. In particular, research in molecular genetics, epidemiology and clinical pharmaceuticals have achieved widespread international recognition. Strong traditions have also been built up in research into certain common diseases, such as cardiovascular diseases, diabetes and neurodegenerative disorders. The launch of a national centre for register research will support the use of our internationally unique registers for purposes of clinical research.

Finland has a prominent role in clinical trials. Although Finland accounts for no more than 0.4 per cent of the international pharmaceuticals market, around eight per cent of all clinical trials on new pharmaceuticals are carried out in Finland. This is based upon certain national strengths in health care registers as well as in the academic research tradition in certain clinical fields. A new universal trend is that clinical trials are more and more often conducted outside academic environments. However, it is important that university hospitals in particular continue to provide a supportive environment for clinical trials. Another threat is represented by EU directives which are jeopardising researcher-led innovation and indeed all research funded by sources other than the pharmaceutical industry. In Finland a substantial fraction of clinical research has consisted of studies commissioned by the pharmaceutical industry.

Basic education as well as scientific postgraduate training in medicine are provided by universities under the auspices of the Ministry of Education. The bulk of clinical research is carried out at university hospitals maintained by hospital districts and administered by the Ministry of Social Affairs and Health and local councils, although the costs of research are compensated to university hospitals in the form of so-called EVO grants from central government. In 2001, EVO grants for health research amounted to 51.5 million euros, for teaching the sum total was 54.3 million euros. Close to one-half of EVO grants for research go to research projects selected in open competition and to cover researchers' salary costs. Financial problems in the health care sector have reduced the amount of funds allocated to research through the EVO scheme. A recent report commissioned by the Ministry of Social Affairs and Health establishes new, healthier guidelines for the use of EVO grants and the future strategy of clinical and systems research.

In 2001, some 18 per cent of the funding decisions by the Academy of Finland Research Council for Health (some 4.9 million euros per annum) went to research projects in clinical medicine. Although many centres of excellence are closely engaged in clinical research, there is no centre in Finland that is specifically devoted to clinical medicine.

In its funding decisions concerning Academy Research Fellows, the Research Council for Health has sought to take into account the special needs of clinical researchers and to give them the opportunity to engage in clinical work during their fellowship.

Targets for development

Clinical researcher training needs to be further strengthened and the National Graduate School for Clinical Research developed in close cooperation with other graduate schools. A stronger multidisciplinary orientation is needed, together with more active exchange between clinical research, biomedicine and epidemiology. Another major challenge for the future is to maintain the appeal and attraction of the clinical research career. Individual researchers should be encouraged to continue their postgraduate training at research centres abroad and in general to invest in international networking. The Research Council for Health supports the EVO working group's recommendations, which it feels would support the integration of clinical and health systems research. Further the implementation of a national research strategy would contribute to a more systematic, long-term research effort.

3.3 Dentistry

The changes that swept the field of dentistry in the 1990s had a hugely detrimental effect on research. The decision to relaunch basic education in dentistry at the University of Turku marks a first step in restoring the teaching and research posts that were more than halved in number following cutbacks in the early 1990s. Research in dentistry has also struggled to accommodate to the reorganisation of clinical patient work as part of the health care system at community health centre or central hospital level as from the beginning of 2000. Both the universities of Helsinki and Oulu have tried to resolve this problem. However, in both of the models adopted the changes have hampered the recruitment of young dentistry researchers in this field. In recent years most of the Academy's support to dentistry awarded on the basis of open competition has been channelled to a few select groups. There is one centre of excellence in the field that specialises in the dental developmental biology. Another centre of excellence that concentrates on biomaterials research also includes a dentistry component. Research in the field has clearly benefited from networking among Nordic and European research and researcher training in dentistry.

Targets for development

As the difficulties in dentistry research continue to persist, the field will apparently need special measures of support in order to remain internationally competitive. Although its integration with the community health centre and hospital system has meant that dentistry research is now eligible for EVO grants, the level of research funding available for this field is not at all satisfactory. Efforts to encourage closer collaboration among different dentistry units have not been entirely successful, apparently because of the different research approaches at these units. Closer integration with medical research might help to promote the development of research and postgraduate training in dentistry. A national review of the state of dentistry research and postgraduate training might also provide useful clues for future directions of development. Dentistry does not have a graduate school of its own; the integration of the discipline into local graduate schools has also been somewhat problematic. However, dentistry is represented at the National Graduate School for Clinical Research.

3.4 Veterinary medicine

The University of Helsinki Faculty of Veterinary Medicine will be moving to the Viikki Campus in 2004–2006. With the Veterinary Medicine and Food Standards Research Institute (EELA) making the same move, the biosciences cluster at the campus will provide a strong foundation indeed for the growth and development of veterinary medicine research in a multidisciplinary environment. The Faculty is also keen to establish closer contact with research groups at the Meilahti Campus, and in 2003 it has joined forces with the Faculty of Medicine to set up a five-year professorship in viral zoonosis. The centre of excellence in biomaterials research also includes a veterinary medicine component.

Since 1999 the Faculty has run a postgraduate training programme in veterinary medicine. That programme has been developed in close collaboration with two graduate schools based at Viikki. In addition, the Faculty continues to work closely with the Nordic Forestry, Veterinary and Agricultural University (NOVA), which will be having an increasingly prominent role in postgraduate training especially in clinical fields. In line with the development plan for veterinary medicine, the Research Council for Health has primarily supported researcher training, allocated vacancies for postgraduate training, supported postdoctoral researcher training abroad and provided funding for training courses within the context of the veterinary medicine researcher training programme.

Targets for development

Further intensification of researcher training remains a key priority in the development of veterinary medicine. More attention should be given to training needs especially after completion of the doctoral thesis, when researchers have the opportunity to move to other research groups, preferably abroad, and eventually to repatriate. The Faculty should also invest greater effort in defining and delineating the strategic goals and priorities of research. In this it should take note of other disciplines, particularly those that are active at the Viikki Campus, seeking to make the best possible use of synergy benefits in pursuing those goals.

3.5 Public health research

EU legislation and world trade agreements are likely to have a profound effect upon health promotion and the health care system in Finland. The recent changes that have taken place in social living conditions and public health in Finland’s neighbouring regions, the opening up of the Finnish labour market to people from these countries as well as changes in Finland’s demographic structure (its low fertility rate and population ageing) and the regional breakdown of the population are all putting the health care system under considerable pressure.

The new technology produced by research in biomedicine as well as the blurring of priorities resulting from commercial marketing, have thrown up important questions about the responsibility of research: to what extent should the focus of public health research be shifted from its former priorities to questions related to the assessment and control of medical technology?

The crisis in the Finnish health care system has inspired growing interest in public health research. At the same time, though, the difficulties dogging health care have imposed unrealistic goals and timetables for research. The Academy of Finland has a very prominent role in supporting research in public health. That support allows for "end-critical" research that is not necessarily geared to finding immediate solutions to problems or launched in response to specific practical problems. The choice of focus for etiological research has particularly important implications with regard to health promotion. Ongoing explorations of the biological foundations of the human genome have provided a welcome breakthrough in the effort to understand the determinants of health. However, in the current situation of limited researcher resources there is a real risk that excessive targeting of research funding on genetics diverts attention away from research topics that might open up easier ways to the promotion of health and the prevention of illness.

Targets for development

There is no centre of excellence in the field of public health research (cf. environmental health). High-level research in this field is often based on extensive networking and cooperation. The centre of excellence strategy should be developed towards greater diversity in such a way that it supports all fields of health research regardless of their typical structures.

The number of graduate school training positions in public health is not enough to satisfy current demand, and these places are offered only by few universities. Having all students crammed into one graduate school (or two, if the National Doctoral Graduate School Consortium in the Administrative Sciences is taken into account) is no doubt good for interdisciplinarity, but it also makes it much harder for researchers working in new fields of research to gain entry.

It is very difficult for new and emerging fields of public health to secure research funding through open competition. These fields include research into functional capacity, mental health and social health as well as qualitative research and other non-traditional methodological approaches. One of the reasons why these fields have such poor success is that evaluation is based upon the criteria of biomedical research. Although health studies should primarily be problem-driven, it is also important to recognise and take account of the diversity of disciplines that are involved in public health research. Conceptual clarification might provide useful guidance for the identification of those fields that are most in need of additional support. The Research Council for Health and its evaluation panels need to have stronger expertise in the social sciences.

Empirical studies in public health research often require the cooperation of health care units and/or people. This situation where the "laboratory" is beyond the researcher's control imposes special demands upon the administration as well as upon the time scale of research. These distinctive features should be taken into account in the allocation of funding as well as in the level of detail required of research plans. Epidemiological research in particular often requires extensive follow-up periods in order to produce meaningful results. If funds are allocated to projects for no more than a few years at a time, that may well reflect adversely upon the preservation and effective utilisation of valuable research materials. On the other hand, there is certainly scope for improving the coordination among different materials and the researchers collecting those materials. Steps are needed to improve the start-up, preservation and use of major cohort materials.

3.6 Environmental health

The main concerns of research in environmental health today are with the health hazards that are caused by small particulates in community air, poor indoor air quality and climate change. As well as working to prevent these health hazards, research in environmental health is concerned to secure access to microbiologically and chemically safe food and drinking water. The successes that Finnish projects have enjoyed in the competition for EU research funding attest to the high quality of their work.

There is one centre of excellence in environmental health. The discipline received a major boost from the Academy-coordinated Finnish Research Programme on Environmental Health (SYTTY) in 1998–2001. One of the main goals of the programme was to promote multidisciplinary research, and in that it certainly succeeded. The international panel of experts who evaluated the programme recommended that it be continued because three years is too short a time to take full advantage of the development potential created by the programme.

At the Academy of Finland, research in environmental health is not covered by any single research council. Therefore it is important that steps are taken to strengthen mechanisms for the promotion of a multidisciplinary research approach. Research and postgraduate training in environmental health are quite heavily concentrated in government research institutes. That base ought to be expanded, with at least some universities having strong research and teaching programmes in environmental health. Closer cooperation is needed with research in veterinary medicine (environmental hygienics).

3.7 Sport sciences

Research in sport sciences is conducted at the University of Jyväskylä Faculty of Sport and Health Sciences, centres of sports medicine and at certain other scientific organisations. In the late 1990s direct support from the Ministry of Education to research in sport sciences amounted to around 3.5 million euros per annum, with project appropriations accounting for 1.3 million and overhead grants for 1.5 million euros. Biomedical research has accounted for around 65 per cent of all project appropriations, research in social and behavioural sciences for around 35 per cent. Funding has not increased in the same proportion as research appropriations overall. According to recent discipline assessments there are now enough multidisciplinary research units in sport sciences, but only part of them provide up-to-date research facilities (Liikuntatieteen arviointi... 1999 and Evaluation of sports... 2003). Some biomedical units are too small and have only weak contacts with units in other fields of research. Some have created a significant network of international contacts and have an impressive publishing record. Postgraduate training in biosciences research lags some way behind the rest of the field, most particularly in cell and molecular biology and genetics.

