Baseline Assessment of the Public Research System in Ireland in the areas of Biotechnology and Information and Communication Technologies

NDP
NATIONAL DEVELOPMENT PLAN

sfi
science foundation ireland

Forfás
THE NATIONAL POLICY AND ADVISORY BOARD FOR ENTERPRISE, TRADE, SCIENCE, TECHNOLOGY AND INNOVATION

Baseline Assessment of the Public Research System in Ireland in the areas of Biotechnology and Information and Communication Technologies

Technopolis

James Stroyan
Ben Thuriaux
Erik Arnold
Alina Östling
Shaun Whitehouse
Sarah Teather

PREST

Kieron Flanagan
Paul Cunningham
Mark Boden

CWTS

Martijn Visser
Anthony Van Raan

August 2002

Acknowledgements

The authors of this report would like to acknowledge the help and advice provided by Michael Fitzgibbon, Bill Hogan and Rhona Dempsey of the Research Evaluation Unit in Forfás as well as the Advisory Committee which steered the project. Our thanks also to the Irish academic community for their co-operation in all phases of the study.

Executive Summary

Rationale and objectives

Forfás commissioned this review in order to provide a 'Baseline Assessment of the Public Research System in Ireland in the areas of Information & Communication Technologies and Biotechnology'.

The aim of the study was to assess the level and quality of ICT and biotechnology research and the capabilities of the Irish research base, to establish how Ireland's current research compares with best international practice, and to provide parameters against which the progress of Science Foundation Ireland could be evaluated over the coming years.

The study involved

- A mapping study to provide factual baseline data on institutions, their research departments or groups, and individual researchers and to provide data and information on demography, facilities and infrastructure, research funding, distribution of effort, and outputs
- A bibliometric exercise, to provide an assessment of the quantity and impact of publications produced by researchers in Ireland in each of the two fields
- A series of panel review exercises, to review the data collected, undertake visits to Irish institutions and provide an overall assessment of the research level, quality and capability of Ireland's ICT and biotechnology research

Status and limitations of the study

The study presents both factual data and the judgements of panels of suitably qualified peers. An element of judgement is inescapable and the central assessments – those made by the panel of peer reviewers – are limited by the quality of the information provided and the openness and detachment of Irish researchers in their interaction with the panel. We believe that the data and analysis gathered from a variety of sources have generated sufficiently robust arguments to support the conclusions presented below.

As with all such studies, this assessment has been conducted during a period when the research communities are already undergoing considerable change and review. Some of the issues identified in this report may already be in the process of being addressed, largely by the investments taking place through very significant initiatives such as the Higher Education Authority managed Programme for Research in Third Level Institutions (PRTLI) and through Science Foundation Ireland (SFI). It is therefore important that future efforts to develop the research base take place in a co-ordinated manner and involve all relevant stakeholders.

Main results

Many of the responses to the questionnaire survey and the discussions with representatives of different research departments allowed us to investigate and evaluate the issues that were raised by the research base. Overall, the comments from panel members highlighted a number of shared underlying issues for ICT and biotechnology. These are presented below.

- The overall performance of Irish research is driven by a small number of strong areas. However, a high degree of fragmentation exists within Irish research
- Groups lack critical mass to generate economies of scale and protect themselves against variations in research funding. In addition, the lack of central or overhead funding for research departments means that there is little slack in the system for research managers to behave strategically. The substanstial funding under the PRTLI (over €600m allocated since 1998) is of course supporting research strategies.

Before the start of this programme researchers and institutions had little alternative but to behave opportunistically in their search for research funding.

- Lack of core research funding means few departments have much experience of managing significant central resources and of formulating and implementing departmental-level research strategies
- Irish research managers are highly resourceful and have become highly entrepreneurial in the recent period of under-investment. However, it is not clear that the current research managers (heads of departments and senior department staff) have the experience to manage research groups in a period of rapid growth in funding and manpower. Research leaders should be supported throughout the growth period in order to ensure effective use of resources
- There has in the past been a significant under-funding of the research base. The community had – until recent developments in PRTLI and SFI – been largely dependent on foreign sources of funding (EC, Wellcome Trust) for larger research projects capable of supporting world-class research competence. PRTLI has provided significant capital funding for dedicated research space and large specialised items of equipment to increase infrastructural capacity
- Teaching requirements have been the main driving force for the recruitment of junior staff in many departments. This has hindered the development of coherent research capabilities. In general, Irish researchers appear to have high teaching loads and contact hours compared to their European or North American counterparts
- The education system appears to be concentrating on producing graduates and, to a lesser extent, MSc students, as opposed to doctoral students, particularly in ICT
- Principal Investigators often lack the support of sufficient numbers of post-doctoral research assistants who can oversee PhD and MSc students and thus provide the managerial leverage to co-ordinate a research group of sufficient size
- More generally, there is a lack of career structure for professional researchers in academia that will make it hard for research groups to attract the best international applicants. There are few incentives for researchers to stay active in research in Ireland. Correcting this will become increasingly important if Ireland is significantly to increase its research capabilities by recruiting strong international researchers
- Irish researchers have excellent international collaborative networks but there appears to be strong intra-university departmental rivalry which prevents the sharing of core facilities
- The current IPR arrangements vary from institution to institution and there does not seem to be a uniform policy for supporting the protection of IPR resulting from university research. In many cases there are few incentives for researchers and departments to address IPR issues
- More needs to be done to address the declining popularity of science-based subjects in Irish education
- In terms of infrastructure, not withstanding recent investments through PRTLI, there is much yet to be done to create sustainable and nationally accessible "large-scale" research facilities and equipment and for these to be properly supported with trained technicians

To become truly competitive, Ireland will need to recruit from an international research community. Current and planned recruitment seems to focus on repatriating Irish scientists but, if the country is to benefit from having the best postdoctoral researchers, Ireland needs to address barriers to incoming scientists (e.g. by facilitating work permits and reducing the differential in overseas research student fees).

Changes in the overall economic situation might, in the future, threaten the continuation of research budgets at existing levels after the current funding period. Large injections of funding, especially when they involve the creation of new research structures and environments, must be sustainable, otherwise Ireland will be unable to exploit the research community it aims to develop over the next 4-5 years. Such a situation could make a significant part of the research infrastructure obsolete and damage confidence in public sector long-term planning.

Bibliometric results

The bibliometric study, which considered research outputs from 1991 – 2000, revealed strong areas of competence spread around the difference research institutions. This was confirmed throughout the four panel visits to 36 different research departments / organisations. The conclusions are that the performance of the Principal Investigators[1] considered for the baseline study appears to be

- Slightly above the world average for biotechnology. However, the bibliometric indicators suggest that relative performance over the last few years has been in slow decline
- At, or slightly above, the world average for ICT research. However, the relative performance over the last few years has varied significantly

Biotechnology

Given the historical conditions under which Irish scientists have had to work, the overall standard is surprisingly high with a number of strong groups to build upon. The independence and individualism fostered by the previous funding situation now needs to be tempered by an increase in co-ordination and collaboration both within and across institutions, nationally and abroad.

The main conclusions are that Irish biotechnology research at the time of the baseline assessment is not competitive enough to enable distribution of the funds to existing groups and departments only, even if this were done via a peer-reviewed process. New structures for research programmes, better technology platform services and organised doctoral research training are required for Irish biotechnology research to become truly world class.

The bibliometrics suggest that Irish research is reasonably strong in the following subfields

- Biochemistry and Molecular Biology. This field was the most important subfield for the study accounting for 10% of the total output. The impact of papers published in this subfield were significantly above world average
- Microbiology and Analytical Chemistry. These subfields accounted for 5% of total publications each and the impact of papers in these two fields were significantly above the world average
- Food Science and General Medicine. Although these account for a smaller percentage of the national research effort, published papers in these subfields achieved the highest levels of impact

The panel members highlighted the relative strength of Irish research in biochemistry and molecular biology, food science and nutrition, environmental science, molecular microbiology, human genetics, immunology, mechanisms of inflammation and fibrosis.

The other key findings of the biotechnology baseline study are

- The bibliometric assessment and the panel visits identified two world-class[2] research departments and a handful of strong research departments that are capable of becoming excellent, world-class units in the next five years
- Irish research in certain areas of modern and developing areas of biotechnology appears sub-critical. The community lacks sufficient resources to compete at an international level with leading groups

[1] The bibliometric assessment was carried out based on Principal Investigators nominated by their institutions. Although these account for the majority of Irish publications in the relevant fields they may not be fully representative of the national research base as a whole.

[2] There are many definitions of world-class and it is difficult to provide a definition that everyone agrees upon. For this study, world-class can broadly be assumed to be equivalent to a 5 rating in the UK Research Assessment Exercise: "Quality that equates to attainable levels of international excellence in more than half of the research activity submitted and attainable levels of national [UK] excellence in the remainder."*

- Both the research community and the panel of experts indicate that access to modern research equipment and services is well below that of research groups in leading European countries and North America
- There are plans to increase access to facilities but, with a few notable exceptions, these do not seem to encourage departments and universities to share resources. The low level of funding has created an environment in which departments do not have a culture of sharing resources
- The research areas covered by Irish biotechnology researchers are fragmented and there are simply not enough researchers active in areas of modern biotechnology to create the critical mass needed to compete internationally. In addition, the average size of research groups appears to be too small and to have too few post-doctoral level researchers

- More than other countries, Ireland has relied on the quality of its PhD students to provide much of the research effort. Although the quality of PhD education is internationally competitive, other countries are investing in providing PhD students with broader research skills through graduate programmes

ICT

The panel members found the researchers they met to be highly motivated and professional with a good understanding of the need to maintain research and parallel teaching capabilities to ensure a supply of well-educated and skilled graduates. Many research groups have, on the whole, performed well given the various constraints imposed by limited funding.

However, the conclusion of this study is that the current research base will not be able effectively to continue to utilise large injections of project-based funding. There is a need to expand the research base (along with a change in the research culture) and this must be done from the bottom up. Given the relatively short time horizon, researchers will need to be recruited from abroad.

The bibliometrics and panel visits suggest that Irish ICT is strongly multidisciplinary with no one subject dominating within Irish ICT research. The bibliometric survey highlighted the following areas of strength for Irish research in ICT

- Engineering, Electrical & Electronic is the most important sub-field, with nearly 200 papers, and an average citation impact
- Physics. Three physics sub-fields are responsible for over 15% of publications and all achieve a high citation impact
- Output in computer science fields tends to be small in volume, but the impact is high in Computer Science and Artificial Intelligence, and slightly above average in Computer Science and Interdisciplinary Applications.

The panel highlighted some of the limitations of the bibliometric review (particularly in the area of Computer Science) but broadly supported the results of the bibliometric study and concluded that

- Basic research in Physics and Mathematics is strong and some of this is world-class research
- There are strong pockets of expertise in research in Computer Science and AI but the overall research performance in Ireland is fragmented and some departments lack sufficient critical mass
- Research in Microelectronics is strong but fragmented and there is a need to encourage more collaboration / joint ventures between departments, particularly in the Dublin area
- The bibliometric assessment and the panel visits identified one world-class[3] research centre and a handful of research groups that can become world-class in the next five years

[3] See previous footnote for a definition of world-class

- The education system appears to be concentrating on producing graduates and to a lesser extent, MSc students. In most areas there are insufficient numbers of PhD students compared with leading international research groups. There are also fewer positions for post-doctoral researchers than in leading international research groups
- Funding for ICT research appears to have been over-dependent on EC grants and there has been limited collaboration within the national research community. On the other hand, national research grants have been too small to properly support researchers and PhD students
- The performance of researchers considered for the baseline study appears to be at, or slightly above, the world average. However, the performance over the last few years has varied somewhat and there is room for improvement

Monitoring future performance

Future assessments of research performance should consider tracking the inputs used by research organisations including

- Sources of funding obtained (industrial, governmental, EU, charity funding). In particular, tracking the total level of funding for research institutions will provide information on the displacement effects of SFI investments
- The structure and staffing of different organisations
- The infrastructure available to the organisation

In addition, the quality of the research should be monitored and the core indicator for the performance of the research groups should be the quality of the research published in peer-reviewed journals and conferences.

The results of bibliometric assessments would benefit from being benchmarked against the performance of leading international groups in order to provide external international reference points.

Other robust indicators might include

- The number of Irish residents who are awarded membership in honorific scientific societies
- Ability of researchers to leverage national funding to attract substantial investments from outside Ireland
- The numbers of Irish trained scientists who choose to stay in Ireland to work as researchers in university or industry

More formal and rigorous research assessment exercises based on expert panels are an expensive option but would overcome some of the problems experienced in this study. Developing a strong assessment exercise will require more active participation by researchers. SFI or other funding organisations will need to provide an incentive to participate in this kind of review and will also need to exercise more serious leverage if truly robust standardised data from departments and universities are to be collected.

Finally, it will be important to have ongoing performance assessments of SFI's investments to ensure that groups that receive funding are held accountable to the rest of the research community for their use of resources.

Contents

1 Introduction

This report presents the results of a study undertaken by Technopolis, PREST and CWTS to provide a 'Baseline Assessment of the Public Research System in Ireland in the areas of Information & Communication Technologies and Biotechnology'. Forfás commissioned the study in February 2001.

1.1 Background to the study

In 1998 the Irish Council for Science, Technology and Innovation (ICSTI) embarked on Ireland's first National Technology Foresight exercise, a major process of consultation and communication aimed at identifying the actions needed to sustain Ireland's economic prosperity in the long term. Eight expert panels were convened in order to set out the opportunities and challenges that will be encountered by Ireland's major industrial sectors over the next 15 years. Each panel reported separately to ICSTI, detailing the steps that will need to be taken to yield economic and social benefits and sustain industrial competitiveness into the future.

As part of the Foresight process, ICSTI presented its own report setting out a vision of Ireland as a knowledge-based society. Two of the key recommendations of the ICSTI report were that

- Ireland should become a centre of excellence in ICT and biotechnology niches
- The Government should establish a Technology Foresight fund of over IR£500 million over 5 years to bring this about

As part of its considered response to the recommendations contained in the Foresight reports, the Government approved a € 711 million Technology Foresight Fund for the period 2000-2006 and set up a dedicated research foundation to manage it. Science Foundation Ireland (SFI) was established in early 2000, under the aegis of Forfás, to create a critical mass of world-class research in strategic areas relevant to Ireland's economic development, particularly in niche areas within biotechnology and Information and Communications Technologies (ICT).

In October 2000, the Government approved a report from the Technology Foresight Implementation Advisory Group. One of the recommendations contained in the report was that a 'baseline study' should be carried out to establish the present level, quality and capability of basic research in Ireland in ICT and biotechnology. The purpose of the proposed study was to establish how Ireland's current research compares with best international practice and provide parameters against which the progress of the Foundation can be evaluated over the coming years.

1.2 Structure of this report

The report is organised into four further sections. Section two deals with the methodology for the study. Sections three and four present our assessments of the public research system in Ireland in biotechnology and ICT respectively. Section five discusses options for monitoring the progress and impact of SFI funding.

2 Methodology

The terms of reference provided by Forfás set out the objectives of the study. These were to undertake an assessment of the current state of basic research in Ireland in Biotechnology and Information and Communication Technologies (ICT) in order to establish

- The present level and quality of this research
- The capability of the research groups and facilities involved
- How this research level, quality and capability compares with best international practice

The study was also required to identify appropriate parameters against which the progress and achievements of SFI could be evaluated over the coming years.

2.1 Agreed method

In our written tender, the study team proposed a method involving three primary work packages, as follows

1. A mapping exercise, gathering factual baseline data on institutions, their research departments or groups, and individual researchers. This step was undertaken by PREST, University of Manchester, and sought to provide data and information relating to people and demography, facilities and infrastructure, research funding, distribution of effort, linkages and outputs
2. A bibliometric exercise, to provide an assessment of the quantity, level and impact of publications produced by researchers in Ireland in each of the two fields. CWTS, University of Leiden undertook this work package
3. A series of peer review exercises, to appraise the data collected at points 1 and 2, undertake visits to Irish institutions and provide an overall assessment of the research level, quality and capability of Ireland research base in each of the two fields. This work package was organised and managed by Technopolis using panels of international experts in biotechnology and ICT

Technopolis was also responsible for overall management of the study.