Targets for development

Research groups in sport sciences are heavily dependent on funding from the Ministry of Education, most of which is geared to supporting sectoral and applied research in this field. Recent reviews of the field have encouraged researchers to turn more often to other sources of funding. The quality of research in the field of sport sciences would undoubtedly benefit if funding for basic research in the biosciences were provided not through a separate, closed system but awarded instead on the basis of open competition. Academy research programmes also provide one possible source of funding in sport sciences. The relative isolation of research and postgraduate training in sport sciences is certainly holding back development in this field. Units that have close scientific exchange and interaction with other national and international research communities in closely related fields, are at once those that have shown the strongest growth and development. Closer involvement in the national graduate school system would help to raise the standard of scientific postgraduate training in sport sciences.

3.8 Nutrition research

Comprising work in nutritional epidemiology as well as clinical and experimental research, nutrition research is concerned to explore the associations between diet and health. The emphasis in nutrition research is upon major public health problems such as obesity, diabetes, cardiovascular diseases and cancer. Two universities give students the option of majoring in nutrition, i.e. the universities of Helsinki and Kuopio. Nutrition research is also done at other universities, the National Public Health Institute and the Finnish Institute of Occupational Health. Although the research units at different universities and research institutes are relatively small, the field as a whole has made impressive progress, witness the large number of graduating PhDs and the growing research community. The field does not have a graduate school of its own, but training is organised through multidisciplinary graduate schools.

Dedicated Academy support for nutrition research is quite limited, but in several projects nutrition research represents an important component; many diabetes studies provide a good example. Food science research comes under the administration of the Academy's Research Council for Biosciences and Environment. The National Technology Agency, for its part, supports product development in the closely related field of foodstuffs research.

Targets for development

As well as applying the tools of nutrition and food sciences, research into the health effects of nutrition needs to show a stronger multidisciplinary orientation. Studies into the health effects of foodstuffs have also opened up new contacts of cooperation with other disciplines, such as medicine and pharmacy. One possible future direction for nutrition research might be in resolving major public health problems on a multidisciplinary basis. A research project jointly administered by the Research Councils for Health and for Biosciences and Environment and focusing upon nutrition, foodstuffs and health would certainly provide a stronger foundation for addressing broader research problems and for improving multidisciplinary cooperation.

3.9 Nursing science

Nursing science has become firmly established as an independent discipline at five universities, but it still has more limited resources than most other fields of research. In response to growing demand, faculties have increased their student intake on Master's degree programmes, but the volume of basic funding has not increased accordingly. The main obstacles to the development of research remain the same as before, i.e. the limited number of research posts relative to teaching posts and the fact that research careers begin relatively late. The latter problem is further exacerbated by the requirement in most training units that students applying to a programme leading to a Master's degree in Health Sciences shall have prior professional training. A key objective in this field has been systematically to develop research programmes and PhD training. Different units have their own areas of research expertise.

All departments have active international cooperation, some of them are part of a European postgraduate training network. A domestic network (HealthNet) set up with support from the Ministry of Education has also contributed to increasing cooperation with health sciences. Although research in nursing science has gathered momentum and become increasingly internationalised, the amount of research funding it receives in open competition through the Academy of Finland remains fairly modest. Recently, however, the discipline has benefited from increased international research funding.

Nursing science units have been working closely with one another in the field of doctoral training since 1988. Founded in 1995, the Finnish Postgraduate School in Nursing Science has had an important role in coordinating postgraduate training in nursing science. The graduate school provides a wide range of training programmes.

Targets for development

More resources need to be invested into research and postgraduate training in the field of nursing science. With the teaching resources currently available, it will not be possible to develop and strengthen doctoral training in this field. Support should be channelled particularly to senior and postdoc researchers. The Academy of Finland launched in 2002 a discipline assessment of nursing science; the results and recommendations from that assessment will be available by the end of 2003.

3.10 Pharmaceutical research

High-quality basic research coupled with a dense network of biocentres, centres of excellence and graduate schools run by medical faculties, provides a strong platform for the pharmaceutical innovation process. Finland is also in an excellent position to take advantage of the research done in dentistry and veterinary medicine and to put its findings to use in the development of new drugs, diagnostic tests and biomaterials. There is a shortage of experts of pharmacology in industry (Brännback et al. 2001). The same goes for medical doctors with experience in conducting clinical trials. The Clinical Drug Trials Graduate School and the National Graduate School for Clinical Research play a key role in the training of these specialists. Training in administrative issues related to clinical research, pharmacovigilance, regulatory affairs and health economics is currently highly fragmented in Finland.

Pharmacy faculties play a crucial part in drug research and development. Qualified researchers are needed in various fields of pharmaceutical product development, most specifically in research and development related to drug formulation. The Graduate School in Pharmaceutical Research has stimulated further training in this field and contributed to raising the quality of research. The Drug Discovery Graduate School concentrates on certain therapy areas and is pharmacologically oriented, as is the Clinical Drug Trials Graduate School. All these three graduate schools would certainly benefit from closer cooperation. Drug discovery technology centres have been launched at the universities of Helsinki and Kuopio to further explore and develop the drug discovery process. Jointly administered by the National Technology Agency and the Academy of Finland, the Drug 2000 technology programme is aimed at bringing forward basic research and technology that can significantly contribute to drug discovery and development and boost the competitiveness of the Finnish pharmaceutical industry.

Targets for development

It is crucially important for the future development of the pharmaceutical sector that medical faculties and biocentres step up their cooperation. There is also need for closer collaboration among the various graduate schools in the field, who should also work closely in planning the priorities of research and education. There is an obvious need for an increased number of training positions at these graduate schools, whose PhD graduates have excellent prospects of finding employment.

4 Impacts of research

Health research is in an excellent position to promote public health and well-being. However, the critical transfer and application of research knowledge into practice requires practitioners' understanding and experience of research. In health care, it is the individual doctor who in each case has to assume responsibility for diagnosis and treatment decisions; there is no impartial mediator in-between research and the people applying its results. Political decision-making on health issues also benefits from an understanding of the processes of producing and interpreting research evidence. Basic and applied research in the field also provides a useful basis for international business ventures.

4.1 Impacts of research on public health

Health research is aimed at practical application: it is, by definition, a line of inquiry aiming to having a positive impact. The most important outcome of health research is health (understood in a broad sense). Other relevant outcomes include "social peace" (security and confidence in the availability of help in the event of illness, regardless of wealth, place of residence or other factors) and the positive effects of the development of health technologies upon business and industry.

There are two main pathways via which research has an impact on health: (1) increased knowledge (which factors influence health and illness, and the preventive measures designed on the basis of that knowledge) and (2) the service system and the technology (understood in a broad sense) and care provided through that system. There have been some attempts in other countries to assess the impacts of health services on health, but these attempts have been rather disappointing: knowledge, services and other factors influencing health are so intricately interwoven with one another. Impacts of various specific interventions are often known in experimental conditions, but little is known about the impacts in real life situations. In particular, comparative data with other interventions is lacking. It is easy to find examples from health research of how health knowledge or technology have impacted health; it is much harder to single out the contribution of individual research projects or researchers. Generally speaking the accumulation of relevant knowledge is a slow, incremental process that draws upon the work of a large number of researchers from the international science community.

Rather than weighing the impacts of health research in general, it makes more sense for research funding bodies to ask whether their funds are channelled to those lines of work and those projects that are the most cost-effective (in terms of useful outcomes relative to resources invested). Cost efficiency analyses are not easy, though: apart from the general complications mentioned above, it is extremely difficult to compare studies conducted within very different time frames and dealing with very different kinds of subject-matters. We can offer some crude estimates by consulting experts who know about the determinants of health and by asking researchers themselves to weigh the impacts of their work. Since researchers working in a certain area play a key role in translating knowledge from that area to the practical domain, one useful approach to assessing impacts is to establish whether all the main lines of health research are represented in Finland. Making funds available to different types of research is a good way to minimise the risks of not attaining impact on health.

The Academy of Finland has provided quite good support for research aimed at understanding biological phenomena and the genome in particular. Funding for research which applies information yielded by basic research (including other than biological research) in the treatment of patients has not increased quite as rapidly, and more resources need to be invested. Research into the role of factors outside the human body, especially if it is based on interventions, is a quick and useful avenue to finding new ways of maintaining health and preventing illness. Bearing this application potential in mind, this line of research certainly warrants more resources.

4.2 Impact of research funding for biotechnology

The most extensive discipline assessment by outside experts during the period under review concerned the impacts of public funding on biotechnology. Since this assessment covered large parts of basic biomedical research, many of the observations and recommendations it made apply to health research and the Finnish research system more generally. The panel concluded in its report that the strong growth of research funding for biosciences has had a very positive impact on the state and quality of research in Finland. It said that the network of biocentres set up in Finland had contributed significantly to raising the quality of research in Finland and had helped to bring down barriers between individual disciplines as well as between the academic world and business and industry. All in all, the experts took the view that the steps taken in Finland had helped to strengthen and internationalise its research and innovation system, which was also reflected in the country's success in several international comparisons. In recent years large numbers of new businesses have been set up in the Finnish biotechnology sector. However, as well as heaping praise on Finland's increasing investment in the biosciences, the panel also had a number of recommendations to make, many of which concern health research as well. The reviewers suggested that practices with regard to ownership of intellectual property rights be clarified with a view to making more effective use of research results. Improvements were also recommended to the technology transfer system so that discoveries made in basic research could be put to better use.

4.3 The pharmaceutical industry: a major user of health research

The pharmaceutical industry combines many different areas of health research and is the most important commercial user of research in this field. Besides the pharmaceutical industry, health research has significant commercial potential in diagnostic testing, medical instruments, information systems and services (clinical experiments and screening tests) and in functional foods.

Basic research in drug development started in Finland some 20 years ago. Most of the early work was done within pharmaceutical companies; the first products of this research have now reached the international marketplace. These first proprietary drugs show that in spite of its limited resources, Finnish pharmaceutical research and development is indeed capable of producing internationally significant results. Biocentres and centres of excellence in research have emerged as a new major source of innovation in pharmaceutical research. The mechanisms are now in place to support better and earlier use of the results of basic research from universities, and there is also growing awareness of the need not just to publish results, but also to look into options of patenting new discoveries. Quite a few small pharmaceutical start-up companies have now emerged in Finland. These companies are especially keen to network with research groups at universities and to license their innovations early on to major international pharmaceutical companies. Apart from these drug development companies, there are also many other new businesses that integrate basic research in the biosector and medical know-how and that are focused on diagnostics, biomaterials applications, the development of medical instruments and services. These companies have received substantial support from the National Technology Agency and the Finnish National Fund for Research and Development. In recent years the high expectations pinned on the biosector have begun to wane somewhat – and the availability of international venture capital has become more limited. Under mounting financial pressures, many of the start-up companies may face a wave of mergers.