2.2 Description of Activities Undertaken

2.2.1 Mapping study

The original workplan foresaw data collection and reporting operating at two levels

1 **At the level of research departments or major research groups.** This would involve gathering information on numbers and qualifications of research staff, research activities, sources of research funding, facilities and equipment, linkages, outputs, training and research strategies. It would also provide names and contact details of individual researchers within each department or group.

2 **At the level of individual researchers.** This would involve the collection of data on individuals' publications and other research outputs over a ten-year period.

However, at a launch meeting for the study, the Deans of Research of the Irish institutions advised Forfás and the study team against this approach, suggesting instead that data collection activity should be focused exclusively at the level of individual researchers. The Deans of Research offered to provide the study team with comprehensive lists of the researchers active in each field, and suggested that each be sent a questionnaire to complete. It was argued that this would be the most effective and efficient route to gathering the required information.

Following this initial meeting, the study team prepared a briefing note for the Research Deans. This set out the procedure to be followed and the definitions of the two fields (shown in Appendix A) to be used in identifying researchers. The study team also adjusted the questionnaire survey in order to gather data at the researcher-level rather than at the department- or group-level. The revised questionnaire used to survey the nominated researchers is shown in **Appendix B**.

The initial round of researcher nominations conducted by the Research Deans resulted in 441 names being put forward by twelve different organisations. On the biotechnology side, ten organisations nominated 186 researchers from 72 different departments or research units.[4] On the ICT side, ten organisations nominated a total of 255 researchers from 69 departments or research units. **Exhibit 1** plots the results of the nomination exercise, by nominating organisation.

Exhibit 1 *Researcher Nominations – Initial Set*

	Biotechnology		ICT	
	Depts / units	Researchers	Depts / units	Researcher
Athlone Institute of Technology	2	5	-	-
Dublin City University	6	14	8	37
Dublin Institute of Technology	5	20	6	15
NMRC	-	-	n/a	16
NUIG	11	20	6	18
NUIM	2	18	5	51
RCSI	5	7	1	1
Trinity College Dublin	19	47	12	38
Teagasc	5	6	-	-
University College Cork	13	38	7	25
University College Dublin	-	-	1	15
University of Limerick	4	11	23	39
Total	**72**	**186**	**69**	**255**

In addition to the nominations shown above, the Research Dean's Office at UCD provided the study team with an additional spreadsheet listing 318 individuals from 54 departments or research units.

[4] As a benchmark for the coverage of the nominations, the ISI database suggest that there are 244 researchers in Ireland who have published 5 or more biotechnology papers in the period 1991-2001.

Following the nomination process, the questionnaire was mailed to individual researchers in April 2001. By the end of June 2001 less than 100 completed questionnaires had been received. This initial low response rate gave rise to concern among the project team that gathering data at the level of (only) individual researchers would not allow it to establish a 'complete' picture of the Irish research base in the two fields. Furthermore, the information provided by the Deans did not allow the study team to differentiate who the key individuals were within the total set of nominees. As such, it was unclear as to whether the completed questionnaires covered most of the 'major players' or none of them.

There were also some reasons for believing that the Deans had adopted different approaches in arriving at their list of nominations. Some had adopted an 'inclusive' approach, nominating everyone that might be in scope (as in the case of UCD), whilst others had been more selective, nominating only the Heads of Departments plus one or two additional individuals. Therefore, even if the study team had been able to get a full set of responses there remained a possibility that the data set contained some significant omissions.

Forfás was appraised of the situation and a decision was taken to allow the study team further time to phone nominated researchers in order to improve the response rate. Around 300 individuals were contacted during July 2001 and in parallel the study team embarked on a number of exercises aimed at shedding light on the integrity of the data set that the Deans had provided. Four separate data sources were used together in order to validate the data provided by the Deans:

1 Information concerning Irish researcher's participation in the Fourth Framework Programmes (specifically Biotechnology, Esprit, Acts and Telematics)

2 Co-nomination data contained within the received questionnaires

3 Information provided by CWTS at the outset of the study on the main research groups in Ireland (based on a bibliometric analysis)

4 Information shown on Departmental websites

These checks identified a number of researchers who had not been picked up in the original nomination process, suggesting that some Deans of Research may have failed to identify one or more important researchers within their institution. Furthermore, efforts to improve response rates through direct telephone contact with non-respondents proved to be extremely time-consuming and had limited success. The project team therefore felt that it would be wise to contact the Heads of the Departments in order to enlist their assistance. The process began in August 2001 with telephone calls or email messages being sent to the Heads of all nominated departments (170+). The phone call or email message requested three things:

1 Validation of the list of nominated researchers identified as belonging to their department or centre by our database

2 Help with persuading nominated researchers to return the questionnaires

3 In a compromise with the original idea of a department-based survey, Heads of Department were asked about what sorts of department-level data could be provided on research activities from existing sources (such as departmental annual reports)

This process resulted in a number of additional nominations, and allowed the study team to 'clean' the database via the removal of some departments and individuals. However, it failed to have a substantial impact on the rate of return of outstanding questionnaires.

Although around 800 questionnaires were distributed, a significant number of recipients were removed from the list, either by themselves or by their Head of Department. As of the termination of the exercise at the end of October 2001, 691 researchers were identified as within scope for the study.

There was a total of roughly 150 research departments or groups in the final (cleaned) data set. One or more completed questionnaires were obtained from around half of these.

Following termination of the questionnaire survey, the study team analysed and reviewed the received data. Despite attempts to validate and 'clean' the data set and to improve the response rate, the obtained information described the research activities of less than one-third of the researchers identified as relevant to the study.

The low response rate, coupled with the fact that the data pertained to individuals rather than research departments or units, also caused problems in how the data was to be presented, and the units of analysis to be used in the remainder of the study. It was not possible to aggregate responses across researchers to arrive at a reasonable description of the activities within each department or research unit, since only a partial response had been obtained. We were, therefore, not able to automatically provide the expert panels with a balanced description of biotechnology or ICT research activities within each of the participating institutions. Furthermore, it was always expected that the expert panels would only be able to visit a sub-set of the research active departments and groups in Ireland, but the data on individuals made identification of the 'key' departments problematic.

A decision was taken to revisit a number of available data sources in order to identify a sub-set of 'key' departments around which the peer review visits could be organised. The following indicators were used:

- The number of researchers within each department or research unit that had been nominated by their institution. This gave an indicator of the likely scale of the research activities
- The number of questionnaire responses obtained from researchers within those departments / units. This gave an indication of the 'willingness' to participate in the study through the provision of data. It was assumed that departments whose nominated researchers had not, despite repeated prompts, responded to the survey would be less willing to accommodate a visit from one of our panels of experts
- The number of co-nominations received (within our survey) from researchers in other institutions. This provided an indication of their standing within the Irish research community
- A bibliometric exercise, which sought to identify all papers classified to accepted biotechnology or ICT sub-fields that had been authored by researchers based in Ireland. This data was sorted by department or research group in order to identify the most active units in terms of publications in relevant ISI journal sets
- Public information on research grants secured by departments and research units within relevant national and international research programmes

The data set above was used to identify 15-20 'key' departments within each of the two fields. The selection of these departments was checked with Forfás and the Steering Committee for the study in order to improve confidence that the main research groups had been covered. Following selection of these departments and research units, the study team used a number of secondary data sources (principally departmental, faculty and university annual reports and websites) in order to prepare a series of 'departmental profiles'. These were intended to assist in the process of briefing the peers prior to their visits to selected departments / research units.

The outputs from the 'mapping' phase of the study can therefore be summarised as follows

- A list of 691 researchers identified as active in the fields of biotechnology or ICT. These researchers were drawn from across 12 institutions and around 150 departments or research units
- Analysis of survey responses from 182 of the nominated researchers
- Publication profiles for ~150 of the nominated researchers
- A series of 'departmental profiles' describing the research activities of 15-20 of the most significant departments / units in each field.

This data set represents the 'factual' baseline data pertaining to Irish research groups in the two fields.

2.2.2 Bibliometric study

Bibliometrics is the quantitative study of written products of research. One of the key methods by which scientists engaged in basic [or strategic] research communicate their results is through publications that are submitted to evaluation by professional colleagues. In the references of their papers, scientists acknowledge relevant publications by others, as they build on previous work. Therefore, the number of times a publication is referred to (cited) gives a partial indication of the 'impact' of a publication, its reception and use by scientists at the research front. This is the basis of the bibliometric analyses conducted here.

Data-Collection and Checking

The process of data-collection and the methodology applied in this study are comparable to those adopted in previous studies on, for instance, physics research (Leeuwen et al., 1996), biology (Nederhof et al., 1999), medicine (Tijssen et al., 2002), electrical and electronic engineering (Leeuwen et al., 2000), the humanities (Nederhof, 1996), and psychology (Nederhof, van Leeuwen & Visser, 2000). Publications were derived from a large bibliometric database of scientific publications. This database contains all scientific articles in publications processed during the period 1991 - 2000 by the Institute for Scientific Information (ISI) for the CD-ROM versions of the Science Citation Index (SCI), the Social Science Citation Index (SSCI), the Arts & Humanities Citation Index (A&HCI), as well as six specialist Citation Indices (Compumath, Materials Science, Biotechnology, Biochemistry & Biophysics, Neuroscience, and Chemistry). The database includes citation data on all journals processed for the SCI, SSCI, A&HCI, and specialist Citation Indices worldwide or CI for short. A detailed description of the main principles behind this database is given in Moed, De Bruin & Van Leeuwen (1995). (Full details for these and other relevant publications can be found at www.cwts.nl)

The 'mapping' phase provided two primary inputs to the bibliometric component of the study:

- a database of 691 nominated researchers
- publication records for some 150 researchers who provided these as part of their response to the questionnaire survey

The publication records were used to compile publication files for each individual researcher who had supplied the study team with data. For all other researchers, the CI database was searched with the researchers' names, using organisational and departmental affiliations to ensure that the correct articles were identified. For each researcher, all relevant publications from 1991 - 2000 (the most recent available ten-year period at the start of the data collection round) were extracted from the CI publication database. Actually, these are 'database' years: papers are included for the year in which they were processed by the Citation Indices on CD-ROM. Due to a time lag in processing articles, at one end, late papers from 1990 are included, while at the other end late papers from 2000 are not included. Complete data on more recent articles was not available during the data collection period of this study.

If a researcher joined a specific department after 1991, his/her publications elsewhere in the world are included. This includes all publications listing the researcher as nth co-author. Only papers classified in the CI as normal articles, letters, notes, and reviews, published in source serials processed for the CI on CD-ROM, were included in the analyses. Similarly, other publication types, such as meeting abstracts, corrections, comments, and book reviews were not included. Also, papers in non-CI source journals were not counted (see below), while only those papers in the limited number of journals partly covered by CI were included that were on the CI CD-ROMs.

The publication lists provided by Irish researchers showed that CI journals covered 89% of all journal papers for biotechnology and 79% of all journal papers for ICT. If monographs, contributions to published edited volumes, and proceedings papers are counted in addition to journal articles, CI-coverage was still 75% for biotechnology but just 37% for ICT. The latter figure is due to the high output of proceedings papers in ICT (N = 1097). This limited check on CI-coverage suggests that the vast majority of journal articles in both fields are covered in the bibliometric analyses, as are most of the (other) published outputs of biotechnology researchers. However, the bibliometric analyses provide only a limited coverage of non-journal outputs within the ICT field.

Once CI publication lists had been prepared for each of the 691 researchers nominated to the study, the lists were published on a dedicated part of CWTS own website. The nominated researchers were then contacted and asked to check their CI publication lists interactively through the Internet. A small number of researchers indicated that their activities were not relevant to our study and were excluded from the analysis. Other researchers requested to be included in the study, and (subject to approval from their Research Dean or Head of Department) were included in the analysis. In biotechnology, 39% of the researchers verified 52% of the total set of publications. In ICT, 47% of the researchers verified 57% of the total number of publications. All received additions and corrections were checked and entered into the database. For researchers who did not respond, CWTS performed a number of additional tests to ensure that other scientists with similar names had not authored any of the attributed articles. Although this procedure was carried out with great care, publications can be missed because of unknown variations (sometimes erroneous) in the name and/or the address of the main organisation and/or its departments/units.

The final count of researchers included in the bibliometric analysis is set out in **Exhibit 2** below. It should be noted that six individuals were entered for both ICT and biotechnology.

Exhibit 2 *Researcher Nominations – Final set used for bibliometrics*

	Biotechnology		ICT	
	Depts / units	**Researchers**	**Depts / units**	**Researcher**
Athlone Institute of Technology	1	1	-	-
Dublin City University	3	13	7	39
Dublin Institute of Technology	4	10	7	20
NMRC	-	1	-	15
NUIG	9	19	5	16
NUIM	2	17	5	48
RCSI	1	5	1	1
Trinity College Dublin	17	47	11	40
Teagasc	-	5	-	-
University College Cork	10	35	6	23
University College Dublin	36	204	18	87
University of Limerick	2	11	7	35
Waterford Institute of Technology	-	-	1	1
Total	**85**	**368**	**67**	**325**

Bibliometric indicators

Indicators were computed at the following levels of aggregation:

- the total collection of all articles, published by the Irish biotechnology scientists involved in the study (Biotechnology)
- the main universities and institutes
- departments

Double occurrences of papers are excluded within each unit of analysis. So one paper, labelled to two or more different research units, is counted only once on a higher level of aggregation. Similarly, a paper, co-authored by several scientists belonging to the same unit, is counted only once.

The bibliometric analysis relates to journal articles published during the period 1991 - 2000. Data on more recent articles was not available during the data collection period of this study. In addition to the overall analysis of the 1991 - 2000 impact data, an analysis of the main indicators across five-year periods at the level of departments was also conducted.

Output and impact indicators

The method used involves the calculation of several indicators for the oeuvre (total output) of a research unit, as produced within the time-frame of the study. One reason for computing indicators on the oeuvre of a research unit rather than on individual papers is that within an oeuvre, later papers or review papers may draw citations that otherwise would have gone to earlier papers. One of the advantages of this approach is that it overcomes the problem of having to treat the transfer of citations within a group as a statistical error in the assessment of single papers.

The first statistic gives the total number of papers published by the research unit during the entire period (**P**). Only papers classified as normal articles, letters, notes, and reviews are included. Meeting abstracts, corrections, and editorials are not included. In a few cases a paper is published in a journal for which no citation data is available, or that is not assigned to a CI journal category. These papers are not considered in the calculation of the indicators presented in this study.

The next two indicators give the total number of citations received, without (C) and with self-citations (**C+sc**). A self-citation (sc) to a paper is a citation given in a publication of which at least one author (either first author or co-author) is also an author of the cited paper (either first author or co-author). As an indication of the self-citation rate, the percentage of self-citations (% Selfcits), relative to the total number of citations received (sc/C+sc), is presented.

The fourth indicator is the average number of citations per publication calculated while self-citations are not included (**CPP**).

A fifth indicator is the percentage of articles not cited during the time period considered (%**Pnc**), excluding self-citations.

Next, two international reference values are computed. A first value represents the mean citation rate of the journals in which the research unit has published (**JCSm**, the mean Journal Citation Score). The JCSm takes into account both the type of paper (e.g., normal article, review, and so on), as well as the specific years in which the research unit's papers were published. For example, the number of citations received during the period 1991 - 2000 by a letter published by a research unit in 1991 in journal X is compared to the average number of citations received during the same period (1991 - 2000) by all letters published in the same journal (X) in the same year (1991). Generally, a research unit publishes its papers in several journals rather than one. Therefore, a weighted average JCS (indicated as JCSm) is calculated, with the weights determined by the number of papers published in each journal. Self-citations are excluded from the computation of JCSm.

The second reference value presents the mean citation rate of the subfields (journal categories) in which the research unit is active (**FCSm**, the mean Field Citation Score). The definition of subfields is based on a classification of scientific journals into categories developed by ISI. Although this classification is certainly not perfect, it is at present the only classification available. In calculating FCSm, the same procedure as the one applied in the calculation of JCSm is used, with journals replaced by subfields. In most cases, a research unit is active in more than one subfield (i.e., journal category). In those cases, a weighted average value is calculated, the weights being determined by the total number of papers the research unit has published in each subfield.

The two most important indicators compare the average number of citations to the oeuvre of a research unit (CPP) to the two international reference values, namely the corresponding journal and field mean citation scores (JCSm and FCSm, respectively), by calculating the ratio for both. Self-citations are excluded in the calculation of the ratios CPP/JCSm and CPP/FCSm, to prevent the ratios being affected by divergent self-citation behaviour.

The **CPP/JCSm** indicator matches the impact of papers closely to the publication pattern of research units. If the ratio CPP/JCSm is above 1.0, the mean impact of a research unit's papers exceeds the mean impact of all articles published in the journals in which the particular research unit has published its papers (the research unit's journal set). A limitation of this indicator is that low-impact publications published in low-impact journals may get a similar score as high-impact publications published in high-impact journals.

The 'crown indicator' CPP/FCSm indicator is free from this limitation, because it takes the impact level of a unit's journal set into account. Therefore, it seems the most suitable indicator of the international position of a research unit. If the ratio CPP/FCSm is above (below) 1.0, this means that the oeuvre of the research unit is cited more (less) frequently than an 'average' publication in the subfield(s) in which the research unit is active. FCSm constitutes a world subfield average in a specific (combination of) subfield(s). In this way, one may obtain an indication of the international position of a research unit, in terms of its impact compared to a 'world' average. This 'world' average is calculated for the total population of articles published in CI journals assigned to a particular subfield or journal category. As a rule, scientists from the United States, Canada, Western Europe, Australia and Japan author about 80 percent of these papers. Therefore, this 'world' average is dominated by the Western world.

Finally, a third important indicator, JCSm/FCSm, is calculated. If the ratio JCSm/FCSm is above 1.0, the mean citation score of the journal set in which the research unit has published exceeds the mean citation score of all papers published in the subfield(s) to which the journals belong. In this case, one can conclude that the research unit publishes in journals with a relatively high impact. It should be noted that the last three indicators mentioned are not independent. The value of each one of these follows directly from the values of the other two indicators.

Statistical test

A statistical test is run to establish whether the average impact of a research unit's publication oeuvre (CPP) differs significantly from the average impact of all papers in the research unit's journal set (JCSm) or from the world subfield average (FCSm) in the subfield(s) in which the research unit is active. If a research unit has a citation per publication ratio (CPP) significantly above (below) the average field (FCSm) or journal citation score (JCSm), this is indicated in the tables by means of a '+' ('-') symbol directly after the numerical value of the indicators CPP/FCSm and CPP/JCSm. A question mark ('?') indicates that the test lacks sufficient information to interpret the result.

Due to the presence of error (Moed et al., 1995), only the first decimal of the ratios is usually reliable, given that it is based on a sufficient number of publications (N>50). Even for a quite large number of publications, a 5% difference or shift in the value of an indicator should not be regarded as a significant result.

Frequently cited publications

An additional set of impact indicators reflects the contribution to the most frequently cited papers worldwide. Two research units may have equal impact scores on the CPP/FCSm indicator, but one produces a steady stream of publications that are cited well but fails to produce really high-impact publications, while the other contributes considerably to the high-impact publications (and also has a larger number of less well-cited publications). To examine the distribution of frequently cited papers, each publication is ranked on the number of citations it received up to four years after publication, and marked those belonging to the 5% most frequently cited papers in a given year. The use of such a fixed-length citation window implies that the analysis only involves papers published during 1991 - 1997. Moreover, letters were excluded. Thus, the **P91-97** figure gives the number of review articles and normal articles published during 1991 - 1997. The indicator **Ptop** renders the absolute number of papers that are represented among the top 5% most frequently cited of all papers similar in publication year, document type, and subject category. The rank of papers is calculated based on the actual impact distribution of all similar papers worldwide, and self-citations are excluded.

E(Ptop) gives the expected number of highly cited papers based on the number of papers published by the research unit. This figure reflects deviations from the 95th percentile if tied values occur due to the discrete nature of the impact distribution. Finally, the **A/E(Ptop)** indicator marks the relative contribution to the 5% most frequently cited papers, and is calculated as the ratio of the Ptop and E(Ptop). Here, a value above (or below) 1 indicates a relatively high (or low) contribution to the 5% most frequently cited papers.

Analysis of cognitive orientation

The cognitive orientation (or research profile) of a research unit is analysed by classifying its papers according to scientific (sub-)fields. In the Citation Indices, publications are classified by means of the journal (sub-)field categories in which they appear such as 'Cell Biology', Physics, Applied', 'Engineering, Electrical & Electronic', and so on. These CI subject categories are attached to each publication of a research unit. Subsequently, these publications are aggregated for each CI subfield, and output and impact indicators are computed separately for these aggregates. The purpose of this procedure is to show how frequently a unit has published papers in various subfields of science, what the impact of the unit is in its main subfield(s), and how the impact of the unit in its main subfields of science compares to its impact in (for the unit) more peripheral subfields of science. This research profile analysis is conducted for the period 1991 - 2000.

If a paper appears in a journal that is classified in more than one subject category, the paper (and its citations) is distributed over the subject categories. Thus, a paper with 7 citations published in a journal categorised in three subject categories is counted as 0.33 publication with 2.33 citations in each subject category. For publications in each subject category, the impact (citation per publication) is compared to the mean field citation score (FCSm), as described earlier. At the subject category level, relatively low numbers of publications prevent frequent use of statistical tests. As an indication, if the ratio CPP/FCSm is lower than 0.8, the impact is said to be 'low', if the ratio is higher than 1.2, the impact is designated as 'high', while a ratio between 0.8 and 1.2 is called 'average'. A CPP/FCSm value above 2 indicates a very strong performance, and above 3 the results can generally be considered as excellent and comparable to that of top-groups at the best US universities.

Indicators for scientific collaboration

Indicators for scientific collaboration are based on an analysis of all addresses in papers published by a research unit. Each paper is classified in one of three categories. First, all papers authored by scientists from one research unit only are identified. These papers are classified as 'no collaboration' or 'single institute', as they involve no collaboration or only 'local' collaboration. The remaining papers are classified as 'national collaboration' when all addresses on a paper are from one country only. Finally, papers containing addresses from at least two different countries are assigned to the collaboration type 'international'. For example, if a paper is the result of collaboration with both another Irish institution and an institute outside Ireland, it is marked as 'international'. Papers in each of the three categories are aggregated for each research unit, and for each of these aggregated sets, impact and output indicators are computed.

The purpose of this analysis is to show (1) how frequently a research unit has co-published papers with other research units, and (2) how the impact of papers resulting from national or international collaboration compares to the impact of papers authored by scientists from one research unit only. For publications in each collaboration category, the impact is compared to the field citation average (FCSm), as described earlier. At this level of aggregation, relatively low numbers of publications prevent frequent use of statistical tests.

Exhibit 3 below sets out a brief overview of the main bibliometric indicators used in assessing the research publication performance of the research base.

Exhibit 3 *Overview of bibliometric indicators and reference values*

P	The number of articles (normal articles, letters, notes and reviews) published in journals processed for the CD-ROM (CI) versions of the Science Citation Index, the Social Science Citation Index, the Arts and Humanities Citation Index, and six speciality Indices
C	The number of citations recorded in CI journals to all articles involved. Self-citations are excluded.
C+sc	The number of citations recorded in CI journals to all articles involved, including self-citations.
CPP	The average number of citations per publication. Self-citations are not included.
Pnc	The percentage of articles not cited during the time period considered, excluding self-citations.
JCSm	Reference value. The average citation rate of all articles published in the journals in which a research unit has published (the research unit's journal set). Self-citations are excluded.
FCSm	Reference value. The average citation rate of all articles in the subfields in which the research unit is active. Also indicated as the world citation average in those subfields or 'world subfield average'. Subfields are defined by means of CI journal categories. Self-citations are excluded.
CPP/JCSm	The impact of a research unit's articles, compared to the average citation rate of the research unit's journal set. A '+' ('-') symbol immediately after the numerical value indicates that the impact of the research unit's articles is significantly above (below) the average citation rate of the journal set.
CPP/FCSm	The impact of a research unit's articles, compared to the world citation average in the subfields in which the research unit is active. A '+' ('-') symbol directly after the numerical value indicates that the impact of the research unit's articles is significantly above (below) world (subfield) average.
CPP/D-FCSm	The impact of a research unit's articles, compared to the Irish citation average in the subfields in which the research unit is active. D-FCSm is designated as the "Irish subfield average". Self-citations are excluded.
JCSm/FCSm	The impact of the journals in which a research unit has published (the research unit's journal set), compared to the world citation average in the subfields covered by these journals.
% Self-Citations	The percentage of self-citations. A self-citation is defined as a citation in which the citing and the cited paper have at least one author in common (either a first author or a secondary author).
P91-97	Number of papers (normal articles and reviews) published in journals processed for the CD-ROM version of ISI's Citation Indexes (CI) in the period 1991 - 1997.
Ptop	The absolute number of papers that are among the 5% most frequently cited of all similar papers in the period 1991 - 1997.
E (Ptop)	Reference value. The expected number of papers among the top 5%, based on the number of papers published by the research unit in the period 1991 - 1997.
A/E (Ptop)	Indicates the relative contribution of a unit to the upper percentiles of the citation distribution in the period 1991 - 1997. Equal to Ptop / E (Ptop).

2.2.3 Peer Review

The primary objective of the peer review component of the study was to provide an independent assessment of Irish research resources and capabilities in ICT and biotechnology, identifying strengths, weaknesses, gaps, and so on. The work of the expert panels was, therefore, not restricted to, or focused on, any specific technical area within the two fields. Accordingly, the identification and appointment of experts was conducted on the following basis

1 International experts who manage ICT or biotechnology research institutes or university departments

2 People who have a good general overview of current and future research trajectories in these areas

3 People who have a solid track-record in providing strategic advice concerning the development of research capabilities in these fields

The agreed arrangements for the study were that there would be four panels of experts, two covering each field. The available budget allowed for 12 experts in total (or three per panel).

Early on in the study two 'Panel Chairs' (one biotechnology expert and one ICT expert) were appointed to the study team. These two individuals were assigned an additional set of responsibilities over the other panel members. The additional responsibilities included

- The provision of assistance to the study team in identifying suitable experts to constitute the peer review panels
- A leadership role in relation to the activities of the expert panels
- The provision of advice and guidance to the rest of the study team in relation to technical and scientific matters (domain specific knowledge)
- Assistance with the preparation of the peer review elements within the final report delivered to Forfás

The two panel chairs were

Professor John O'Reilly (ICT); Chief Executive of the UK Engineering and Physical Sciences Research Council (EPSRC); Vice-President IEE; Technical Editor for IEEE Transactions on Communications; Fellow and Council member of Royal Academy of Engineering; Member of peer review panel for evaluation of the TELTEC Programme in Advanced Technology; Member of a UK Academy of Engineering mission to Ireland

Professor Olli Jänne (Biotechnology), Professor & Director of Biomedicum Helsinki, University of Helsinki, Finland. Previously member of Steering Committee of joint EMBO/Academy of Finland review of molecular biology and biotechnology research in Finland. Member of the Finnish National Academy of Science and Letters; Chair of the Medical Sciences Section. Member of the American Society for Microbiology and the American Association for Advancement of Science and member of a number of steering boards in Finland and abroad.

Following completion of the mapping phase of the study, and in parallel with the bibliometric analyses, the study team embarked on a search for experts. A number of international organisations and networks were invited to nominate potential panel members. The panel chairs also generated lists of known contacts that were experienced in providing policy advice in relation to the development of these two research fields. In excess of 100 experts across the two fields were identified and contacted concerning the study. The study team then drew up a shortlist of potential panellists, each of whom had indicated a willingness to participate in the study.

The study team, in conjunction with the panel chairs, reviewed the CVs of potential panellists and agreed on a final selection. The list of selected panellists was checked with Forfás prior to contracts being issued.

The biotechnology experts selected to undertake the review, in addition to Olli Jänne (the panel chair) were as follows

Professor James Dahlberg, Professor of Biomolecular Chemistry, University of Wisconsin Medical School, USA. Member of US National Academy of Science; President of the RNA society; Foreign Associate of EMBO; Editorial Board of Proc. Nat. Acad. Sci.

Professor Grahame Bulfield, Director and Chief Executive, Roslin Institute, Scotland, UK. Member of Animal Procedures Committee; Member of various Research Council and UK government advisory committees and working groups including BBSRC Strategy Board, Animal Procedures Committee, Banner Committee, SDA –AgBio 2000 Scottish Initiative in Agricultural Biotechnology, SHEFC Scottish Enterprise Task Group on Knowledge Transfer.

Professor Iain Campbell FRS, Professor of Structural Biology, Biochemistry Department, Oxford University, UK. Fellow of the Royal Society; Member of the European Molecular Biology Organisation (EMBO); Chairman of the Oxford Centre for Molecular Sciences; Biochemical Society BDH Medal; Editor or editorial advisor to significant biochemical journals (EMBO J., Structure etc.)

Professor Brian Clark, Professor of Biostructural Chemistry, Department of Molecular and Structural Biology, University of Aarhus, Denmark. President of the IUBMB; Chairman of the Task Group on International Relations of the EFB (European Federation of Biotechnology); Previously Chairman of FEBS Federation of Biochemical Societies; Coordinator of European Commission Concerted Action Programme on Genage; Foreign Member of the Royal Danish Academy of Sciences and Letters

Professor Daniela Corda, Head of the Department of Cell Biology and Oncology, Mario Negri Sud Center for Pharmacological and Biomedical Research, Italy. Council Member and Chair of the Committee on Career Development of the European Life Scientist Organisation (ELSO); Member of the European Molecular Biology Organisation (EMBO)

The ICT experts selected to undertake the review, in addition to John O'Reilly (the panel chair) were as follows[5]

Professor Moira Norrie, Director of ETH Strategic Programme for Information Sciences and Deputy Head of Department, Department of Computer Science, ETH Zurich, Switzerland. International Review Panel, UK Computer Science Research; Chair for Conference on Advanced Information Systems Engineering; Co-Leader of the Swiss e-Space Initiative: a joint initiative for the formation of an ICT cluster in Switzerland led by ETH and A.T. Kearney; Editorial Board, Intl. Journal of Cooperative Information Systems.

Dr Albert Heuberger, Deputy director of Fraunhofer Institute for Integrated Circuits IIS-A, Germany. He has worked in applied research in RF/Microwave systems and Communication systems. He is head of the communications department working on transmission technology for digital broadcasting systems (terrestrial and satellite based), digital media communication, and wireless networks. He is a Member of IEEE.

Professor José Moura, Professor of Electrical and Computer Engineering, Carnegie Mellon University (CMU), USA. Fellow of the IEEE; Board of Governors of the IEEE Signal Processing Society (and editor in chief of Transactions on Signal Processing); corresponding member of the Academy of Sciences of Portugal; has served on a number of similar national review panels.

[5] It should be noted that there were seven ICT panel members in total as John O'Reilly was not able to undertake all of the planned visits to Irish institutions.

Professor Rod Goodman, Professor of Electrical Engineering, California Institute of Technology, USA. Previously, Director, Center for Neuromorphic Systems Engineering, National Science Foundation Engineering Research Center, CalTech; Fellow IEE, Chartered Electrical Engineer, and Member of IEEE.

Professor Jouni Heleskivi, Director Microelectronics Centre, VTT-Electronics, Finland. Evaluator for Swedish R&D microelectronics programmes and EU projects; Member of Materials Research Society, American Physical Society, Finnish Academy of Technology and Swedish Academy of Engineering Sciences.