Under the joint administration of the National Technology Agency and the Academy of Finland, the Drug 2000 programme represents one recent effort to improve and develop evaluation of the impacts of research funding. Among the measurable objectives of the programme are the following: new drug target molecules, molecule families, screening methods, drug candidates, diagnostic methods, patent applications, patents issued, licensing agreements, research service contracts and new companies. Furthermore, the programme is keen to monitor progress in national and international cooperation between universities and business companies as well as the transfer of researchers to the business sector. One important consideration in assessing the success of funding programmes is the long time required by the development of a new drug: the drug discovery phase may last from 5 to 10 years, and the drug development phase from 7 to 12 years. Thus, the impacts of funding must be assessed over a sufficiently long period.

5 Conclusions and recommendations

Strengths and opportunities

Finland's demographic structure, its sufficient heterogeneities and the unique bottlenecks in the country's population history, provide an exceptionally favourable setting for interdisciplinary research into common diseases. Among the main strengths of this Finnish research setting are the extensive patient and sample materials that have been collected; the detailed and comprehensive population-based registers that have been compiled; and the country's egalitarian and high-quality health care system with its uniform diagnostic criteria. In addition, people in Finland are generally willing to let scientists use the data compiled in existing registers, in so far as that contributes to the well-being of future generations. No other country in the world has access to the same kind of dataset that can shed light on the interactions between hereditary factors, morbidity, lifestyle and the environment in the aetiology of diseases. The collection of these data has required close cooperation between epidemiologists, public health researchers and clinical researchers as well as government research institutes, and that cooperation should be easy to expand within both basic and applied research. The evidence that can be unearthed in this line of work is bound to have a major impact on future health care as well as on business in the pharmaceutical and diagnostics sectors.

The Finnish research system has strengthened considerably over the past ten years: this can be attributed among other things to the establishment of interdisciplinary biocentres and their service units, the graduate school system, the postdoctoral system, the centre of excellence and research programme policy and the special funding made available to biotechnology. The Finnish research and innovation system enjoys widespread recognition for its modern efficiency. All this puts health research in a strong position in the competition for international research funding. One of the key strengths of the Finnish research system is its rapid responsiveness. For instance, following the publication of the biotechnology evaluation report on 9 December 2002, the Ministry of Education and the Academy of Finland began work to implement its recommendations in spring 2003.

Weaknesses and threats

Although there are no indications in sight of an actual shortage of research staff, the Research Council for Health is concerned about the declining proportion of researchers with a basic training in the field of health research. There are no doubt several reasons why a career in research appears a less attractive proposition than before. While the graduate school and postdoc systems have brought greater clarity to the early stages of the research career, the uncertainties for the young independent researcher remain and indeed have become increasingly pronounced, as was pointed out in the biotechnology evaluation. The post of an Academy Research Fellow is the only straightforward option for postdoctoral researchers who are looking to gain their independence, but fellowships are available for no more than some 15 per cent of applicants. Universities have not been able to adjust their system of teaching and research posts in such a way that they could have resolved this problem. The difficulties of launching upon a career in research seem to be the greatest in the field of clinical research.

There are still no mechanisms in place for the provision of systematic support for research infrastructures (equipment, core facilities and databases), which makes it difficult to take full advantage of the strengths of our research system. The same problems concern the archiving and use of major national population cohorts for research purposes.

Recommendations

Amongst the various targets for development identified in different disciplines, the Research Council for Health wishes to highlight the following:

1. Improving the position of young researchers seeking independence. The establishment of clear career paths in research and the removal of uncertainties related to the research career are considered crucial to increasing the appeal of a career in research and to securing a sufficient number of new recruits. Universities will also need to take steps to upgrade their systems of teaching and research posts in such a way as to make the option of a research career more attractive. The Research Council considers the development of the clinical research career particularly problematic. The general trend whereby responsibility for clinical research (and indeed other lines of research) is being taken over by other than those with a degree in health sciences, should be halted by giving medical doctors and dentists the opportunity simultaneously to engage in research, to spesialise and to continue in clinical work.

2. Research infrastructures. The maintenance and improvement of research equipment and other infrastructure at universities and research institutes is another important area that calls for increased development efforts. Steps are also needed to make sure that nationally important research materials can be properly preserved and put to the best possible use.

3. The problems of small disciplines. Although the problems of certain small fields of research in health research have been addressed through the launch of graduate schools, research programmes or through dedicated support from the Research Council, these problems continue to persist – especially in those fields that have not benefited from such support measures. There are several possible strategies for addressing the future problems of small disciplines. One such solution might be the closer paradigm-driven integration of research in these fields with other fields of research. Discipline assessments are one useful way of getting advice on how to go about developing the field in question (as exemplified by the 2003 evaluation of sport and health sciences). A lighter-weight solution is provided by an overview of research facilities and resources as well as postgraduate training and an action plan drawn up on the basis of the findings made. One proven solution is to develop and expand the graduate school system to as many different fields of health research as possible.

4. Changes recommended to training programmes and the doctoral thesis institution. The recommendations made by the international biotechnology evaluation included proposed changes to training programmes and their overall volumes. Special attention should be paid to starting up training and research programmes in such fields where there is a need for research personnel (e.g. drug development, health economics, biometrics and bioinformatics). In many fields of research clear changes were recommended to the Finnish doctoral thesis system (a lowered volume at the same or higher standard) towards a European direction. The Research Council for Health subscribes to these recommendations.

5. Clarifying the national innovation strategy. Current legislation that governs the ownership of immaterial property rights in research results should be clarified without delay and revised in such a way as to support more effective use of research results. Technology transfer companies have been set up in connection with universities to facilitate the protection of new discoveries. The commercialisation of innovations, on the other hand, still requires considerable effort and input. At least for the time being there remains a shortage of biotechnology companies in Finland that take advantage of scientific innovations; researchers are having themselves to set up companies to do just that. As the final report of the biotechnology evaluation observes, the number of people working in technology transfer needs to be increased and the standard of expertise raised.

6. Internal development. One of the main objectives in the Research Council's own work is to further improve the applications review process. With the continuing growth of interdisciplinary cooperation the relevance of current classification of research fields is somewhat dubious. Instead, more attention needs to be paid in the review process to paradigmatic classifications. This would support the integration of research with closely related disciplines and also make it easier to evaluate applications for research funding on an equitable basis.

Academy Research Councils should continue to work more closely with one another, especially in the field of health sciences as well as social and behavioural sciences. Epidemiological research often requires long follow-up periods in order to produce meaningful results, which should be taken into account when funding decisions are made. If funds are allocated to projects for limited periods, that may well reflect adversely upon the preservation and effective use of valuable research materials.

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Appendix 1. Research Council for Health in 2001–2003

Chair
Eero Vuorio, Professor
University of Turku

Markku Alén, Medical Director
Peurunka Medical Rehabilitation and Physical Exercise Centre

Esa Heinonen, Senior Vice President
Orion Pharma, Orion Corporation

Elina Hemminki, Professor
National Research and Development Centre for Welfare and Health, Stakes

Helena Leino-Kilpi, Professor
University of Turku

Lars-Axel Lindberg, Professor
University of Helsinki

Marja Makarow, Professor
University of Helsinki

Pirjo Pietinen, Professor
National Public Health Institute

Taina Pihlajaniemi, Professor
University of Oulu

Hilkka Soininen, Professor
University of Kuopio

Timo Vesikari, Professor
University of Tampere

Science Adviser Jaana Aalto, Science Adviser Saara Leppinen and University Trainee Sari Purhonen from the Academy's Health Research Unit were involved in preparing the Research Council's report.

Contents

RESEARCH IN THE NATURAL SCIENCES AND ENGINEERING

Academy of Finland
Research Council for Natural Sciences and Engineering

Contents

1 General overview

1.1 Operating environment

Funding for basic research in Finland is primarily the responsibility of universities and the Academy of Finland. In recent years about half of the funding from the Academy's Research Council for Natural Sciences and Engineering has gone to the exact natural sciences (physics, chemistry, space sciences, mathematics) and around one-third to disciplines that support information technology (electrical engineering and electronics, computer science). Traditional engineering fields (process and materials technology, mechanical engineering and manufacturing technology, construction technology and municipal engineering) have received between one-tenth and one-fifth of the monies awarded each year. The total value of applied funding in proposals received by the Research Council in the general call for research appropriations has increased all the time. In 1999 the total value stood at 53 million euros, by 2002 the figure was more than 96 million euros; in 1999 the amount of grants awarded was 21 per cent of the value of applications, in 2002 the proportion was down to 14 per cent.

The majority of graduate schools and doctoral students funded by the Ministry of Education, Academy postdoctoral researchers, Academy Research Fellows, Academy Professors and national centres of excellence that come under the Research Council for Natural Sciences and Engineering are in the fields of physics, chemistry and chemical engineering, process and materials technology, mathematics and information industry related sciences (see Table 1). These are also the Research Council's main priority areas.

Table 1. Graduate schools and doctoral students funded by the Ministry of Education, Academy postdoctoral researchers, Academy Research Fellows, Academy Professors and centres of excellence in the fields of natural sciences and engineering, April 2003.

Field	Graduate schools/ Doctoral students funded by Ministry of Education	Academy postdoctoral researchers	Academy Research Fellows	Academy Professors	Centres of excellence
Space sciences	1/12	4	6		
Physics	4/68	22	18	3	4
Geosciences	2/14	1			
Chemistry, chemical engineering, process and materials technology, energy technology	13/154	33	15	2	3
Mathematics and statistics	6/36	7	10	1	1
Information industry related sciences	14/288	33	10	5	6
Industrial engineering and management	1/9				
Mechanical engineering and manufacturing technology	2/27	3	2		1
Construction technology, municipal engineering, architecture	2/10	1	1		
Total	45/618	104	62	11	15

Ministry of Education graduate schools have 618 doctoral students in the field of natural sciences and engineering who are funded from Ministry of Education sources, plus several times that number of students who are funded from other sources.

Disciplines that support the information industry have great significance to the national economy, but Academy funding to these fields continues to fall short of demand. The Research Council for Natural Sciences and Engineering has sought consistently to increase the share of funding allocated to the information sector. However, since the total amount of funding from the Research Council has remained more or less constant and competition for these monies has continued to intensify, the targeted levels have not yet been reached. More and more often, good projects remain without funding.