Professor Morris Sloman, Professor and Head of Distributed Software Engineering Section, Department of Computing, Imperial College of Science, Technology and Medicine, UK. Chairman of UK Engineering and Physical Science Research Council (EPSRC) Multimedia and Network Applications research funding programme (1995-2000); Member of the HEFCE 2001 Research Assessment Exercise Panel for all computing Departments in British Universities; Member of the UK Computing Research Committee (UKCRC)

In brief, the panels' responsibilities were as follows

1 Review the information and analyses prepared in the mapping and bibliometric phases of the study

2 Undertake visits to leading research departments / units in Ireland to review current capabilities and discuss future development of the fields

3 Provide an overall report on the present level, quality and capability of public research in Ireland in ICT and Biotechnology and to make recommendations concerning the development of the research base

Once contracted, the expert panels were provided with a full written briefing on the objectives of the review and the tasks to be performed, including background information on Science Foundation Ireland and the Technology Foresight fund. They were also provided with copies of the questionnaire analyses and departmental profiles prepared within the mapping phase of the study, and the reports prepared during the bibliometric phase. Finally, and at their own request, they were provided with a full listing of all publications that formed the input to the bibliometric exercise.

A series of panel visits to a selection of research departments or research units was then arranged. The departments / units were selected so as to ensure that most of the key research groups were covered, based on the work that had been conducted in the mapping phase. In setting up the visits, care was taken to ensure that there was a good degree of institutional /geographical coverage. Once visits to the 'key' groups had been arranged, a number of additional visits with smaller groups were arranged in order to ensure that their views were also taken into account.

The experts were organised into four panels of three for the purpose of undertaking visits to Ireland. For logistical reasons, the visits were arranged such that one panel within each field covered institutions in the Dublin area whilst the other panel visited institutions located in the rest of Ireland. The organisation of the panels is shown in **Exhibit 4** below.

Exhibit 4 *Organisation of the peer review panels*

Biotechnology Panel 1 (Dublin area)	Professor Olli Jänne, Finland Professor James Dahlberg, USA Professor Grahame Bulfield, UK
Biotechnology Panel 2 (Rest of Ireland)	Professor Iain Campbell FRS, UK Professor Brian Clark, Denmark Professor Daniela Corda, Italy
ICT Panel 1 (Dublin area)	Professor Rod Goodman, USA Professor Jouni Heleskivi, Finland Professor Morris Sloman, UK
ICT Panel 2 (Rest of Ireland)	Professor Moira Norrie, Switzerland Professor Albert Heuberger, Germany Professor José Moura, USA

Professor John O'Reilly acted as a 'floating' expert, attending a sub-set of the visits undertaken by both of the ICT panels.

The panel visits were undertaken during May and June 2002. Each panel visited 9 distinct research units / groups giving a total of 36 visits evenly split between the two fields. The specific departments / units visited by the two biotechnology panels are set out in **Exhibit 5** below.

Exhibit 5 *Groups visited by the Biotechnology Panels*

Biotechnology Panel 1 – Dublin	**Biotechnology Panel 2 – Rest of Ireland**
► TCD - Genetics	► GAL - Microbiology
► TCD - Biochemistry	► GAL - National Centre for Biomedical Engineering Science
► UCD - Chemistry	► GAL - National Diagnostics Centre
► UCD - Medicine and Therapeutics	► TEAGASC – Athenry site
► UCD - Biochemistry	► UL - Institute for Bioscience
► RCSI - Clinical Pharmacology (+ other RCSI groups)	► UCC - Biochemistry
► DCU - Biotechnology	► UCC - Microbiology
► MAY - Biology	► TEAGASC – Fermoy site
► TCD - Microbiology	► UCC - Food Science, Food Technology and Nutrition

The specific departments / units visited by the two ICT panels are set out in **Exhibit 6** below.

Exhibit 6 Groups visited by the ICT Panels

ICT Panel 1 – Dublin	ICT Panel 2 – Rest of Ireland
► TCD - Physics	► GAL - Information Technology
► TCD - Mathematics	► UL - Electronic and Computer Engineering
► TCD - Electronic and Electrical Engineering	► WIT – Telecommunications Software Systems Group
► TCD - Computer Science	► UL - Mathematics and Statistics
► DCU - Computer Applications	► UL - Computer Science
► DCU - Electronic & Electrical Engineering (RINCE)	► UCC - Physics Department
► UCD - Electronic & Electrical Engineering	► UCC - Electrical and Electronic Engineering
► UCD - Computer Science	► UCC - Computer Science
► MAY - Computer Science	► NMRC - NMRC

Prior to undertaking the visits, all panel members and the Heads of Department / unit for each group to be visited were provided with a briefing on the purpose of, and arrangements for, the visits.

Each visit lasted for 2-3 hours and was organised into two separate sessions. The first session focused on the department / unit itself, its research activities, research resources, research capabilities and plans for future development. The second session focused on the national situation, major strengths and weaknesses in terms of research activity, resources and capabilities, and how the field should be developed. Each department / unit visited was asked to give a short 'primer' presentation at the start of each session in order to seed discussions.

Following the visits, each of the panel members was asked to provide two written reports. The first report focused on each of the specific groups seen. Experts were asked to report back against the following 'department/unit-level' issues

- What are the research capabilities of the group?
- Does it have critical mass? If not, what is needed?
- Is the group doing research that is relevant to global scientific agendas?
- Does the bibliometric report fairly reflect the department's capabilities in this field?
- Is its work industrially relevant – in both a global and an Irish context?
- Is the group adequately equipped and housed?
- How well is the group involved in research training? Is this sufficient to ensure strong growth of the relevant fields in Ireland?
- Does the group have a viable strategy and plan for its future development?

In their second (main) report, the experts were asked to use their individual department/unit reviews in conjunction with the full set of outputs from the mapping and bibliometric phases to arrive at an overall report on the national situation. The experts were asked to address the following issues in their overall report

- What are the main strengths of the research base in Ireland, both institutionally and from a disciplinary perspective? Which departments are of international significance and why? In which research areas / sub-disciplines is Irish research of international significance and why?
- Are there any significant gaps in the research base (human, infrastructure, equipment, training, etc.) and how should these gaps be plugged?
- Which research areas / sub-disciplines will be important for the development of the field in the next 5-10 years, and does Ireland have enough capability in these areas? If not, what needs to be done?
- Does the existing community/infrastructure appear to be able to effectively absorb and utilise the level of funding envisaged over the next 5 years? If not, what needs to be done?
- Does the creation of new centres / infrastructure and the attraction of leading researchers from abroad appear warranted?
- Are there any major threats that Ireland faces over the next few years? If so, what are these and how can these be overcome?
- What parameters should be used to judge the progress of Science Foundation Ireland and the development of the communities it supports?

Following delivery of the panellists' reports, the study team undertook the process of synthesising the various inputs and preparing this overall report.

3 Baseline Assessment of the Public Research System in Ireland in the area of Biotechnology

3.1 Demographics

The identified biotechnology research base in Ireland constitutes 368 principal investigators and their teams. These researchers are distributed across 85 distinct departments or research groups within a total of 12 institutions. The number of identified biotechnology researchers and departments / groups within each institution is set out in **Exhibit 7** below.

Exhibit 7 *Researcher Nominations – Final set used for bibliometrics*

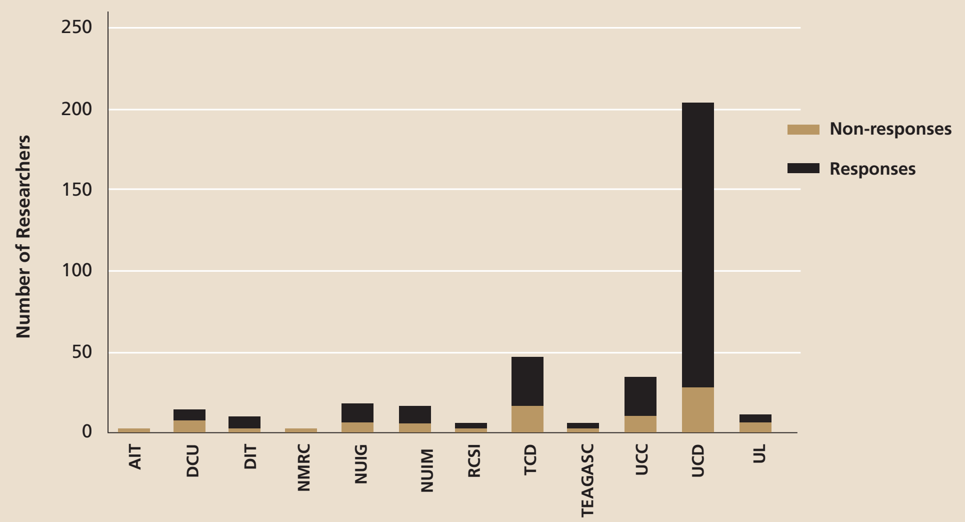
	Biotechnology	
	Number of Departments or Research Units	**Number of Principal Investigators or equivalent**
Athlone Institute of Technology	1	1
Dublin City University	3	13
Dublin Institute of Technology	4	10
NMRC	-	1
NUIG	9	19
NUIM	2	17
RCSI	1	5
Trinity College Dublin	17	47
Teagasc	-	5
University College Cork	10	35
University College Dublin	36	204
University of Limerick	2	11
Total	**85**	**368**

Exhibit 8 below shows the distribution of biotechnology respondents across the different institutions represented in our survey. A total of 85 biotechnology[6] researchers completed and returned our questionnaire - a response rate of 23%. The response rate is low, but is fairly uniform across the different institutions involved in the study, which suggests that the data are likely to provide an accurate reflection of the views of the researchers and organisations involved in the study.

[6] With the exception of UCD the nominations were clearly broken down between Biotechnology and ICT. We categorised UCD nominations based on researchers' publication profile.

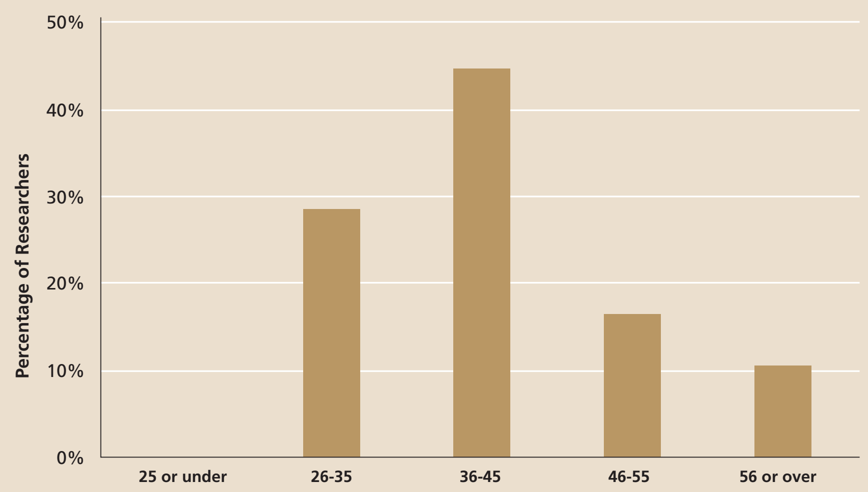
Less than 20% of the respondent population are women and, although this is low, it is consistent with the overall situation in life sciences research in Ireland and elsewhere[7] (women account for over half of Irish graduates in the life sciences but only 16% of Irish senior lecturers are women).

Exhibit 8 *Responses to the researcher questionnaire survey*



The age profile of survey respondents presented in Exhibit 9 below shows that over 70% of the respondents[8] are under the age of 45. This confirms that there is currently no threat to the Irish biotechnology research community from a "demographic time-bomb".

Exhibit 9 *Age profile of Biotechnology Researchers (n=85)*

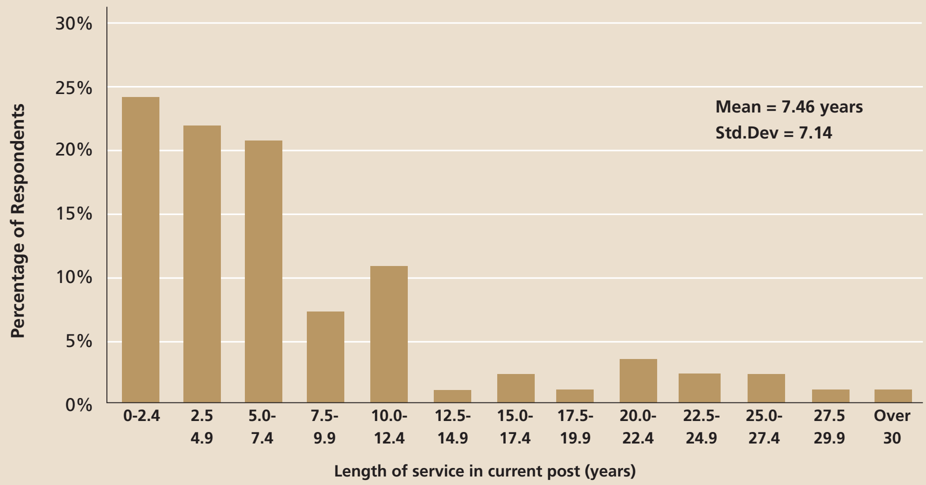


[7] Osborn, M, et al., 2000, Promoting excellence through mainstreaming gender equality: A Report from the ETAN Expert Working Group on Women and Science, European Commission, Research Directorate-General

[8] We asked Deans of Research to nominate researchers of Principal Investigator level or equivalent and, as a result, we would expect the age profile to be biased towards older researchers.

The baseline survey also asked respondents to indicate how long they had been in their present positions, and to list their previous positions. **Exhibit 10** below presents a histogram showing the length of service of biotechnology researchers. The majority of respondents from the biotechnology research communities have been in post for less than 7.5 years. This reflects the age profile discussed earlier and confirms that there are opportunities for researchers to be promoted or to move within the system.[9]

Exhibit 10 *Length of service profile of Biotechnology Researchers (n=83)*



Over 92% of the respondents held PhD degrees and those that did not tended to have DPhils or MDs, so the number of postgraduate 'doctoral level' qualifications among PIs is close to 100%. It is more difficult to explore the seniority of the respondents, given the diversity of titles and positions held by respondents (reproduced in **Exhibit 11** below). Over half the respondents were lecturers, college lecturers or statutory lecturers and there appear to be relatively few respondents who are postdoctoral fellows or research scientists.

Exhibit 11 *Positions held by respondents (N=82)*

Title	Responses	%
Dean of College / Director / General manager	5	6%
Deputy Director / Associate Dean	2	2%
Professor, Head of Department	15	18%
Associate Professor, Senior Lecturer	9	11%
Lecturer/College Lecturer/Statutory Lecturer	44	54%
Research Fellow, Assistant Lecturer, Research Scientist, Research Officer	7	9%
Total	**82**	**100%**

[9] The data presented includes promotion within departments.

3.2 Irish Research Performance and Coverage

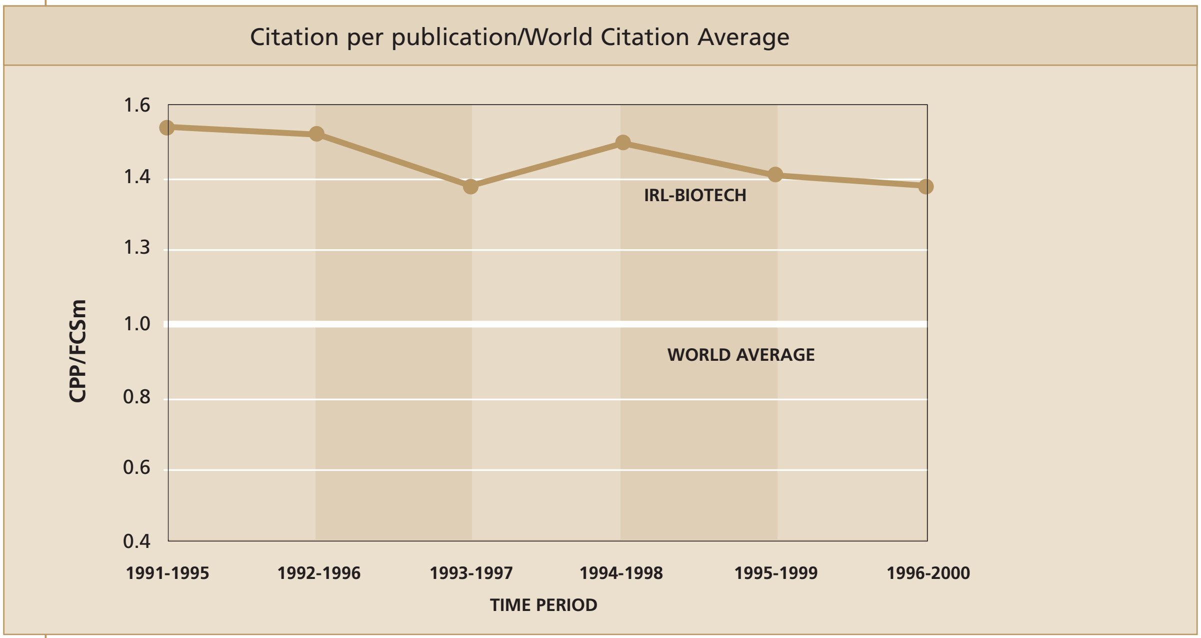
This section is based on the publication performance of Irish researchers, their responses to our questionnaire survey and the results of the peer review reports following meetings with Irish research departments.

The performance of the researchers identified in the baseline study[10] is significantly above the world average. The panel members discuss the strength of the bibliometric indicators and point to some weaknesses in terms of Irish performance in areas of modern biotechnology.

3.2.1 National-level research publication performance

The overall publication performance of the researchers identified within this baseline study was calculated by computing the five-year 'impact'[11] for their publications in the period 1991-2000.[12] The analyses presented in Exhibit 12 shows the citation rates for publications produced by Ireland's biotechnology researchers compared to the average citation rates for all articles in the same subfields. The exhibits show that the impact of senior biotechnology researchers nominated to our study is above the world sub-field average for all five-year periods but with a slight decline over the ten-year period covered. However, there is a potential positive bias in our sample in that our data only covers researchers of Principal Investigator level, whereas the world average is based on researchers at all levels.

Exhibit 12 *Publication Impact of Biotechnology Researchers*



10 The bibliometric assessment was carried out based on a nominated group of Irish researchers. Although these account for the majority of Irish publications they are not a representative sample.

11 'Impact' is measured in terms of citations (excluding self-citation). Most citations to published work occur shortly after publication so it is standard bibliometric practice to count only citations for the five years following publication and to present this as aggregated data.

12 See page 6 for a full discussion

Exhibit 13 presents the same data, broken down by sub-period. It shows that in all sub-periods, the impact of biotechnology publications is above the average for the journals in which they are published (indicated by a CPP/JCSm score of >1). In the early-mid 1990s, biotechnology researchers published in relatively high-impact journals (indicated by a JCSm/FCSm ratio of >1). However, in recent years, journals in which the research base has published have an average impact rating within the subfield. Between the early 1990s and the late 1990s, the volume of published papers citing Irish biotechnology research increased by 44%.[13]

Exhibit 13 *Bibliometric statistics for Irish biotechnology, 1991 - 2000*

Time Period	Papers	Citations	CPP*	Pnc**	CPP/ JCSm***		CPP/ FCSm****		JCSm/ FCSm****	Self Citations
1991 - 2000	**6,162**	**68,199**	**11.07**	**29%**	**1.42**	+	**1.53**	+	**1.08**	**20%**
1991 - 1995	2,591	12,494	4.82	45%	1.32	+	1.54	+	1.17	26%
1992 - 1996	2,844	14,011	4.93	45%	1.35	+	1.52	+	1.13	25%
1993 - 1997	3,053	14,472	4.74	45%	1.31	+	1.38	+	1.05	25%
1994 - 1998	3,280	17,878	5.45	45%	1.47	+	1.50	+	1.02	23%
1995 - 1999	3,429	17,640	5.14	44%	1.42	+	1.41	+	0.99	24%
1996 - 2000	3,571	18,050	5.05	41%	1.37	+	1.38	+	1.01	25%

A '+' ('-') symbol immediately after the numerical value indicates that the impact of the research unit's articles is significantly above (below) the average citation rate of the journal set.

* CPP: The average number of citations per publication. Self-citations are not included.

** Pnc: The percentage of articles not cited during the time period considered, excluding self-citations.

*** CPP/JCSm: The impact of a research unit's articles, compared to the average citation rate of the research unit's journal set.

**** CPP/FCSm: The impact of a research unit's articles, compared to the world citation average in the subfields in which the research unit is active.

***** JCSm/FCSm: The impact of the journals in which a research unit has published (the research unit's journal set), compared to the world citation average in the subfields covered by these journals.

Further bibliometric analyses also show that Irish biotechnology papers are rated among the top 5% most frequently cited papers in their sub-fields 1.5 times more often than the average. This confirms the relative strength of certain parts of the research base.

13 In the same period the volume of citations in the world has increased by 17%, and the citation score of the average Irish biotechnology paper only increased by 5% so the increase is mainly due to the increase in publications

3.2.2 Institution-level research publication performance

Exhibit 14 provides a breakdown of the research publication performance by institution. At the level of universities and institutes, four units (DCU, UCC, GAL, and TCD) perform significantly above the average impact level of their journal set (CPP/JCSm). Five further units have an impact that is above average but not statistically so.

The results also show that four Irish institutions (DCU, UCC, UCD, MAY, and TCD) perform significantly above the world subfield average (CPP/FCSm), while two institutes have a below average impact. The three other units have an impact that is competitive with their world subfield average (two of these units [DIT, UL] have a CPP/FCSm score above 1.20 but lack sufficient publications for the difference to be statistically significant).

The scores on the indicator JCSm/FCSm indicate that MAY and TCD publish in journals with an impact factor at least 20% above the world subfield average.

Exhibit 14 *Research Publication Performance by Institution*

Institute	P	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citations
DCU	603	4,099	5,953	6.80	24%	1.26	+	1.15	+	0.92	31%
DIT	103	656	888	6.37	31%	1.30		1.26		0.97	26%
Teagasc	63	346	453	5.49	33%	1.22		0.65	-	0.53	24%
UCC	1,084	20,520	23,567	18.93	27%	2.33	+	2.62	+	1.12	13%
UCD	2,575	20,980	27,842	8.15	32%	1.05		1.14	+	1.08	25%
GAL	315	2,134	3,073	6.77	32%	1.34	+	0.99		0.74	31%
MAY	243	2,560	3,317	10.53	26%	1.14		1.46	+	1.28	23%
RCSI	97	484	628	4.99	28%	0.74	-	0.59	-	0.80	23%
TCD	1,205	18,809	22,687	15.61	25%	1.50	+	1.80	+	1.20	17%
UL	108	1,075	1,316	9.95	29%	1.26		1.45		1.15	18%

3.2.3 Research publication performance by sub-field

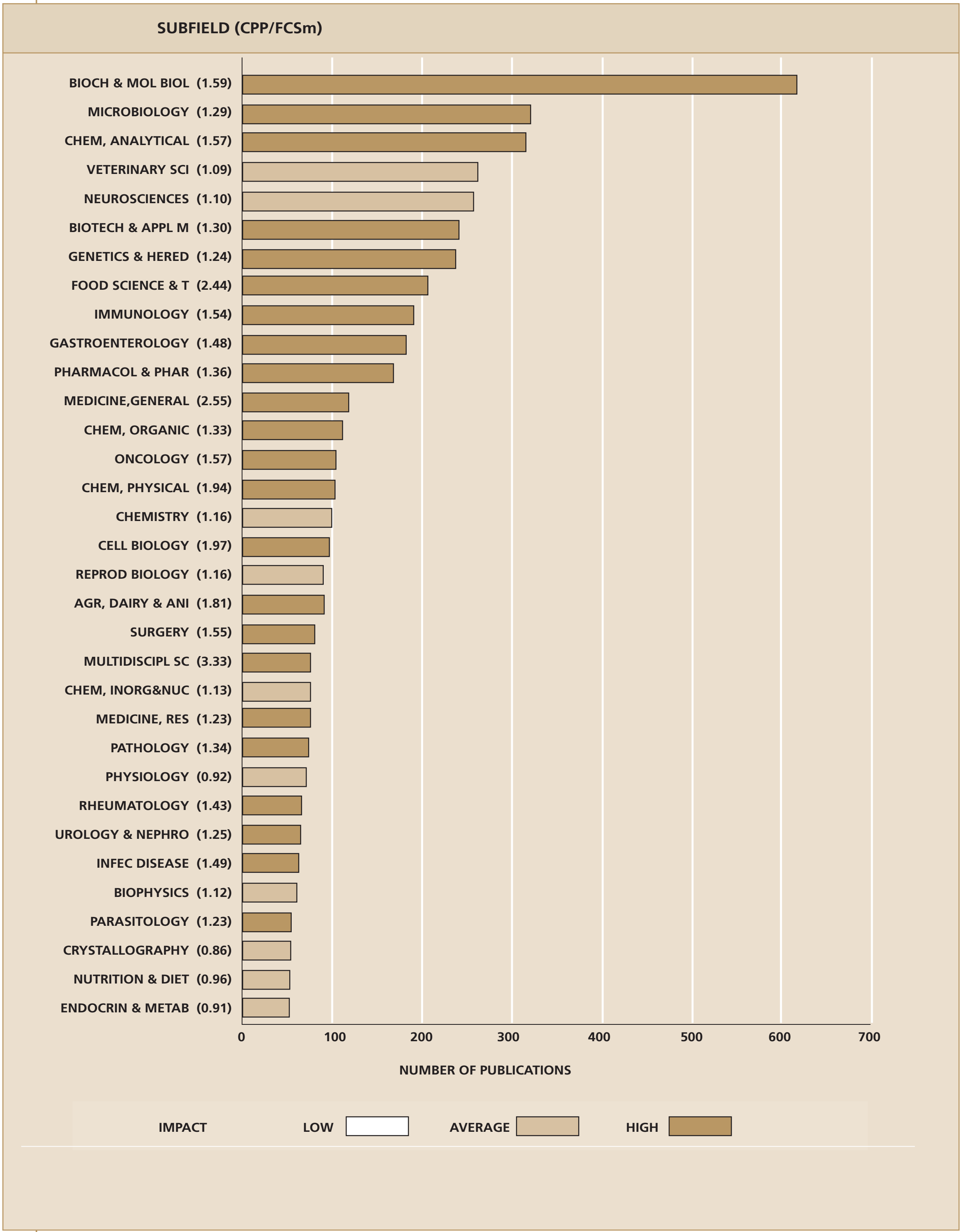
Exhibit 15 presents an overall picture of the areas in which Irish researchers are involved by comparing the performance of the key researchers nominated for the baseline study against the world average in a number of sub-fields associated with biotechnology.[14] The graph shows that:

- Biochemistry & Molecular Biology is the most important subfield for Irish biotechnology researchers, including well over 600 publications (10% of the total output). The impact of the papers published in this subfield is significantly above the world average.
- Two other important subfields are Microbiology and Chemistry, Analytical (associated mainly with DCU and UCC), with over 300 publications each (representing 5% of the total output each). The impact of the papers published in these subfields is significantly above the world average.

[14] A subject category, for example 'Cell Biology', refers only to a combination of journals, and not to an institutional or departmental affiliation. As a consequence, it is not unusual that publications in one subject category have been contributed by members from several research units within one institute.

- These subfields are followed closely by Veterinary Sciences (associated with UCD) and Neurosciences (associated with TCD and UCD), Biotechnology and Applied Microbiology, and Genetics & Heredity, each counting about 250 publications (4%). The impact of the papers published in these subfields are representative of international research in this area.

Exhibit 15 *Cognitive orientation: publications by subfield 1991-2000*



The impact of biotechnology researchers is well above the world subfield average in thirteen of the fifteen subfields counting more than 100 publications.[16] It is high (CPP/FCSm = 1.59) in, for instance, Biochemistry & Molecular Biology, and very high (CPP/FCSm > 2) in both Food Science & Technology and Medicine, general.

Exhibit 16 presents the research publication performance for each university and institute in their most important subfields in terms of publications. The profiles of main universities and institutes highlight a certain amount of fragmentation in terms of research coverage but confirm that Irish research is internationally competitive in a number of research fields. (See page 10 for explanation of symbols in the Exhbit).

Exhibit 16 *Research profiles of Irish research institutions*

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citation
Dublin City University (DCU)												
CHEM, ANALYTICAL	198.8	33%	1,765.5	2,380.9	8.88	10%	1.49	+	1.61	+	1.08	26%
CRYSTALLOGRAPHY	46.0	8%	114.0	275.0	2.48	43%	1.72		0.94		0.55	59%
BIOTECH & APPL M	45.3	8%	262.3	365.0	5.78	29%	1.22		0.84		0.69	28%
PARASITOLOGY	28.0	5%	173.5	313.5	6.20	16%	1.24		1.80	+	1.45	45%
CHEM, INORG&NUC	26.0	4%	161.0	242.0	6.19	31%	1.03		1.45		1.41	33%
CHEMISTRY	22.2	4%	279.0	365.5	12.59	17%	0.96		1.82		1.89	24%
BIOCH & MOL BIOL	21.3	4%	114.3	196.8	5.38	34%	0.74		0.35	-	0.48	42%
CHEM, PHYSICAL	20.6	3%	78.0	156.3	3.79	39%	0.84		1.02		1.21	50%
CHEM, ORGANIC	17.3	3%	214.0	278.3	12.41	14%	1.77		2.29		1.29	23%
BIOCHEM RES METH	17.0	3%	58.3	79.5	3.43	37%	0.73		0.62		0.85	27%
ONCOLOGY	15.0	2%	49.5	73.5	3.30	40%	0.72		0.35	-	0.48	33%
Dublin Institute of Technology (DIT)												
CHEM, PHYSICAL	15.5	15%	99.0	124.0	6.39	45%	1.59		1.95		1.23	20%
CHEM, INORG&NUC	10.0	10%	29.0	55.0	2.90	30%	0.82		1.27		1.56	47%
ONCOLOGY	10.0	10%	27.5	48.0	2.75	30%	0.48	-	0.29	-	0.60	43%
BIOLOGY, MISCELL	7.3	7%	43.0	70.0	5.93	14%	1.33		1.69		1.27	39%
RAD NUCL MED IM	7.3	7%	43.0	70.0	5.93	14%	1.33		1.83		1.37	39%
PHYSICS, AT,M,C	6.5	6%	81.0	93.0	12.46	0%	1.27	?	1.30	?	1.02	13%

[16] This only covers institutes with over 50 publications in our database.