The continuity of high-quality research in Finland requires that there are a sufficient number of talented young applicants seeking entry to university in the fields of natural sciences and engineering. This, in turn, requires that schoolchildren are encouraged from a young age to take an interest in mathematical and natural science subjects and that they have a good enough knowledge in these subjects. The Research Council has sought to encourage young people to take up a career in research through the various events arranged in connection with the national Science03 review, for instance. One way to make research a more attractive career proposition is through consistent, long-term funding that guarantees young researchers a competitive pay package.

There is active research cooperation among the various natural sciences and engineering disciplines. Over the past three years projects funded by the Research Council have shown a much stronger multidisciplinary orientation than before. Adequate public funding must be made available for a sustained multidisciplinary research effort in engineering so as to ensure continued technological development in the business sector. The Academy of Finland has met this challenge by launching in 1999 and 2000 three-year research programmes in Process Technology (PROTEK), Future Mechanical

Bioscience applications of mathematics, physics, chemistry and engineering sciences

The biosciences depend for their progress to an ever greater extent on mathematics, physics, chemistry and engineering. Research that addresses bioscience problems is essentially about seeking to understand and model complex dynamic phenomena. Modelling is used in studying biological systems, generating hypotheses, testing theories, making predictions and in analysing research data. These fields of research are highly demanding and require high-level methodological research as well as close collaboration among researchers in different fields of expertise. Significant new fields here include bioinformatics and neuroinformatics. Bioinformatics applies the methods of computer science, mathematics and statistics to resolve biological problems. These methodological sciences are needed for such purposes as describing, modelling and utilising the interactions and laws of the gene-protein system. For example, the mapping of genome information at molecular level may lead to new breakthroughs in medicine. Working at the interface of neurosciences and information sciences, neuroinformatics is aimed at producing comprehensive information about the function of the human brain and the nervous system. This requires modelling of individual nerve cells, cell networks and brain structures as well as analysis of functional brain imaging studies. Research in materials technology, chemistry and process technology is paving the way to the production of new biomaterials and to new biotechnological production methods and products. The biotechnological production process requires not only knowledge and know-how about genes, but also about processes so that the external cell environment can be controlled and the products produced purified. The complex behaviour of biological materials is now attracting growing interest in the field of computational physics as well. Chemistry and process technology have a key part to play in developing technological solutions and biotechnological applications related to energy conservation, recycling, access to clean water and the management of climate changes.

Engineering (TUKEVA) and Mathematical Methods and Modelling in the Sciences (MaDaMe). The Research Council for Natural Sciences and Engineering is currently preparing for the start-up of a research programme in the application of information and automation technology in the construction, mechanical and manufacturing industries.

Closer networking among the Academy of Finland, the National Technology Agency Tekes, universities and business and industry is vitally important for the development of natural sciences and engineering disciplines. Universities and businesses are now working closely with one another as a matter of routine, and business companies are keen to learn about the results of basic research. The Research Council for Natural Sciences and Engineering has plans to set up joint research programmes with other Academy research councils, universities, research institutes, Tekes and business and industry. Cooperation between universities and research institutes has also shown encouraging progress in recent years.

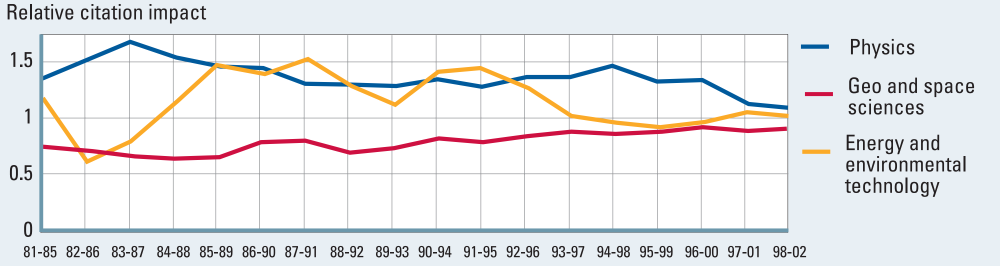
Research in the natural sciences and engineering is very much an international exercise. Foreign researchers are involved in a number of projects funded by the Research Council for Natural Sciences and Engineering, and Finnish research groups send out their own members to work abroad or have other kinds of international cooperation. The Research Council contributes to several international science organisations (e.g. CERC3, CERN, EISCAT, ESA, ESRF, EUPRO, NOT) for instance by providing funding for research projects as well as for travel that is necessary for maintaining contact. The Research Council for Natural Sciences and Engineering has international funding cooperation among others with European Science Foundation’s (ESF) research programmes.

1.2 Scientific impact and visibility

The international impact and visibility of research is often described by reference to citation impact figures. Although bibliometric analysis involves certain problems, it nonetheless gives a useful picture of the broad trends in development in different fields of research. The bibliometric analyses in this report are based on the Institute for Scientific Information’s (ISI) National Science Indicators (NSI) database, which provides only selective coverage of the journals and publications within each discipline. As a rule, each paper is slotted under one discipline heading, which in the case of multidisciplinary fields and those at the interface of different disciplines causes some inaccuracy. For example, Finnish space scientists publish frequently in journals that in the NSI database are classified under the geosciences. For the purposes of the analysis below, therefore, the database categories “space science” and “geosciences” are combined. Increasing degrees of multidisciplinarity complicate the interpretation of analyses even further. Another difficulty with the NSI database is that it does not give enough weight to growing disciplines that have large numbers of new journals.

Overall, Finnish research in the natural sciences and engineering shows a fairly high level of international impact and visibility. Figures 1–3 show that in terms of NSI relative citation impact figures, Finland is above the world average in physics, mathematics, computer science, chemical engineering, industrial engineering and management, mechanical engineering and in energy and environmental technology. Furthermore, the relative citation impact figures are close to the world average in geo and space sciences, electrical engineering and electronics as well as in chemistry. The relative citation impact figures for chemical engineering, mechanical engineering and industrial engineering and management have increased clearly since the 1980s, pointing at a higher level of international impact. The number of citations in geo and space sciences relative to the number of publications has also shown some tendency to grow of late. In construction technology and municipal engineering, the relative citation impact is below the world average. Since the beginning of the 1990s, the number of publications indexed in the NSI has shown the sharpest growth in computer science, electrical engineering and electronics as well as in energy and environmental technology.

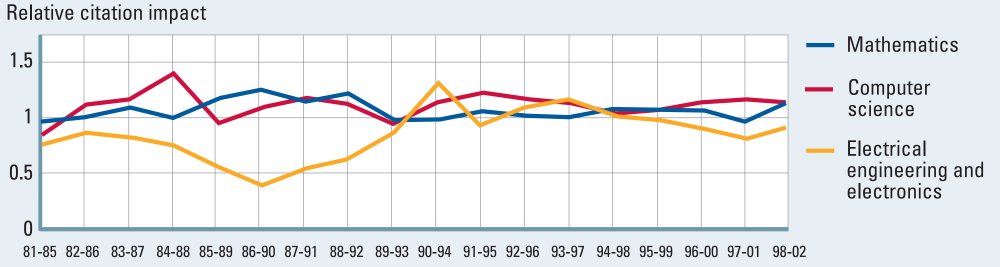
Figure 1. Finland’s relative citation impact (= Finland’s impact factor / world impact factor; Impact factor = number of citations / number of publications)* in physics, geo and space sciences, and energy and environmental technology. Sliding five-year periods: articles published during each period and citations received by those articles in the same period.



* Papers are classified as Finnish when at least one of the authors' addresses is in Finland. Values over one are above the world average.

Source: The Institute for Scientific Information (ISI®) database National Science Indicators 1981-2002 (NSI), Standard Fields: physics, geosciences, space science. Deluxe Field: environmental engineering/energy.

Figure 2. Finland’s relative citation impact (= Finland’s impact factor / world impact factor; Impact factor = number of citations / number of publications)* in mathematics, computer science and electrical engineering and electronics. Sliding five-year periods: articles published during each period and citations received by those articles in the same period.

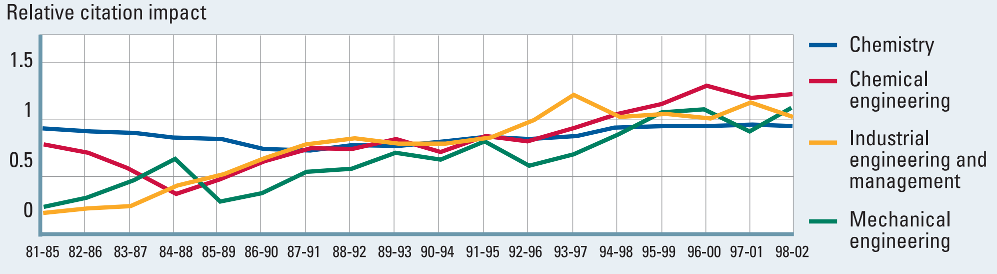


*Papers are classified as Finnish when at least one of the authors' addresses is in Finland. Values over one are above the world average.

Source: The Institute for Scientific Information (ISI®) database National Science Indicators 1981-2002 (NSI), Standard Fields: mathematics, computer science, Deluxe Field: electrical & electronics engineering.

Contents

Figure 3. Finland's relative citation impact (= Finland's impact factor / world impact factor; Impact factor = number of citations / number of publications)* in chemistry, chemical engineering, industrial engineering and management, and mechanical engineering. Sliding five-year periods: articles published during each period and citations received by those articles in the same period.



* Papers are classified as Finnish when at least one of the authors' addresses is in Finland. Values over one are above the world average.

Source: The Institute for Scientific Information (ISI®) database National Science Indicators 1981-2002 (NSI), Standard Field: chemistry, Deluxe Fields: chemical engineering, engineering management/general, mechanical engineering.

1.3 Social impacts of research

Basic research and applications in electronics and information technology represent an area of huge significance to Finnish business and industry, and advances in this field are crucial to the development of the information society. The rapid growth and development of the electronics sector especially in the 1990s was crucial in helping Finland pull out of recession and get back on a growth track sooner than its competitors in the world markets. In the 1990s, production in the electrical and electronics industry showed a fivefold increase in value. Today it is the biggest single industrial sector in the country, worth around 20 billion euros in 2002 (Statistics Finland, preliminary data). The sector also has the highest share of exports, standing at 13 billion euros in 2002 (National Board of Customs, statistical service). Estimates by the Federation of Finnish Electrical and Electronics Industry indicate that R&D investment by the electrical and electronics industry in 2002 amounted to 1.9 billion euros, representing around 55 per cent of the figure for the total private sector. The relative weight of the electrical and electronics industry has grown significantly: in 1993 R&D investment in the sector was still at less than 0.4 billion euros, accounting for 35 per cent of the sum total for the business sector (Statistics Finland 2003). In 2002 the sector had a workforce of around 67,900 (Statistics Finland, Labour Force survey, preliminary data). R&D staff in the electrical and electronics industry accounts for over 40 per cent of the total R&D personnel number in the business sector. The information industry is a more significant employer in Finland than in any other OECD country. The numbers working in research and development in computer and related services increased by 230 per cent from 1997 to 2001. (Statistics Finland 1999, 2003.)

Research in other fields is increasingly dependent on new advanced information technology equipment and methods: the information industry sector as a whole has a great catalytic effect on all areas of research. Finland has an impressive record in the development of biomedical engineering and meteorological and space equipment, and it is well placed to gain a prominent position in other fields as well. The sector has a major indirect effect upon traditional industries such as wood processing, mechanical engineering, and the process and construction industry, both in terms of boosting their competitiveness and increasing their energy and materials efficiency. Furthermore, new information technology innovations help to improve the quality of life of the ageing population as well as disabled groups, for instance.

Optoelectronics in Tampere

Professor Markus Pessa and his research team at the Tampere University of Technology have long been studying compound semiconductor materials and the production of optoelectronic components The research networks created around Professor Pessa have received substantial funding from the Academy of Finland. In addition to their academic outputs (PhDs, publications, etc.), these groups have produced several innovations in the areas of semiconductor technology and optical telecommunications. The Tampere region has also seen the growth of significant business ventures in optoelectronics: in 2002, two spin-off companies (Coherent–Tutcore Ltd and Modulight, Inc.) showed a combined turnover of more than 15 million euros.

Academy-funded research programmes provide a showcase of the impacts of research in the natural sciences and engineering. Table 2 describes the outputs of three such programmes under the Research Council for Natural Sciences and Engineering, which have included both scientific and social impacts. The programmes have produced significant new information for business and industry, and their results have been and will be used in Finnish research and development. The programmes have produced new innovations and inventions such as new methods, processes, technologies, products, methods of characterisation and mathematical models. Research programmes have also produced spin-off companies, and enterprises have made intensive use of the research results. Researchers working on these projects have also been highly successful in the open job markets. (Research Programme for Electronic... 2002, Research Programme for Process... 2002, National Programme for Materials... 2002.)

Table 2. The outputs of three research programmes according to the projects' self-assessments (Materials and Structure Research – MATRA, Electronic Materials and Microsystems – EMMA and Process Technology – PROTEK). Some impacts are not seen until after the programmes have been completed.

Research programme	Funding, million euros	Number of articles	Number of conference publications	Number of patents	Number of PhDs	Number of Licentiates
Materials and Structure Research (MATRA) 1994–2000	31	1,247	700	?	107	82
Electronic Materials and Microsystems (EMMA) 1999–2002	5.1	361	208	5	31	7
Process Technology (PROTEK) 1999–2002	2.5	51	63	4	4	6

There are 15 centres of excellence in the disciplines hosted by the Research Council for Natural Sciences and Engineering (Appendix 1). These have helped to increase awareness and add to the exposure of scientific research among the general public as well. Most centres of excellence have close contact with industry, which is important from the point of view of transferring research results into the practical domain. Research at centres of excellence has also produced a number of spin-off companies.

From basic research in combustion processes to Finnish top expertise and business

In the late 1980s development efforts in combustion technology were heavily concentrated in the fields of chemistry and chemical engineering: many of the problems with which scientists were working revolved around details in the combustion process and particularly with their chemistry, such as emission compositions. Ahlström, Tampella and Wärtsilä Diesel were some of the Finnish industry names that began to invest heavily in research and product development. These companies also had a major part in launching the national research effort in combustion and fuel technology at universities and the Technical Research Centre VTT. The focus in this effort was on an in-depth investigation of various details in the combustion process, such as the chemistry of emission formation and degradation, mathematical modelling of the combustion chamber process, new methods of measuring combustion chamber events, pressurised combustion processes as well as determination of the properties of new fuels. Finland emerged as the world leader especially in clean combustion technologies and in applications using new, non-homogeneous fuels, such as biofuels, waste and mixed fuels. Research was organised into national programmes in which development projects in the business sector were supported by basic research at universities. The Academy of Finland has also contributed significantly, most notably through project funding.

As a result of this sustained, 15-year investment programme, the field now boasts an extremely high level of expertise. More than 30 doctoral theses have been completed on the subject of combustion technology, and many of the PhDs are currently working in the industry. There are several internationally recognised research groups in the field; one example is the group under Professor Mikko Hupa at the Åbo Akademi University Process Chemistry Group, an Academy-appointed centre of excellence in research. Exports of Finnish energy technology have benefited directly from the high standards of R&D: throughout the 1990s exports showed sustained growth at an annual rate of almost 20 per cent, rising from 0.5 billion in 1990 to more than two billion today. Boilers and other combustion technology products represent a significant fraction of these exports. Although new, international owners have now moved in to take control, much of the technological know-how and the jobs in manufacturing have remained in Finland, largely by virtue of the country's highly efficient R&D infrastructure. Andritz (formerly Ahlström) and Kvaerner Power (Tampella) are world market leaders in the manufacture of recovery boilers: in recent years they have together accounted for more than 80 per cent of world deliveries in recovery boilers. Finnish technology also leads the world in fluidised bed boilers and major diesel power plants (Foster Wheeler, Wärtsilä).

As well as having a direct impact on the surrounding society (contributing, among other things, to the development of new innovations, patents and businesses), Academy research funding also has a more indirect social impact: examples include its effects that come through doctoral training and the training of future professors. The impacts of funding awarded by the Research Council for Natural Sciences and Engineering are also seen in the number of Academy Research Fellows who have moved on to take up professorships (Table 3). By spring 2003, around 30 per cent of all Academy Research Fellows appointed in these fields during 1999–2001 had left their position to take up a professorship.

Table 3. Number of Academy Research Fellows in disciplines hosted by the Research Council for Natural Sciences and Engineering who have left their position to take up professorships. Situation as at 29 March 2003.

Year	Academy Research Fellow appointments	Number taking up professorships
1999	15	4
2000	21	8
2001	15	3
Total	51	15

1.4 PhD employment in the natural sciences and engineering

PhDs in the natural sciences and engineering have had no difficulty finding employment. During the 1990s, doctoral unemployment was much lower than at other levels of education. In 2000, no more than 0.6 per cent of Doctors of Technology and 1.8 per cent of PhDs in the natural sciences (including biology and environmental sciences) were out of work. In 1999, 75 per cent of natural science PhDs were engaged in the state sector, 14 per cent in private businesses and 9 per cent in the local government sector. The corresponding figures for Doctors of Technology were 61 per cent (state), 32 per cent (private business) and 4 per cent (local governments). In industry, PhD employment was at the highest level in the hi-tech sector. (Husso 2002.) In 1999, more than 70 per cent of all PhDs working in industry had a degree in the natural sciences or engineering. In 1989–2002, the number of higher university degrees completed in engineering was four times greater than in medicine, but no more than one in fifteen of those completing a higher university degree in engineering proceeded to take the doctorate. In the 1990s, unemployment among doctoral graduates in engineering fields was virtually zero. (PhDs in Finland... 2003.)

Reports compiled by the Ministry of Education's graduate schools in the natural sciences and engineering indicate that almost two-thirds of their PhD graduates were employed in universities and research institutes and one-third in the private business sector (Table 4; data primarily for 1999–2001). Employment in the university sector was made possible by the sharp increase in external research funding and by the fact that not all current office holders at university had a PhD. According to these reports doctoral graduates in the fields of geo- and space sciences, mechanical engineering and manufacturing technology and information industry related sciences, were most frequently employed in universities and research institutes. Those with a degree in industrial engineering and management, chemistry and process technology and mathematics, moved more often than doctoral graduates from other fields to work in industry. At least one-fifth of

Table 4. Placement of PhDs from graduate schools in the natural sciences and engineering according to the 33 graduate school reports filed with the Academy of Finland in 2002. Data mainly for 1999–2001; information for 25 graduates not provided.

Main field of graduate school	PhDs reported	Business and industry	Universities and research institutes	State, local government, polytechnics	Other
Physics	126	29%	60%	10%	
Space sciences	21	5%	90%	5%	
Geosciences	14	14%	86%		
Chemistry and process technology	161	44%	50%	4%	2%
Mechanical engineering and manufacturing technology	27	19%	78%	4%	
Mathematics	40	40%	55%	5%	
Information industry related sciences	177	28%	71%	1%	
Industrial engineering and management	29	52%	45%	3%	
Total	595	33%	62%	4%	1%

those working at universities and research institutes had moved abroad. This was most common in physics and space sciences.

The Science and Technology Policy Council of Finland points out in its recent report (Knowledge... 2003) that new jobs are more and more often created in fields that require high levels of expertise, meaning that people with a doctoral training are bound to assume a far more prominent role in knowledge production in these fields. According to a survey by Taloustutkimus Oy, business companies are now recruiting, and look set to continue recruiting first and foremost people with an engineering doctorate (particularly in the fields of electrical engineering, electronics, information technology, automation technology and engineering physics). There is also some demand for people with a PhD in natural sciences (particularly in chemistry in the chemical industry, oil industry, and pharmaceutical industry). Most PhDs are recruited into research and product development positions as well as into production and corporate management. (PhDs in Finland... 2003.)

The Confederation of Finnish Industry and Employers expects to see the demand for knowledge and know-how in the information industry to grow even further. Indeed the pressure is now to increase the amount of doctoral training in information industry related sciences, both for purposes of maintaining a high standard of university education and safeguarding the quality of R&D in this industry. (PhDs in Finland... 2003.) This is a highly research-intensive industry, and reasons of competitiveness dictate that the number of doctoral degrees as a proportion of all university degrees must be higher. The number of new students admitted to electrical engineering, electronics and information technology programmes, for example, has been sharply increased, but as yet there has been no corresponding investment to increase doctoral training programmes.

2 Fields of research

2.1 Space sciences (space research and astronomy)

Space sciences have long been in the position where international cooperation has been an absolute necessity: the running of modern ground-based observation sites and space telescopes requires close collaboration among both research groups and funding bodies. Existing ground-based telescopes have been built in multinational projects in which Finnish researchers have played a central role. Many satellite projects are now proceeding to the stage of scientific utilisation, and Finnish scientists and engineers have an established place within the space science community. Space research is gradually becoming everyday routine now, and many of its practical applications are assuming priority status. A good illustration is provided by the joint space strategy adopted by the European Space Agency (ESA) and the European Union.