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citations
Irish Agriculture and Food Development Authority (Teagasc)												
REPROD BIOLOGY	15.3	24%	94.5	124.0	6.20	28%	1.22		1.00		0.82	24%
MEDICINE, RES	8.0	13%	6.0	18.0	0.75	38%	1.24	?	0.05	?	0.04	67%
NEUROSCIENCES	6.7	11%	59.5	81.1	8.93	0%	1.00	?	0.70	?	0.70	27%
AGR, DAIRY & ANI	6.5	10%	13.0	21.5	2.00	62%	1.92		1.86		0.97	40%
PHARMACOL & PHAR	6.3	10%	117.8	130.6	18.61	4%	1.60		2.09		1.31	10%
BIOCH & MOL BIOL	6.3	10%	26.0	39.0	4.16	44%	1.02		0.30	-	0.30	33%
NUI, University College Cork (UCC)												
FOOD SCIENCE & T	129.2	12%	843.5	1,109.7	6.53	43%	2.43	+	2.94	+	1.21	24%
MICROBIOLOGY	125.2	12%	1,180.9	1,574.7	9.43	25%	1.17		1.39	+	1.19	25%
BIOCH & MOL BIOL	101.0	9%	7,451.5	7,818.1	73.79	25%	6.22	+	4.89	+	0.79	5%
GASTROENTEROLOGY	97.5	9%	1,157.5	1,415.5	11.87	30%	1.17		1.56	+	1.33	18%
CHEM, ANALYTICAL	90.7	8%	642.2	803.2	7.08	18%	1.60	+	1.44	+	0.90	20%
BIOTECH & APPL M	74.1	7%	802.3	1,090.2	10.83	16%	1.33		1.75	+	1.31	26%
GENETICS & HERED	34.3	3%	663.5	816.7	19.33	13%	1.22		1.57		1.29	19%
NUTRITION & DIET	27.7	3%	73.0	121.2	2.64	33%	0.90		0.80		0.89	40%
NEUROSCIENCES	21.7	2%	295.7	402.2	13.65	13%	0.98		1.01		1.03	26%
IMMUNOLOGY	21.5	2%	604.8	663.0	28.13	23%	2.39		1.96		0.82	9%
CELL BIOLOGY	20.3	2%	765.5	870.2	37.80	20%	2.93		2.53		0.87	12%
NUI, University College Dublin (UCD)												
BIOCH & MOL BIOL	275.3	11%	2,759.8	3,796.4	10.03	40%	0.92		0.73	-	0.79	27%
VETERINARY SCI	244.2	9%	505.7	692.8	2.07	52%	0.99		0.99		1.00	27%
NEUROSCIENCES	101.0	4%	1,197.9	1,681.8	11.86	13%	1.00		1.08		1.08	29%
GENETICS & HERED	78.5	3%	1,385.0	1,765.6	17.65	11%	1.12		1.38		1.23	22%
CHEM, ORGANIC	77.0	3%	404.3	558.3	5.25	32%	1.17		1.12		0.95	28%
BIOTECH & APPL M	75.7	3%	610.3	839.2	8.06	32%	1.28		1.28		1.00	27%
REPROD BIOLOGY	74.0	3%	569.5	825.8	7.70	24%	1.54	+	1.21		0.79	31%
CHEM, PHYSICAL	68.2	3%	669.7	909.7	9.82	21%	1.71	+	2.36	+	1.38	26%
IMMUNOLOGY	64.5	3%	782.8	1,039.2	12.14	15%	0.92		1.01		1.10	25%
RHEUMATOLOGY	63.0	2%	522.0	653.0	8.29	32%	1.29		1.43		1.11	20%
AGR, DAIRY & ANI	61.0	2%	154.5	255.0	2.53	40%	1.15		1.32		1.15	39%

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citations
National University of Ireland, Galway (GAL)												
MICROBIOLOGY	38.4	12%	339.3	529.8	8.83	18%	1.24		1.42		1.15	36%
BIOCH & MOL BIOL	38.2	12%	322.1	518.4	8.44	35%	1.29		0.83		0.64	38%
MEDICINE, RES	23.9	8%	27.3	67.1	1.14	59%	2.10		0.10	-	0.05	59%
INFEC DISEASE	22.7	7%	221.0	308.0	9.75	7%	1.38		1.34		0.97	28%
PHARMACOL & PHAR	20.2	6%	141.8	194.1	7.03	28%	1.35		1.90		1.41	27%
OPTICS	15.3	5%	40.5	55.0	2.64	28%	0.77		0.49	-	0.64	26%
BIOTECH & APPL M	14.9	5%	83.5	118.8	5.60	33%	1.01		1.23		1.22	30%
IMMUNOLOGY	13.8	4%	172.3	260.6	12.45	19%	2.47		1.54		0.62	34%
GENETICS & HERED	10.2	3%	95.0	106.5	9.34	21%	1.07		0.83		0.77	11%
ASTRON & ASTROPH	8.0	3%	32.0	48.0	4.00	13%	0.44	-	0.59	-	1.35	33%
NEUROSCIENCES	7.2	2%	21.5	38.3	3.00	33%	0.93		0.61		0.66	44%
National University of Ireland, Maynooth (MAY)												
IMMUNOLOGY	38.5	16%	385.3	557.8	10.01	19%	1.08		1.16		1.08	31%
ZOOLOGY	16.5	7%	151.5	190.0	9.18	27%	5.09	+	3.04		0.60	20%
MICROBIOLOGY	15.5	6%	151.0	177.0	9.74	23%	0.88		0.74		0.85	15%
GASTROENTEROLOGY	15.0	6%	304.0	407.0	20.27	0%	1.02	?	1.90	?	1.87	25%
BIOTECH & APPL M	14.4	6%	54.2	67.8	3.76	28%	0.78		0.79		1.01	20%
BIOCH & MOL BIOL	14.3	6%	139.8	164.3	9.76	34%	0.63		0.59		0.93	15%
ELECTROCHEMISTRY	9.0	4%	24.0	45.5	2.67	44%	1.36		1.73		1.28	47%
INFEC DISEASE	8.2	3%	131.3	192.8	16.08	12%	1.89		2.40		1.27	32%
MATERIALS SC	8.0	3%	31.5	45.0	3.94	31%	1.25		1.24		0.99	30%
METALLURGY & MET	8.0	3%	31.5	45.0	3.94	31%	1.25		2.31		1.85	30%
NEUROSCIENCES	7.5	3%	25.0	42.5	3.33	13%	0.53	-	0.52	-	0.97	41%
Royal College of Surgeons in Ireland (RCSI)												
PATHOLOGY	15.3	16%	88.3	103.5	5.76	18%	1.25		1.09		0.88	15%
BIOCH & MOL BIOL	12.0	12%	68.8	79.0	5.74	49%	0.68		0.38	-	0.56	13%
IMMUNOLOGY	10.7	11%	45.3	70.3	4.25	22%	0.41	-	0.39	-	0.96	36%
SURGERY	8.7	9%	64.5	74.2	7.44	23%	0.77		1.05		1.37	13%

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citations
University of Dublin Trinity College (TCD)												
BIOCH & MOL BIOL	165.6	14%	3,291.8	3,837.9	19.88	21%	1.37	+	1.39	+	1.01	14%
NEUROSCIENCES	122.8	10%	1,281.2	1,763.6	10.43	20%	1.21		1.22		1.00	27%
GENETICS & HERED	108.6	9%	1,395.7	1,832.4	12.86	11%	1.09		1.13		1.04	24%
MICROBIOLOGY	80.3	7%	948.3	1,218.0	11.82	16%	1.48	+	1.58	+	1.07	22%
PHARMACOL & PHAR	73.2	6%	501.8	658.9	6.86	17%	1.17		1.29		1.10	24%
IMMUNOLOGY	51.5	4%	1,303.7	1,533.8	25.31	17%	1.75	+	2.00	+	1.14	15%
MEDICINE,GENERAL	41.3	3%	1,438.7	1,637.7	34.81	19%	1.56		3.68	+	2.36	12%
MULTIDISCIPL SC	31.0	3%	3,311.0	3,682.0	106.81	6%	2.05	+	5.49	+	2.69	10%
GASTROENTEROLOGY	28.5	2%	244.0	273.0	8.56	23%	0.90		1.11		1.22	11%
HEMATOLOGY	23.0	2%	262.2	311.8	11.40	34%	1.31		1.18		0.90	16%
CELL BIOLOGY	22.1	2%	1,872.5	2,052.3	84.79	15%	3.27		5.14	+	1.57	9%
University of Limerick (UL)												
FOOD SCIENCE & T	20.5	19%	77.0	110.5	3.76	34%	1.40		1.59		1.14	30%
BIOTECH & APPL M	12.8	12%	68.5	72.5	5.34	30%	0.73		0.68		0.93	6%
ENDOCRIN & METAB	8.2	8%	182.8	237.5	22.39	0%	1.32	?	1.94	?	1.46	23%
IMMUNOLOGY	8.2	8%	278.8	330.0	34.14	0%	1.96	?	3.01	?	1.54	16%
CHEM, ORGANIC	6.5	6%	6.5	11.0	1.00	31%	0.27	?	0.33	?	1.22	41%

Our data reveal the relative orientation and strength of different research organisations as follows

- Dublin City University is strongly oriented towards Analytical Chemistry, which accounts for about a third of its output
- For the Dublin Institute of Technology, Physical Chemistry is the main subfield
- Trinity College Dublin has Biochemistry and Molecular Biology as its main subfield, and a strong impact in Neurosciences Multidisciplinary Sciences, Cell Biology, and Medicine, general
- University College Dublin has Biochemistry and Molecular Biology as its main subfield, and a focus on Veterinary science, Neurosciences, and Physical Chemistry
- University College Cork has a strong focus on Food Science and Technology and achieves a strong impact score in the area of Biochemistry & Molecular Biology.
- The University of Limerick has a focus on Food Science and Technology
- National University of Ireland, Galway shows a strong focus on Microbiology and Biochemistry & Molecular Biology

- National University of Ireland, Maynooth is oriented on Immunology and Zoology
- Royal College of Surgeons in Ireland shows a strong focus on Pathology
- Teagasc focuses on Reproductive Biology

3.2.4 Interpretation of bibliometric indicators

The expert panels were asked to comment on the bibliometric indicators presented in the previous sections. The main conclusions were that:

> *The bibliometric data provide a fair indication of the past performance of the units reviewed. However, the bibliometric data are blind to recent changes and trends and must be accompanied by expert review if it is to be used to assess current performance.*

Although the panel largely endorsed the accuracy of the bibliometric assessments, they commented that results needed to be interpreted with care. Whilst the bibliometric indicators provided a reasonable picture of the unit's past performance, in about a quarter of the departments visited recent changes in personnel have impacted significantly (and positively) on the capabilities of the groups.[17] As such, past performance can not automatically be taken as a good measure of current capabilities.[18] For example, the panel visiting TCD commented that the bibliometric indicators did not reflect recent changes of personnel in key departments and predicted that the bibliometric performance would improve significantly in the next few years. The panel visiting RCSI commented that the bibliometric indicators (which pointed to a low level of research output and quality) did not seem to fit with the material and evidence presented. They argued that the recent recruitment of at least half the current PI complement, and the establishment of core technologies and networks in the last two years, could not be captured by the bibliometric indicators.

3.2.5 Research coverage

The panel members confirmed the relative strength of Irish research in the following fields: some aspects of biochemistry and molecular biology[19], food science and nutrition[20], environmental science, molecular microbiology, human genetics, immunology, mechanisms of inflammation and fibrosis, cellular immunology, inflammation and signalling, both in bacteria and eukaryotes.

Despite the generally positive bibliometric performance, the panel felt that as a result of the small absolute size of the science base and the relative dearth of funding for fundamental research, Irish research as a whole does not have strength in many areas of modern molecular biology. However, the panels identified two world-class departments (Genetics at TCD and Biochemistry at UCC) and a number of departments with the potential to become world-class in the next five years or so.

The panel also found that, when compared to countries with population sizes similar to that of Ireland, there were research fields in which Ireland appears to be lagging behind internationally.[21]

17 These positive changes were not linked to SFI awards. Some were linked to PRTLI awards and others were linked to Wellcome Trust funding or strategic investments by departments.

18 This is largely because of the 2-3 year time lag associated with Bibliometric indicators. As a result it cannot capture the impact of recruiting world-class researchers until a few years later.

19 Some of the panel members were slightly surprised at the dominance of biochemistry in the Bibliometric indicators and commented that they would have expected genetics to be a stronger area of research than biochemistry.

20 Food science is relatively strong but also relatively low tech at the moment.

21 There were in most cases examples of good work being performed in these areas but without the benefit of a national research network or of critical mass.

In terms of coverage, these main areas of weakness were: functional genomics, proteomics, structural biology and genomics, nucleic acid chemistry, transgenics research, stem-cell research, modern cell imaging, and developmental biology. In addition, whilst there are pockets of capabilities in the area of bioinformatics, research capabilities seems to be relatively thinly spread and could do with improved co-ordination.

The panel attributed the weak coverage of some of these rapidly developing areas to the lack of core facility services and specialised equipment within Irish Universities (see Section 3.3.4 below). The term core facilities and specialised equipment covers a range of infrastructure including

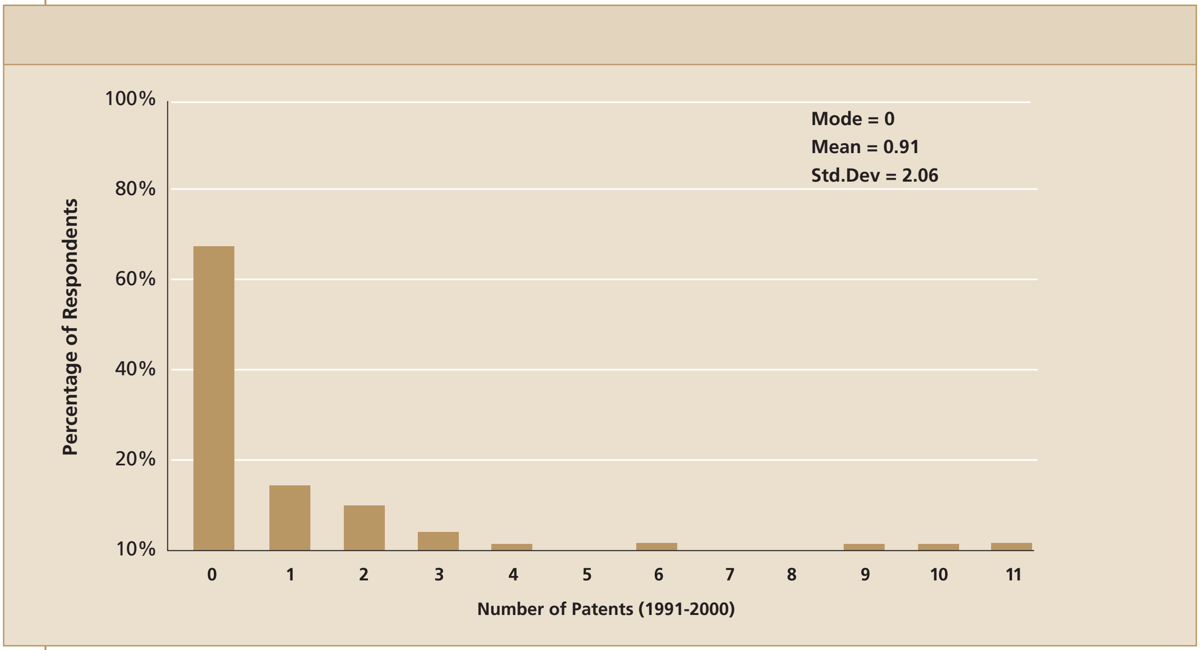
- Department specific equipment (e.g. major Molecular Biology departments now try to provide some central infrastructure that can be used by many members: fermentation, centrifugation, tissue culture - these are relatively non-specialised and could be in almost all such departments.)
- Other more specialised facilities, (e.g. imaging suites, NMR X-ray crystallography, microarrays, protein sequencing etc.) would not be in all Departments but could be funded in one and used by many, or provided in a central (shared) unit.

At present most departments are able to cope with the lack of facilities by drawing on their extensive European networks (see Section 3.3) but the lack of access limits the ability of the researchers to familiarise themselves with the research potential afforded by new instrumentation. In the near future, the lack of access to core facilities may prove to be a problem if Ireland is to attract (or repatriate) scientists from Continental Europe or North America who expect to access such facilities as part of their research programme.

3.2.6 Other Types of Output

The baseline questionnaire asked respondents to provide data on other types of 'outputs' from their work, including patents and non-academic, industrially oriented publications. **Exhibit 17** shows that over 65% of respondents reported no patents with just 15% indicating one or more patents.

Exhibit 17 *Patents output (N=83)*



Respondents reported having produced 333 industrial publications in the period 1991-2000. The distribution of responses is heavily skewed because a single individual was responsible for over a third of all publications. Of the 85 respondents, 55% had not produced any industrial publications, and 92% had produced less than 10 industrial publications.

3.3 Irish Collaboration Patterns

In the past, low levels of national funding has pushed Irish scientists to seek funding from the EU and abroad and the system has encouraged an entrepreneurial attitude to gaining access to facilities that are not available in Ireland. Previous studies[22] in Ireland have confirmed the relatively strong participation in international networks by Irish scientists.