Finland's priorities and objectives in the field of space research are set out in the national space strategy that has recently been updated (Avaruustoiminta Suomessa 2002). One of the points stressed in the new strategy document is the continuity of high-quality space science. Launched in 2001 by the Academy of Finland and the National Technology Agency Tekes, the three-year ANTARES research programme has provided important funding for this field. The field remains afflicted by the same weaknesses as before, viz. the small size of research units, the lack of cohesion in the field of research and the lack of administrative and technical support in large research projects. Appointed by the Ministry of Education, the space research working group has recommended that a national space research centre be set up under the auspices of the Finnish Meteorological Institute to serve as a national forum for the preparation and implementation of major projects in this field (Avaruustutkimuslaitostyöryhmän muistio 2000). However, the necessary funds for the start-up of such a centre have not been forthcoming.

In 2002 Finnish space scientists worked a total of around 150 research-years, of which some 80 were doctoral years. In all there are some 70 active postgraduate students in the field. (Koskinen & Valtaoja 2003.) Many research units in the space sciences currently operate in conjunction with physics departments at universities, providing an added dimension to basic education in physics and new opportunities for research cooperation. Researchers in space sciences have a broadly-based, international and high quality education. Space technology, the development of scientific instruments and the use of highly efficient methods of dataprocessing and modelling provide graduates with a solid foundation for employment in business and industry.

Space sciences add to our understanding of the universe and its various phenomena and in so doing shape our image of the world around. Much of the work in these fields consists of making observations, which also involves developing high-quality space technology. The growth of the Finnish space industry and Finland's involvement in the ESA can also be attributed to space research. Research projects in these fields involve large numbers of business companies; projects in the ongoing ANTARES research programme, for instance, involve 12 Finnish companies.

Space research holds great fascination in the public's eye, and space sciences have provided inspiration for many youngsters keen to study mathematics and the natural sciences. ANTARES projects have included a special programme to support communication about research results. The SPACE 2001 exhibition also gave much exposure to space sciences, attracting 25,000 visitors in three days.

Recommendations

1. In order that Finland can make the best possible use of ESA science programmes and her possible membership of the ESO, a firm national commitment is required to long-term projects. That, in turn, requires a sound financial basis. The Academy of Finland is not in the position to support these kinds of projects because all its funding decisions are based on open competition and the scientific standards of research, and its grants are intended for fixed periods only.
2. Researcher training in space sciences provides a useful set of skills and competencies for teaching, research and engineering jobs. People graduating with Master's degrees and doctorates should be encouraged to seek employment in other fields as well where they can make good use of their knowledge and expertise.
3. Since there are no more than three departments of astronomy in Finland, they need to continue work to develop their cooperation and mutual division of labour.

Contents

2.2 Physics

Modern physics has become an increasingly important base for applications development in other disciplines. At the same time, it has been showing a stronger interdisciplinary orientation and worked more and more closely with industry. Materials physics, chemical, medical and biological physics, modern optics and optoelectronics, future electronics and sensor and instrumentation technology have become prominent areas of Finnish physics research.

Measured in terms of relative citation impact figures, Finnish physics has retained its position above the world average (Figure 1), but the declining trend towards the end of the 1990s does raise questions: Is this a reflection of the lowered level of resources made available to physics research, or is Finnish physics research concentrating too heavily on subjects that have lost their international appeal?

Experimental physics continues to suffer from the ageing of university infrastructures, which is why it is now gathering into a smaller number of units with sufficient critical mass. The amount of funding available for investments in equipment has not increased, but on the other side of the coin both the Academy of Finland and many private foundations have included an overheads share in their grants that departments can use to cover the infrastructure costs of research groups. Computational physics has emerged strongly as a field with national and international significance. Particle physics gained some stability from the decision to concentrate research in this field into the Helsinki Institute for Physics (HIP) at the University of Helsinki.

In times of strong economic growth physicists have had plenty of job opportunities even in the fields of electrical engineering and electronics, and physics PhDs have had no difficulty finding work in either business or the public sector. However, the base for potential physics students is no longer as strong and broad as it is used to be because both universities and polytechnics have also increased the intake of students in other fields that require the same background of secondary school physics and maths. The proportion of women involved at different stages of physics researcher training has increased, but still remains far too low.

Steps have been taken to support professional careers in research. Universities have begun an active competition for appointing talented young researchers to professorships. The number of professorships has been increased, partly by creating posts in new, interdisciplinary fields of research. This gives more and more young researchers the chance to consider an academic career and also ensures a balanced age structure in the profession of physicists.

Recommendations

1. The most important factors must remain the priority: to maintain a high standard of research and to formulate intellectually inspiring research problems. Physicists must also show the intellectual audacity to tackle new and current issues, even if the old problems have not yet been fully exhausted.

2. More funding shall be made available for investment in equipment.
3. Contacts and cooperation within the context of CERN, particularly in the field of experimental particle physics, shall be increased so that maximum benefit can be gained of membership.

2.3 Geosciences (geology, geophysics, meteorology)

Research in the geosciences is conducted at university units and at a number of significant government research institutes, which include the Finnish Meteorological Institute, the Geological Survey of Finland, the Marine Research Institute, and the Geodetic Institute. There are strong signs of promising cooperation between universities and research institutes in the areas of both basic education and research. This is seen among other things in the number of joint applications received by the Academy of Finland for research funding. Another indication of the increased cooperation and multidisciplinarity is the close involvement of geosciences researchers in the Academy's Finnish Global Change Research Programme (FIGARE). Steps taken to strengthen national cooperation include the programme drafted for the national graduate school and the start-up of the major Finnish Reflection Experiment (FIRE), which involves several research units. A discipline assessment of geosciences is now under way and will be completed during 2003.

Although much of the research in this field revolves around national problems, it still has a strong international flavour about it. Finnish geosciences researchers and research units are well-respected partners in international projects. A good example of international networking is provided by cooperation with foreign ore prospecting organisations. Finnish geoscientists are involved in many ESF projects, EU framework programmes and IGCP (International Geological Correlation Programme) projects. Finland is also involved in Antarctic research.

Geosciences know-how has extensive application in modern society: examples include the use of natural resources, environmental protection, urban and regional planning and weather services. Geoinformatics has growing use in many sectors of society and business. From a geoscience point of view the natural environment in Finland is in many ways quite unique, providing a broad range of interesting problems for research to tackle. Close cooperation between research institutes and universities has helped to steer dissertation writers towards subjects that have immediate social relevance. The growth of social impact has also increased the demand for research and qualified research staff. However, the average age of PhD graduates in this field is relatively high when compared to other natural sciences.

Recommendations

1. The results of the geosciences discipline assessment in 2003 have to be carefully analysed in order to take concrete steps forward and to create a national strategy of development.
2. Strengthening cooperation between different disciplines within the geosciences and between different university units and research departments provide an important opportunity for developing research and education in these fields.

3. Science popularisation is crucial so that a sufficient number of talented young students can be attracted into the geosciences.

2.4 Chemistry and process technology

The Finnish chemical industry is in the process of accommodating to major structural changes. More and more often now, new products are tailored to specific customer needs. Research, development, standardisation, manufacturing and marketing are all simultaneous processes with mutual interactive effects. Growth in the chemical industry derives mainly from the changeover from bulk production of raw materials to specialised hi-tech products. This, in turn, requires serious investment in research and know-how. In Finland R&D investment is in fact third highest in the chemical industry (Statistics Finland 2003). A growing proportion of the research investment in the fields of chemical engineering and process technology is in long-term basic research.

Key areas of future know-how in the chemical industry include functional and smart materials, receptor-targeted drugs, forest industry chemistry and other special and fine chemistry (special oil products, special metals, food industry components). Key technologies of the future include synthesis technology (e.g. combinatory chemistry), applied materials technology, catalyst technology (e.g. custom-tailored catalysis and biocatalysis), process technology (e.g. modelling and simulation), bioprocess technology and separation techniques, environmental technologies (e.g. recycling and energy technologies and water chemistry), surface chemistry, miniaturisation and biomimetics. These new technologies and the application of interdisciplinary technologies open up various interesting opportunities. It is expected that from around 2010, environmental technologies as well as energy and natural resources technologies will be among the world's leading technology branches (Tekniikan näköalat 2002). Energy and environmental technology are emerging fields with important implications for sustainable development. Publishing in these fields is currently very active.

Close links of cooperation between universities and business and industry are no doubt one of the main strengths of chemistry and process technology; witness the increasing number of joint R&D projects. There is ever closer integration between different fields of chemistry research (e.g. experimental, computational and technical expertise, interdisciplinary cooperation). Scientists in both chemistry and process technology are more and more often publishing in higher profile and higher quality journals. A number of new fields have rapidly grown up to complement the traditional range of chemistry disciplines. Increasingly, scientific articles are published in journals that fall outside the scope of one's own discipline. A sound knowledge of the basics of chemistry allows for the application of that knowledge in many other disciplines as well. Indeed chemistry now has a prominent role in many multidisciplinary research projects: the electronics and bioindustry, for instance, offer numerous potential applications. Chemistry and process technology researchers are actively involved in numerous multinational research projects and multidisciplinary research programmes launched by the Academy of Finland. Long-term basic research funding has been allocated among others to research in process technology, green chemistry and industrial ecology as well as materials technology. By contrast the amount of funding available for investment in research equipment has not increased.

University education is producing more and more experts with a broad range of skills and competencies for the needs of industry and the public sector. In some cases researcher training is started early on during studies leading to the first university degree. The size of research groups has continued to grow, and the researcher profile is more diversified than before. If these trends can be sustained, they are bound to create a more inspiring research environment for researcher training and for new, research-driven innovations. The Academy of Finland's support for professional careers in research is crucially important for researchers working in chemistry and process technology. There are now 15 Academy Research Fellows, appropriations for 33 postdoctoral researchers and three centres of excellence in the fields of chemistry, chemical engineering and process and materials technology.

There is a strong demand for top experts with a doctoral training. According to a survey commissioned by the Confederation of Finnish Industry and Employers in spring 2002, the chemical industry reported the highest demand for new people with a PhD or Licentiate (around 105 during 2002). It was also reported that recruitment of research staff in the chemical industry is set to increase sharply, whereas in other branches the figures would remain unchanged or even decline from 2001. (Osaamistarveluotain 2002.) Forty four per cent of PhDs graduating from chemistry and process engineering graduate schools in 1999–2001 were employed in the private sector (Table 4). One potential threat with regard to the future supply of top experts in these fields is the lack of interest shown by young people in chemistry and process technology studies.

Recommendations

1. Adequate funding must be secured for future research projects in basic chemistry. On the other hand, steps are needed to promote multidisciplinary work, and more risk funding is needed from public sources. Funding must also be made available for new equipment.
2. New, multidisciplinary applications can only be produced on the strength of a high standard of research and education in chemistry and process technology as well as long-term research funding.
3. Further efforts are needed to support the internationalisation of research. Young researchers shall be encouraged to study and work abroad, and new opportunities shall be created for foreign researchers to work in Finland.
4. Steps are needed to increase cooperation between universities and business and industry in the fields of research and education because hi-tech companies need competent experts and partners for their research.
5. Biotechnology research funding should also be made available for the chemistry of biotechnical products and for the design and development of industrial production processes.