Our bibliometric analyses confirmed the strength of international networks as evidenced by the fact that (with the exception of UL) publications produced jointly with other national or international institutions represent at least 50% of the total output for all Irish researchers. Biotechnology researchers contribute substantially to international scientific networks and many receive an important part of their impact from publications that are internationally co-authored.

The bibliometric results presented in Exhibit 18 distinguish between three types of research collaborations

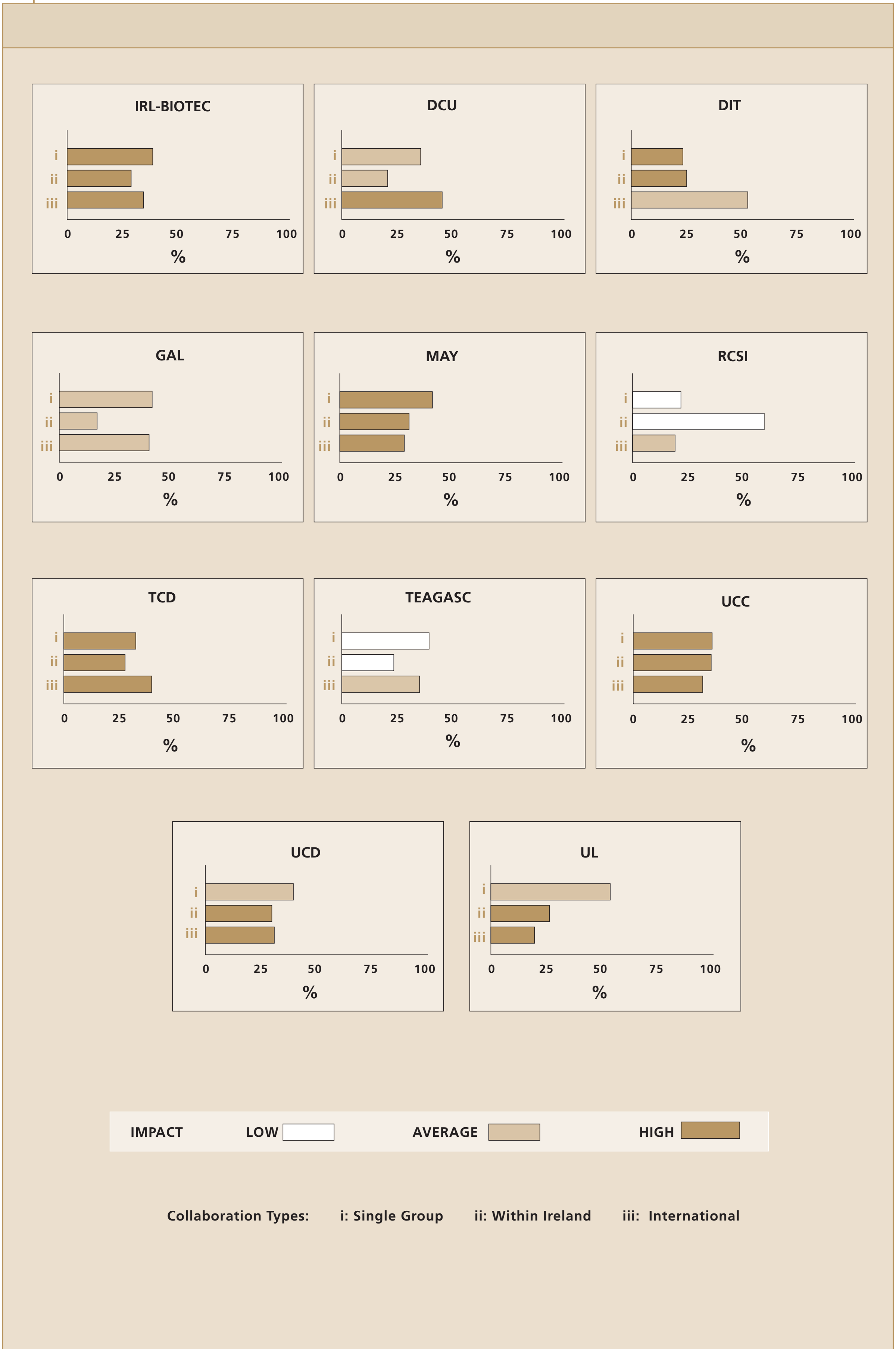
- Publications with only one address were assigned to 'no external collaboration'
- Publications with multiple addresses, all from the same country, were assigned to 'national collaboration'.
- Publications with at least one address outside Ireland were marked with collaboration type 'international'.

The shading indicates whether the impact compared to the world subfield average (CPP/FCSm) is 'relatively low' (<0.80), 'average' (0.80 - 1.20) or 'relatively high' (>1.20).[23]

22 Arnold, E. and Thuriaux, B. 2001, The contribution of basic research to the Irish national innovation system, Science and Public Policy, April 2001;
Guy, K., Tebutt, J. and Stroyan, J., 1999, Evaluation of the Operation and Impacts in Ireland of the EU's Fourth Framework for Research and Development: a report to Forfás; Technopolis, Brighton.

23 Low numbers in categories for some research units invalidate statistical tests. Nevertheless, our experience shows that the present labelling is usually meaningful.

Exhibit 18 *Impact analysis for Irish biotechnology research and institutes by types of collaboration (1991 – 2000)*



The baseline survey questionnaire also asked respondents to indicate previous positions held, giving the name of the institution, the country in which it was located, and the duration. The ability of Irish researchers to draw on foreign resources or to collaborate with research groups abroad is impressive. Exhibit 19 shows that fully half of respondents indicated that they had spent a period of employment outside Ireland.[24] Over 30% of respondents were professionals who had indicated having worked abroad but had not indicated having previously worked in Ireland.

Exhibit 19 *Extent of previous experience abroad (N=85)*

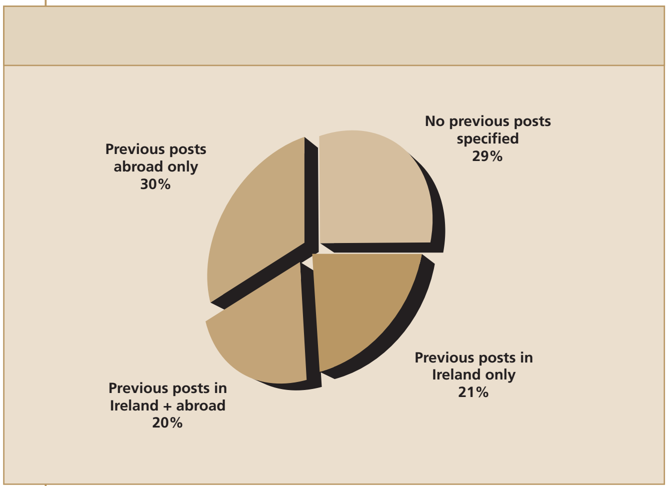


Exhibit 20 shows that The United Kingdom and the United States of America, unsurprisingly, top the table and account for 73% of all international experience.

24 This figure may underestimate the true proportion, given that only limited space was provided on the survey form to record previous positions.

Exhibit 20 *International posts of respondents*

	Number of previous posts abroad	Share of previous posts abroad
UK	34	46%
USA	20	27%
France	5	7%
Netherlands	3	4%
Russia	2	3%
Switzerland	2	3%
Venezuela	2	3%
Austria	1	1%
Canada	1	1%
Denmark	1	1%
Finland	1	1%
Germany	1	1%
Norway	1	1%

3.3.1 Academic Links

The questionnaire responses regarding academic links presented in **Exhibit 21** confirms the international outlook of Irish researchers and shows that over two-thirds of all academic links are international in nature.

Exhibit 21 *Countries with which respondents reported academic links*

Country	Number of times cited	%
Ireland (other institutions)	70	27.2%
UK	55	21.4%
USA	33	12.8%
Germany	13	5.1%
France	12	4.7%
Italy	11	4.3%
Sweden	7	2.7%
The Netherlands	7	2.7%
Canada	6	2.3%
Spain	5	1.9%
Denmark	4	1.6%
Australia	3	1.2%
Austria	3	1.2%

Country	Number of times cited	%
Belgium	3	1.2%
EU (multiple links)	3	1.2%
Norway	3	1.2%
Switzerland	3	1.2%
Iceland	2	0.8%
Japan	2	0.8%
Russia	2	0.8%
China (Hong Kong)	1	0.4%
Finland	1	0.4%
Greece	1	0.4%
Hungary	1	0.4%
Israel	1	0.4%
Kenya	1	0.4%
New Zealand	1	0.4%
Oman	1	0.4%
Portugal	1	0.4%
South Africa	1	0.4%

Exhibit 22 shows that the most commonly cited links were collaborative projects, accounting for almost three-quarters of the links described by respondents. The other significant type of linkage is that mediated by the exchange of staff or students between two academic institutions. This accounts for 11.2% of links reported by the biotechnology community. Links mediated or driven by the need to share equipment, facilities, and sometimes research materials (such as samples or reagents) account for 6.2% of those reported by biotechnology respondents. Finally, teaching links other than the exchange of students (including external examining) account for 1.9% of those reported by biotechnology respondents.

Exhibit 22 *Type of academic links*

Type of Link	No of times cited	% of total
Collaborative Project (including EU projects)	200	74.2
Other 'Network' link (e.g. COST)	1	0.4
Exchange of staff or students	28	10.9
Sharing of facilities or equipment	9	3.5
Sharing of materials	6	2.3
Teaching or training link	5	1.9
Other	17	6.6

3.3.2 Industrial links

The industrial links of Irish biotechnology researchers have somewhat less of an international flavour than the academic links **(Exhibit 23)**. Again the UK is the most common overseas country to have links reported by respondents, followed by the USA, Germany and Belgium.

Exhibit 23 *Countries with which respondents reported industrial links*

Country	Number of times cited	%
Ireland (only)	54	48.6%
UK	11	9.9%
USA	9	8.1%
Germany	6	5.4%
Ireland plus other	6	5.4%
Belgium	5	4.5%
Italy	5	4.5%
The Netherlands	3	2.7%
Denmark	2	1.8%
France	2	1.8%
Austria	1	0.9%
Canada	1	0.9%
EU	1	0.9%
Finland	1	0.9%
Hungary	1	0.9%
Japan	1	0.9%
Norway	1	0.9%
Switzerland	1	0.9%

Collaborative research projects again prove to be most significant form of link, as shown in **Exhibit 24.** Also significant are consultancy and contract research (company funded research carried out in the institution rather than collaboratively) links. Finally, the sharing of equipment, facilities or materials, and teaching or training links, are also significant sources of industrial links.

Exhibit 24 *Type of industrial links*

Type of Link	No of times cited	% of total
Collaborative Project (including EU projects)	247	67.3
Other 'Network' link (e.g. COST)	30	8.2
Exchange of staff or students	34	9.3
Sharing of facilities or equipment	11	3.0
Sharing of materials	10	2.7
Teaching or training link	8	2.2
Other	27	7.4

3.4 Strengths and Weaknesses of Irish Biotechnology Research Base

Using the material available to them and their discussions with a range of different departments, panel members identified a number of factors likely to be important in the development of a world class research community.

- Sources of research funding
- Structure of research groups
- Time spent on research
- Training
- Infrastructure and equipment
- Access to information
- The organisation of research
- Department strategy and leadership
- Intellectual property rights
- Academic pay and promotion

Each of these is discussed in more detail below

3.4.1 Sources of research funding

The questionnaire survey asked respondents to identify sources of funding for their research projects that commenced after 1st January 1995. The results obtained are shown in **Exhibit 25** below. The responses show that national organisations are the main source of funding for researchers, but that the EC programmes and major charities and trusts play an important role in that they tend to fund significantly larger projects. Around 5% of the projects were funded by private companies, though these awards are typically quite small in scale.

The average size of the national research grants is €72k whereas average EC grants are worth about twice as much and Charity grants (e.g. the Wellcome Trust) are worth three times as much. This confirms the problems with continuity of funding that were highlighted as part of the panel visits - national programmes often fail to provide sufficient funding to fully support a PhD student through the project.

Exhibit 26 below further confirms the problem regarding the lack of funding available to fund post-doctoral fellows. It shows that 76% of all the projects reported are worth less than €100k and that 92% are worth less than €250k.

Exhibit 25 *Funding sources reported in questionnaire responses*

	Number of grants	Total funding (€k)	Average size of award (€k)
National Government Department / Agency	**272**	**19,723**	**72**
EI / Forbairt	*121*	*8,184*	*67*
HRB	*54*	*4,423*	*83*
Internal funding	*38*	*1,232*	*33*
HEA	*23*	*1,993*	*86*
National Government Department	*15*	*2,327*	*155*
Teagasc	*10*	*528*	*53*
Other national	*7*	*692*	*99*
EPA	*4*	*344*	*86*
Non-National Governmental	**72**	**9,860**	**137**
EC	*65*	*9,282*	*142*
Non-national Governmental Organisation	*7*	*578*	*83*
Trust/charity	**50**	**11,533**	**231**
Industry	**23**	**1,191**	**52**
Total	**417**	**42,308**	**102**

Exhibit 26 *Breakdown of grants by size of award*

€k	Number	Share
0-49	183	44%
50-99	133	32%
100-149	33	8%
150-199	24	6%
200-249	12	3%
250-299	9	2%
300-349	7	2%
350-399	5	1%
400-449	3	1%
450-499	0	0%
500+	9	2%
Total	**418**	**100%**

3.4.2 Structure of research groups

The low levels of funding for fundamental research in Ireland have had a marked impact on the structure of Irish research groups. The results manifest themselves in two ways

- Insufficient funds to professionalise the research base and adopt the kinds of research group structures that exist in other leading countries.
- A lack of continuity in research funding

3.4.2.1 Professionalising the research community

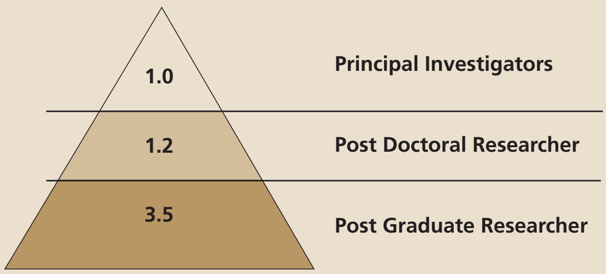
Ireland lacks an appropriate career structure for post-doctoral researchers and there are few opportunities for them to develop (e.g. by applying for their own research grants) or join the faculty.

The panel members argued that post-doctoral assistants are the main drivers for research in top-class labs around the world. These are research professionals who operate efficiently and can take a leading role in supervising the day to day work of graduate students. Typically, the post-doctoral researchers provide the managerial leverage required to allow the group leader to operate effectively. In addition, post-docs also play an important role in the research system because they compete for project based funding and therefore improve the level of competition in the system and create opportunities for development of their own research groups without holding tenured positions.

Exhibit 27 shows that in the leading Irish research groups we visited, there appeared to be relatively few post-docs and the traditional research group structure in Ireland relies heavily on post-graduate students (PhD and leading MSc students) to provide the majority of the effort of

Irish research groups. A simple average suggests that there appears to be a single post-doctoral post for every Principal Investigator and 3 PhD students for each post-doctoral researcher. However, the distribution of resource is far from even and some departments have a PI:PhD or Post-doc:PhD ratio in excess of 1:5.[25] Post-doctoral researchers seemed to be mainly acting as research assistants rather than post-doctoral fellows with their own research grants.

Exhibit 27 *Ratio of Irish PhD students and Postdocs per PI (N=1002).*



Source: Meetings with Biotechnology Departments

The panel members expressed concern about the poor career development schemes in Irish universities. In particular, this applies to the period of post-doctoral research and training. Based on the statements made in the visits to university departments, it appears that post-doctoral researchers

- Are treated as a flexible labour force and not always given status as members of the department
- Do not have pension provisions or the other benefits associated with being employed by the university (e.g. childcare facilities, health insurance etc)
- Are exposed to short-term contracts with little opportunity for career development in terms of gaining access to independent funding

The reason for this appears to be the lack of funding available to support post-doctoral researchers. The problem is compounded by the rising cost of living in Ireland. As a result there is little to keep these highly trained individuals in Ireland, as there are few career opportunities in academia and there is little research being carried out in companies in Ireland that requires post-doctoral experience.