2.5 Mathematics

The current state and quality of Finnish mathematics is good. Figure 2 shows that during the period under review, Finnish articles in mathematics have received at least as many citations as mathematics articles in the world on average.

According to MathSciNet, a database maintained by the American Mathematical Society, the annual number of international articles published by Finnish mathematicians has increased by around 60 per cent during the past decade. At the beginning of the 1990s, the figure stood at around 250 articles per annum, by 2001 it was more than 400. During the same period the annual number of all international mathematical articles published has increased by no more than 17 per cent. In 1991, 0.45 per cent of all mathematical articles were by Finnish scientists, in 2001 the corresponding proportion was 0.62 per cent.

Finnish mathematics grows out of the theory of complex functions, and research is still heavily focused on analysis. In some areas of analysis and mathematical physics, Finland ranks among the top countries in the world. Likewise, we have extremely strong research groups in mathematical logic and certain applied fields (inverse problems, modelling of biological processes, numerical analysis). Other areas of strength in Finnish mathematics include stochastics and number theory.

The work of high-quality research groups and their development have been supported through the centre of excellence in mathematics and through Academy project funding and research posts. International cooperation has been promoted by launching an international visitor programme, a brainchild of the Finnish Mathematical Society. The theme for the first year of the visitor programme in 2003–2004 is inverse problems; next year's theme will be stochastics.

The weakness of Finnish mathematics lies in its narrow scope. In spite of the dominant position of analysis in Finnish mathematics, there is hardly any research into harmonic analysis. Other fields where there is very little research include algebra, differential geometry and topology. (Evaluation of Finnish Mathematics 2000.)

One of the distinctive features of pure mathematics is its independence of the world around. The motives for research often come from within mathematics itself, and it is very rarely that the aim is to resolve a given problem in the real world. Truly significant mathematical results always have their practical application, although it often takes some while for that application to be discovered. However, that time lag is growing shorter all the time. By now mathematicians have a clear understanding as to which areas of pure mathematics are important to the development of the information industry, for example.

Finland is one of the world's leading hi-tech countries, particularly in the information industry, yet there are many areas of pure mathematics that are important to the information industry and in which there is no research at all. The Academy research programme on Mathematical Methods and Modelling in the Sciences (MaDaMe, 2000–2003) has provided important support to research in applied mathematics and added to its impact.

Recommendations

1. Continued funding must be secured for research in applied mathematics.
2. The scope of research in Finnish mathematics should be expanded: support is needed most particularly in fields of pure mathematics that are important to the information industry.

2.6 Disciplines related to the information industry

For the present purposes, the information industry sector is defined as an area of hardware and software technology that comprises the traditional disciplines of electronics, electrical engineering, telecommunications technology, information technology and computer science. Unprecedented growth in the electrical and electronics industry during the 1990s has created for research an operating environment that is in a constant state of flux. One of the key driving forces of development has included miniaturisation, which has seen electronic operations become packed into ever smaller, more powerful and less expensive circuits. Computation-intensive tasks that used to be too demanding have now become possible even in ordinary desktop PCs, and new methods of data mining have in many fields (such as bioinformatics, medicine, geology) allowed scientists to explore huge data masses and on that strength to produce new information.

A strong Finnish research tradition has developed in the information industry sector over the past couple of decades. The influx of talented students remains strong, and graduate schools have produced good results. Many universities offer doctoral and Master's training programmes in the English language, with the number of applicants running into hundreds. However, Finland seems to hold scant appeal among visiting researchers, and there are still very few women among students and researchers in this field.

The growth and expansion of the information industry sector has also brought a sharp increase in the number of publication channels. Unusually, publishing in refereed conference publications is at a very high level among scientists in these fields, which is why traditional citation impact figures do not provide a very reliable picture of the impacts of research. Electronics and information technology are also exceptional fields of research in the sense that they cut across research in virtually all other disciplines: interdisciplinary research programmes and projects involving information industry sectors are therefore bound to increase in the future. Computer science provides useful tools and methods for the development of a wide range of other fields of research.

In the near future system-on-chip technologies are expected to throw up challenging new research problems in circuit design, system description languages and integrated circuit synthesizers. The American Semiconductor Industry Association SIA, the leading interest organisation in the field, forecasts that in 2016, manufacturers will be able to produce 8.8 billion transistors on one chip, over a thousand times more than today. The application potential is mind-boggling: today's PCs, smart phones and home electronics are just the first steps of development.

Sensors and active optocomponents hold promising opportunities for technology miniaturisation. There is significant application potential in human health technologies, such as pacemakers, artificial muscles and other prosthesis technology, as well as in various microinstruments in medicine, biology and chemical research.

So ubiquitous are electronics and information technology in modern everyday life that the question of how people manage in their IT environment has become more and more important. Questions related to data security, interaction between humans and technology and monitoring the operation of different systems underline the role and importance of social sciences and behavioural science in the development of IT applications. A new challenge for software technology lies in the operation of systems in dynamically changing environments and communication with systems on which no detailed information has been available at the stage of design.

Information industry related sciences have recently accounted for about one-third of the research funding granted by the Research Council for Natural Sciences and Engineering. In general call for research appropriations in 2002, the total value of applied funds in proposals received from these fields was significantly higher than in previous years. Over the past three years there has been growing demand for funding most notably in computer science. Public funding is crucially important for basic research, even though the amount of monies available through these channels is no more than a fraction of R&D investment by industry. In relative terms the amount of research funding received through public sources is far below the average figures for the OECD countries.

Since 1998 the Academy of Finland has each year launched one research programme in the information industry sector. There has been increased cooperation among funding bodies. The Proactive Computing Research Programme (2002–2005) is a joint effort with the French Ministry for Research. The EXSITE programme, for its part, is jointly funded by the Academy of Finland, the National Technology Agency Tekes and Swedish funding bodies. The Academy of Finland has continued to work closely with Tekes both in funding and in evaluating research programmes, and this collaboration will continue in forthcoming programmes that are now under preparation.

Recommendations

1. There is an urgent need in information industry related sciences for more young postdoctoral researchers who can provide supervision for graduate and postgraduate students. These young PhDs also need supervision in their own researcher training.
2. The Academy of Finland should continue to support research in information industry related sciences in keeping with its existing policy lines.
3. Special measures of support are needed among others in research in bioinformatics and neuroinformatics. In addition, the utilisation of information industry related sciences in traditional industries needs to be supported.
4. In projects that are close to applied research there is a great temptation to look to the short term only. The Academy of Finland should continue to provide funding for long-term basic research, including higher risk research.

2.7 Industrial engineering and management

Industrial engineering and management is a multidisciplinary field of research which is concerned to explore the operation of industrial companies in broad terms as a technological, economic and behavioural science process. As well as having scientific objectives, research in industrial engineering and management is geared to promoting the competitiveness of Finnish industry.

International cooperation and networking has continued to increase in industrial engineering and management as a result of growing involvement in research programmes. New areas of research include knowledge management and product development. Six new professorships have been set up in the discipline over the past two years.

The number of doctoral degrees completed in industrial engineering and management has increased in recent years, at least in part by virtue of the national graduate school. Almost all graduate school students have spent periods studying abroad. The proportion of women among PhD graduates has increased; today more than one-third of all graduates are women. PhD employment is also at a high level. Half of the PhD graduates from the national graduate school in 1998–2000 went to work in the private business sector, the other half in research institutes and universities. The age distribution of PhD graduates in industrial engineering and management is quite sharply divided: some go on to take the doctorate straight after their first university degree at a young age, others pick up their postgraduate studies while working in industry, sometimes decades later.

Recommendations

1. Steps are needed to develop research management practices in industrial engineering and management, to promote cooperation between research groups in this field and to foster cutting edge research.
2. Further efforts are needed to intensify cooperation between industrial engineering and management and different technology branches so that the distinctive features of industrial engineering and management can be put to the best possible use.
3. Continued support must be made available for scientific research and the supervision of doctoral theses. The six new professorships in the field are still not enough when compared against the number of postgraduate students.
4. Teaching and research in product development must be increased within the field of industrial engineering and management.

2.8 Mechanical engineering

Many Finnish companies in mechanical engineering and the metal industry are world market leaders in their respective fields – a position they would not have been able to achieve without a sound foundation in research and technological application. Mechanical engineering industries generally have greater immunity to fluctuations in business trends than many other, more sensitive areas of business and industry. In Finland the whole business environment of mechanical engineering is changing dramatically as the biggest players in the field are upgrading from their traditional role of equipment supplier and expanding into the business of developing their customers' core process technologies, machinery and services. These changes are affecting the structure of the whole business and putting companies under greater pressure of networking. Electronics, information technology and materials technology have all taken on a much more prominent role in research and development in mechanical engineering: the integration of these technologies has provided a major boost to Finnish mechanical engineering. Finnish know-how in machine automation commands worldwide respect, both within the academic community and among end-users. There is one national centre of excellence in this field.

Future growth and development in mechanical engineering will require the seamless integration of basic and applied research. One of the consequences of the closer cooperation that there is now between the Academy of Finland and Tekes is that a growing proportion of funding is channelled through larger research projects. Graduate schools have expanded and established a firm footing, but all the necessary technology branches are not yet involved. Research in mechanical engineering is still carried on in units that are too small and with resources that are too scattered, which inevitably reflects badly on the quality of research. Multidisciplinary research in mechanical engineering requires that internationally significant research units are set up that have sufficient critical mass and that are capable of producing significant basic research and working closely with the industry sector.

Recommendations

1. Cooperation between different technology branches and with other fields of research needs to be stepped up in order to strengthen and provide direction for research in mechanical engineering.
2. Public research funding must be secured so that multidisciplinary and long-term research in mechanical engineering can continue: this is vital for sustained technology development in industry.
3. The international visibility of Finnish research in mechanical engineering shall be increased by developing contacts with leading research institutes in the field and by supporting the presentations of Finnish researchers in international conferences and the publication of research results in significant journals.
4. Graduate schools in mechanical engineering shall be expanded to those technology branches that are not yet involved.

2.9 Construction technology and municipal engineering

New emerging fields in construction technology include life-cycle engineering and real-estate management. There has been important progress in the modelling of building physics phenomena as well as in their application in the design process, and new openings have been made in IT applications as well as in the development of smart structures.

Many areas of research in Finnish construction technology are of a high international standard, and there are more and more multidisciplinary research projects in this field.

The main strength of the construction technology sector is that it has close contacts with industry, making the transfer of research findings easy and flexible. Research has focused upon topical issues. Research and development at university level and efficient training has helped among other things to support repair technology, which has become a significant line of business.

Researchers in construction technology have plenty of international contacts and EU funding, but nonetheless further steps are needed to promote the internationalisation of research. Financial stringency has meant that the research equipment at universities is somewhat outdated, although some investments in state-of-the-art equipment have been possible thanks to project funding. Funding for basic research, however, is still inadequate.

As for research in municipal engineering (high-way engineering, transportation engineering, water engineering and environmental protection at community level), prominent trends have included the growth of multidisciplinary cooperation and the systems perspective. Recent advances in information technology have paved the way for important progress in such areas as telematics in transportation, the use of positioning data and new, soft calculation methods.

Standards of scientific research in municipal engineering are continuing to rise as the discipline builds up its own research culture. There is a good balance between experimental and theoretical research: experimental work provides a sound basis for systems theoretical approaches. Weaknesses in the field include the small size of research units and the lack of funding for basic research.

Expertise in several areas of municipal engineering (e.g. traffic control/transport telematics and applied hydrology) is by now of an internationally competitive standard, and researchers in the field have good contacts of cooperation with colleagues abroad. Research also has a strong social impact: funded as it is by various sectors of society, research in municipal engineering feeds back its results to those sectors straightaway.

Recommendations

1. Funding for research in construction technology and municipal engineering shall be increased and the research culture in these fields further strengthened.
2. Further efforts are needed to increase and develop international research projects and research results shall be published in high-quality international journals.
3. Research equipment must be upgraded to modern standards.

2.10 Architecture and industrial design

Research in architecture and industrial design is typically a multidisciplinary exercise, involving such fields as technology, business administration, the social sciences and environmental sciences. New areas of interest include the integration of traditional know-how in the fields of industrial design and architecture with the possibilities of new technologies and questions of design consumption. Many new products of industrial design tie in with new technology applications, and the design process itself requires a closer knowledge of information technology than before. Research in architecture is exploring new avenues of technical system development as well as working to create new software.

National research traditions in architecture are well established, but there is still room for improvement with regard to methodological know-how. Architecture research, at the top end of the scale, compares very favourably with work internationally. Major research projects in the field and most doctoral students have international contacts, but researchers in the field could still be more active in seeking international funding. Debate on the most appropriate format of the doctoral thesis in architecture is still ongoing. Although new forms of study have been introduced that combine further vocational training and academic postgraduate studies, it is still primarily from the traditional academic line of study that most degrees are completed. The field of research in landscape architecture has expanded and the need for research increased among other reasons as a result of recent changes in legislation, but the resources available have not been increased.

Research in industrial design focuses on product and service production as well as design consumption. At the beginning of 2003, an estimated 30 researchers were engaged full-time in industrial design research. This is more than ever before, and the figure is still rising. One of the contributing factors has been the launch of the Tekes Industrial Design Technology Programme in 2002, which is complemented by the Academy's Industrial Design Research Programme that will be starting up in 2003. The broader concerns of research groups and research institutes in industrial design are beginning to take precedence over projects based on the interests of individual researchers.

Measured in terms of degrees completed and articles published, research in industrial design lags some way behind more established fields of research. This is due to the small size of the research community and the lack of coherence and unity in the international field of research. However, several research groups have good international contacts. The development of researcher training remains a major challenge in the field because there are only few competent supervisors in industrial design and only limited resources are made available to researcher training.

Research in industrial design is aimed at promoting the competitiveness of Finnish industry; strengthening the distinctive features of our national culture; and improving the quality of the environment. The transfer of research results into industrial practice is ensured by close cooperation with business and industry. The social impacts of architectural research have clearly been increased by the closer links of research with the real world. The promotion of experimental building and product development requires close collaboration with related fields, such as construction technology. Effective development of construction processes also requires cooperation with various agents in society (administration, industry, etc.).

Recommendations

1. The methodological competencies of researchers in architecture, landscape architecture and industrial design need to be strengthened through increased investment in research training, for example.

2. Steps are needed to develop the cooperation of architectural research with closely related disciplines as well as agents in society.
3. Researcher training in industrial design shall be developed among other things by increasing the availability of resources for supervision.
4. Particularly technology know-how needs to be strengthened in research in industrial design.
5. Longer-term researcher exchange and international publishing both need to be increased in industrial design.

3 Recommendations

Research funding

- Continued support should be made available for long-term basic research in the natural sciences and engineering.
- Adequate public funding for multidisciplinary basic and applied research in engineering must be secured for reasons of sustained technology development in industry.
- The Academy of Finland should continue to support the information industry related sciences in keeping with its existing policy lines and promote the use of these sciences in other research fields.
- Further steps are needed to develop multidisciplinary approaches in research projects, and support should also be made available for higher risk research.
- Experimental disciplines must be guaranteed adequate funding for investments in new equipment.

Researcher training and the research career

- Special measures are needed to support schoolchildren's knowledge in maths and natural science subjects and to inspire greater interest among young people in mathematical subjects.
- In order that the university system can produce a continued supply of competent experts in the natural sciences and engineering, steps are needed to secure the high quality of training and to make university education more attractive.
- Much stronger efforts are needed to recruit talented young students and postgraduate students, women in particular, into the natural sciences and engineering.
- In order to make a career in research a more attractive proposition for young researchers, long-term funding must be made available for doctoral students and researchers and they must be offered a competitive pay package.
- Postdoctoral researchers are needed in greater numbers to supervise young people in the early stages of their research career, particularly in the information industry related sciences. These postdoctoral researchers are also in need of supervision themselves. This should be taken into account when planning universities' new system of teaching and research posts as well as when planning the cooperation of universities and business and industry.
- Further support is needed for the international training of Finnish researchers and their involvement in leading international research teams. On the other hand, steps are also needed to support the integration of foreign senior researchers into research teams at Finnish universities.

Cooperation

- Research cooperation among different disciplines in the natural sciences and engineering should be further strengthened in certain areas, such as construction technology and municipal engineering as well as mechanical engineering and manufacturing technology.
- Continued efforts are needed to support interactive cooperation among universities, research institutes and industry with a view to promoting research education and the practical application of research results.
- It remains a key priority to promote networking among the Academy of Finland, Tekes, universities and business and industry.
- Researchers must be encouraged to network with top international researchers and research groups.

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Contents

Appendix 1. Centres of excellence, Academy Professors and research programmes under the Research Council for Natural Sciences and Engineering

Centres of excellence under the Research Council for Natural Sciences and Engineering 2000–2005

Institute of Hydraulics and Automation (IHA) (Tampere University of Technology)
Nuclear and Condensed Matter Physics Programme at JYFL (University of Jyväskylä)
Low Temperature Laboratory: Physics and Brain Research Units (Helsinki University of Technology)
Computational Condensed-matter and Complex Materials Research Unit (COMP) (Helsinki University of Technology)
Research Centre for Computational Science and Engineering (Helsinki University of Technology)
New Information Processing Principles (Helsinki University of Technology)
Tissue Engineering and Medical, Dental and Veterinary Biomaterial Research Group (Tampere University of Technology, Helsinki University of Technology, University of Helsinki)
Åbo Akademi University Process Chemistry Group (Åbo Akademi University)
Signal Processing Algorithm Group, SPAG (Tampere University of Technology)

Centres of excellence under the Research Council for Natural Sciences and Engineering 2002–2007

Formal Methods in Programming (Åbo Akademi University)
Research Unit on Physics, Chemistry and Biology of Atmospheric Composition and Climate Change (University of Helsinki, University of Kuopio, Finnish Meteorological Institute)
Research Unit of Geometric Analysis and Mathematical Physics (University of Jyväskylä, University of Helsinki)
Smart and Novel Radios Research Unit (SMARAD) (Helsinki University of Technology)
Bio- and Nanopolymers Research Group (Helsinki University of Technology, University of Helsinki, University of Turku)
From Data to Knowledge Research Unit (University of Helsinki, Helsinki University of Technology)

Academy Professors under the Research Council for Natural Sciences and Engineering 2003

Helena Aksela, University of Oulu (atom and molecular physics)
Jaakko Astola, Tampere University of Technology (methods of signal processing)
Ralph-Johan Back, Åbo Akademi University (formal methods in programming)
Bjarne Holmbom, until 31 July 2003, Åbo Akademi University (forest products process chemistry)
Kimmo Kaski, Helsinki University of Technology (computational physics and computational information technology)
Matti Krusius, Helsinki University of Technology (low temperature physics and technology)

Antti Kupiainen, University of Helsinki (mathematical physics and statistical mechanics)
Risto Nieminen, as from 1 August 2003, Helsinki University of Technology (computational materials physics)
Erkki Oja, Helsinki University of Technology (information processing technology, particularly neural networks)
Jukka Pekola, Helsinki University of Technology (nanophysics)
Pertti Törmälä, Tampere University of Technology (biomaterials technology, particularly bioactive composites)
Esko Ukkonen, University of Helsinki (efficient computational methods, algorithms)

Research programmes launched in 2000–2003 under the Research Council for Natural Sciences and Engineering

Mathematical Methods and Modelling in the Sciences, MaDaMe (2000–2003)
Future Mechanical Engineering, TUKEVA (2000–2003)
Space Research, ANTARES (2001–2004)
Telecommunication Electronics II, TELECTRONICS II (2001–2003)
Proactive Computing, PROACT (2002–2005)
Future Electronics, TULE (2003–2006)

Appendix 2. Research Council for Natural Sciences and Engineering in 2001–2003

Chair
Riitta Keiski, Professor
University of Oulu

Mats Gyllenberg, Professor
University of Turku

Iiro Hartimo, Professor
Helsinki University of Technology

Pekka Hautojärvi, Professor
Helsinki University of Technology

Jorma Kangas, Professor
University of Oulu

Markku Kivikoski, Professor
Tampere University of Technology

Kaisa Nyberg, Docent
Nokia Research Center

Marja-Liisa Riekkola, Professor
University of Helsinki

Ulla Ruotsalainen, Docent
Tampere University of Technology

Kari-Jouko Räihä, Professor
University of Tampere

Markku Tuominen, Professor
Lappeenranta University of Technology

Science Adviser Eeva Karjalainen and Director Susan Linko from the Academy's Natural Sciences and Engineering Research Unit were involved in preparing the Research Council's report.

This Academy review of the state and quality of scientific research in Finland focuses on developments in the early years of the twenty-first century. Key themes include the social impact and the human resources of research. The review also assesses the impacts of research funding and science policy measures on the development of science and research, and on society more generally. The scientific results and impacts of research are evaluated against different indicators and compared internationally.

In addition, the review charts the progress that has been made in the biosciences and environmental research, in cultural and social research, in the natural sciences and engineering as well as in health research.

ISBN 951-715-466-6 (print)
ISBN 951-715-467-4 (pdf)
ISSN 0358-9153

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