A similar situation exists in regard to professional research technicians. Although the panel did not receive much information on the use of technicians, the evidence suggests that these are principally used to provide support to teaching labs rather than providing experimental support to research groups.

[25] As a benchmark, most of the panel members suggested that in their lab the post-doc – PhD student ratio was close to 1:1. The ratios are generally similar in smaller Nordic countries but PhD programmes in the Nordic countries tend to last longer and PhD students are considered to be departmental staff.

3.4.2.2 A lack of continuity

Until relatively recently, the main national source of funding for fundamental research in Ireland was the Basic Research Grants Scheme. However, the sharp competition for research grants[26] and the short-term nature of the support provided[27] prevented researchers from developing longer-term research programmes. Indeed most researchers complain that the scheme cannot fully support typical PhD students who take 3-4 years to complete their training.

Principal Investigators struggle to maintain the research income required to fund PhD students to the end of their studies and a certain amount of "creative accounting" goes on in order to provide some continuity.

Apart from SFI grants, Irish research funders do not allocate any overhead components in the grants they award and assume a well-funded laboratory when this is clearly not the case. In that respect, the lack of departmental level discretionary funds limits the development of strategic areas or the use of such funds to smooth the irregular research funding.

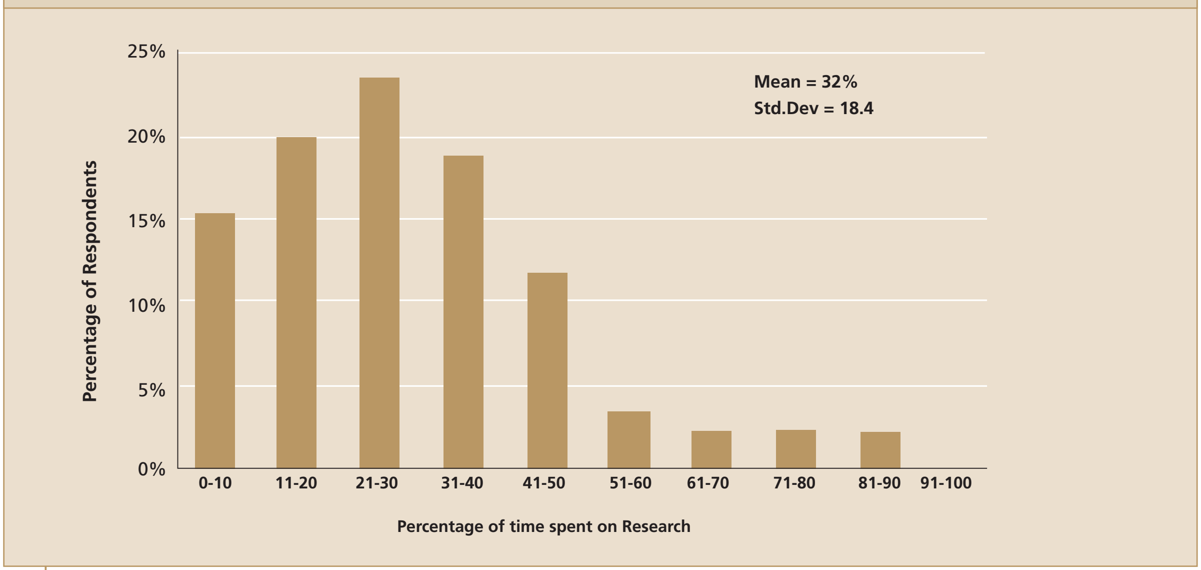
In view of the problems caused by lack of continuity in funding, the majority of departments expressed concerns about the continuity of SFI funding. The potential of the loss of SFI funding is a significant risk and is effectively a disincentive for scientists who are to decide whether to leave their current position abroad to work in Ireland.

3.4.3 Time spent on research

Irish researchers appear to spend relatively little time on research and suffer from high teaching loads.

The responses to the survey presented in Exhibit 28 indicate that researchers spend relatively little of their time on research (over a third of respondents spent less than 20% of their time spent on research; 90% of researchers spent 50% or less of their time on research).

Exhibit 28 *Proportion of time spent on research (N=85)*



26 In the last year of funding the scheme was only able to fund 17% of applications.(N = 474}

27 Until 1995 the scheme only provided support for 2 year projects; since then the project duration has been extended to 3 years.

Exhibit 29 and **Exhibit 30** show that Irish researchers have high teaching loads. For some respondents, undergraduate teaching in particular can take up 60% or more of their time. The panel members also identified high teaching loads in most of the departments they visited.

Exhibit 29 *Amount of time spent on post-graduate teaching (N=85)*

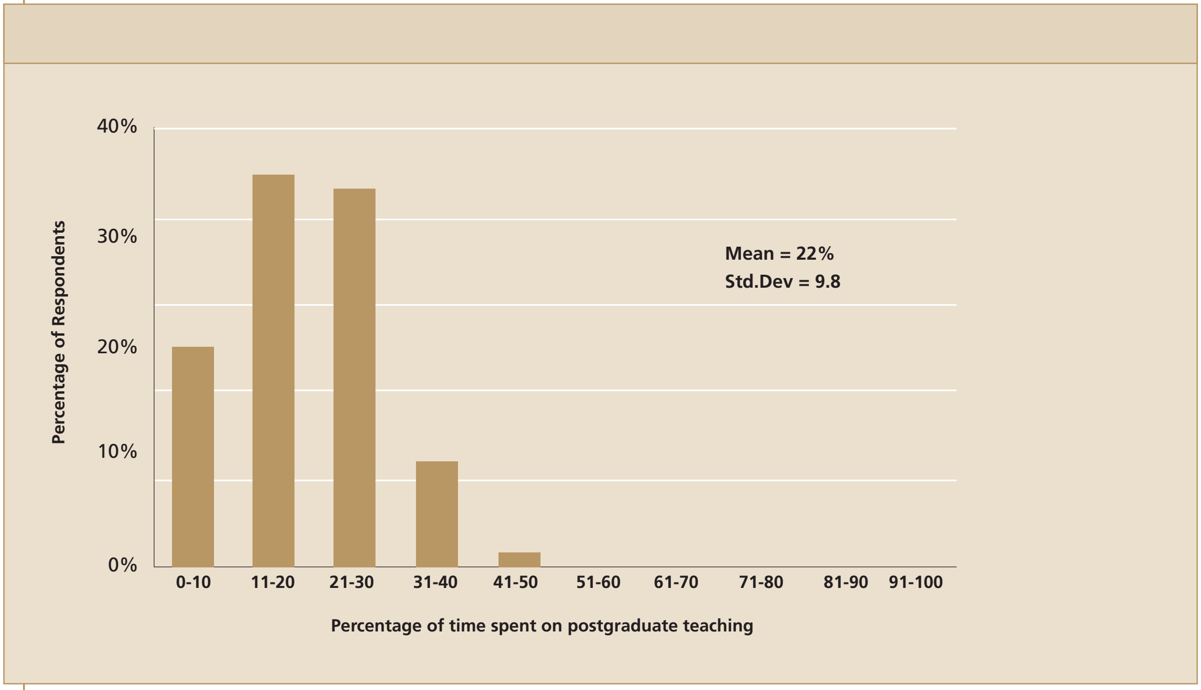
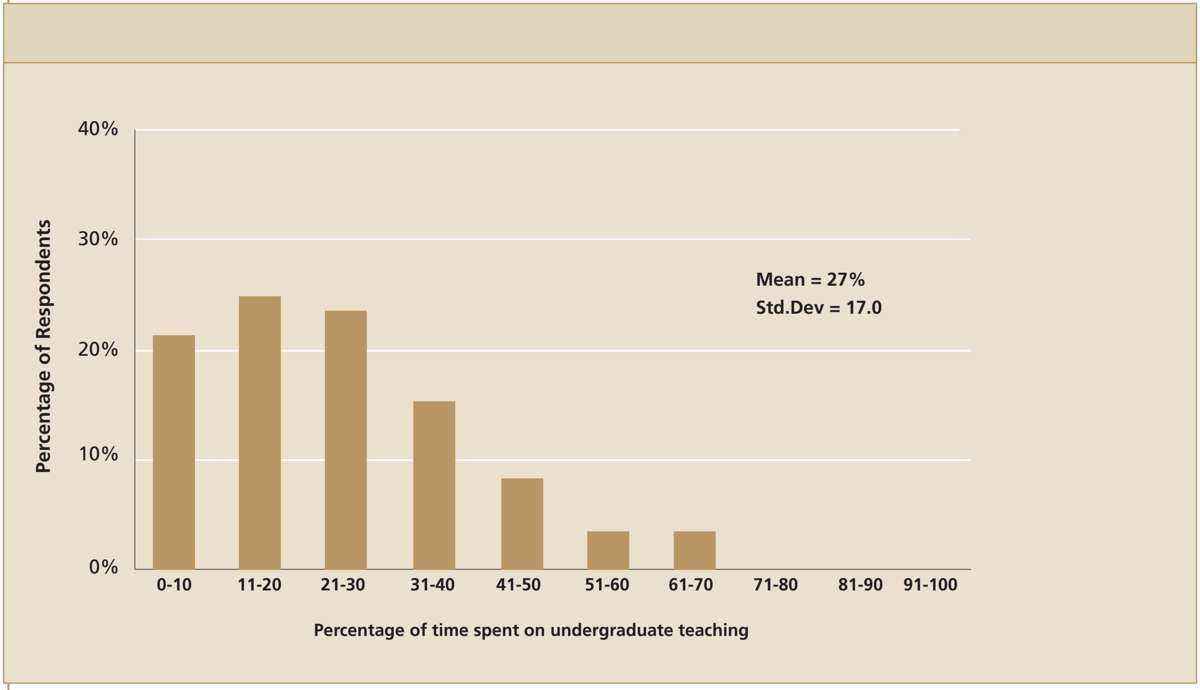


Exhibit 30 *Amount of time spent on undergraduate teaching (N=85)*



The amount of time spent on research reflects the seniority of most of the individuals nominated by the Deans of Research and Exhibit 31 shows that administrative functions displace research time for older (and more senior) researchers. We had expected to see higher teaching loads for younger respondents but our data suggest that high teaching loads are a normal feature of Irish academic life.

Exhibit 31 *Activities by age of respondent (N=85)*

	Mean % of time spent on			
Age	Research	P/G teaching	U/G teaching	Other (mainly administrative)
Up to 25	0	0	0	0
26-35	43	21	26	10
36-45	31	23	28	18
46-55	26	20	25	30
56 or over	20	25	26	29

3.4.4 Training

Panel members commented that, in their experience, Ireland has produced many excellent scientists and the quality of the available students - mainly Irish recruits - appears to be good. They suggested that the quality of PhD students could be improved by introducing structured post-graduate training at the start of the PhD.

Students have been the main resource for Irish academic researchers and will continue to play an important role. However, there does not seem to be any discrimination in the type of students produced and post-graduate students attract the same amount of central funding as first year undergraduates.[28]

Some of the panel members expressed concern over the fact that doctoral training suffers from being predominantly tied to a single supervisor with little formal graduate teaching and mentoring by other members of Departments. Thus, the trainees have no rotation or course work in their curriculum which may lead to training that is much too narrow in scope to deal with the rapid expansion of techniques and instrumentation of modern biotechnology.[29]

If, as expected, the biotechnology industry in Ireland continues to flourish in the next few years, it will experience a lack of well-trained personnel. In view of this, the panel members argued that there should be an increased emphasis on structured graduate training for research staff and improvements in vocational training for technical staff.

There is a lack of university staff capable of supervising high-level post-graduate research in several research areas of future importance, including proteomics, structural biology, transgenics, and stem-cell research. With limited postgraduate training in these areas Ireland will find it

[28] Some of the universities we visited weigh the central allocation so that departments which provide the bulk of 4th year undergraduate training or post-graduate training receive increased funding.

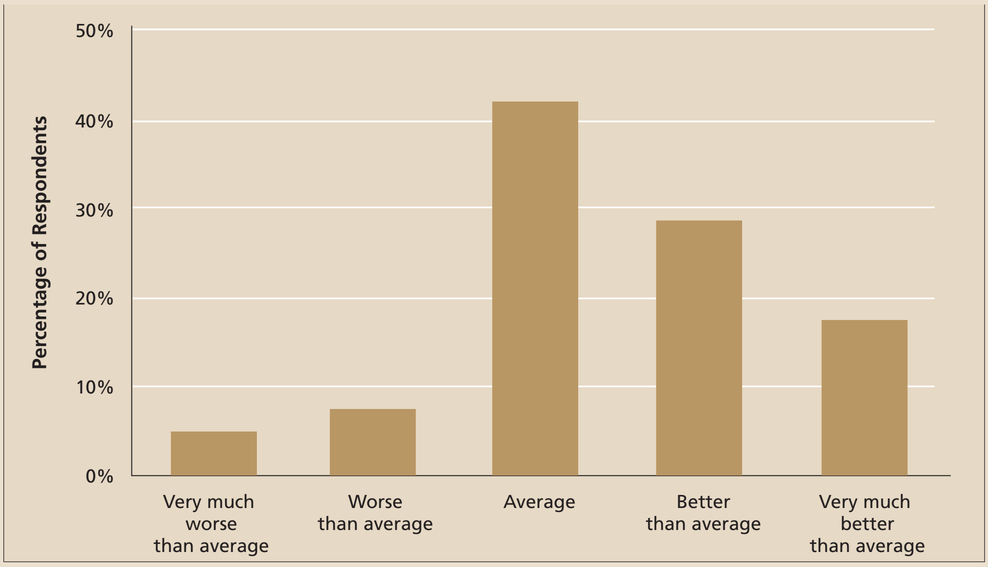
[29] In particular, the visiting panels advocated that taught graduate programmes (as part of a PhD) should be established if Ireland is going to rely on these graduates to catch up in the area of functional genomics.

difficult to build up strong research groups and, whilst some of this expertise can be imported or repatriated,[30] there is an immediate need for improved training in these disciplines.

Exhibit 32 shows that only 10% of biotechnology researchers indicated a concern about their comparative ability to train future generations of researchers. International exposure plays a strong part in shaping response to this question: 64% of researchers who had only worked in Ireland considered that their position was above or very much above world average but only 34% of those who had only worked outside Ireland held the same opinion.

This kind of response can be partially explained by the high quality of undergraduate education in Ireland[31] and by the potential bias that can be expected from supervisors asked to assess the training of their students. Indeed the positive bias was revealed in the responses to a similar question, in which 71% of respondents argued that compared to other national institutions their ability to train high quality undergraduates was above average.[32]

Exhibit 32 *Ability to train post-graduate scientists compared to rest of world (N=81)*



Post-graduate and undergraduate teaching activities are clearly important in most of the institutions covered by our survey. **Exhibit 33** shows that Irish researchers tend to supervise more PhD students than Masters or other types of post-graduate degrees. Respondents reported an average of 5 PhD completions in the period 1991-2000, though 26 reported no PhD completions. Respondents also reported an average of 3 other post-graduate completions, though again 30 respondents indicated no post-graduate completions.

30 There are expert Irish nationals abroad.

31 Irish BSc Honours degree are 4 year degrees.

32 Since we are surveying a high proportion of the research base we would expect a more normal distribution.

Exhibit 33 *PhDs completions: Biotech (PhD N=85; Post-graduate N=84)*

Number of advanced degree supervised to completion	Frequency for PhDs	Frequency of other Post-graduate degrees
0	26	30
1	8	13
2	4	14
3	8	5
4	6	7
5	3	4
6-10	18	4
11-20	5	5
20+	7	2
Total supervised	**418**	**281**

3.4.5 Infrastructure and equipment

With some notable exceptions, the overall finding of our expert panels is that Irish researchers' access to modern equipment and laboratory standards is inadequate. In some cases the panel members commented that the physical working conditions were no longer appropriate for contemporary biotechnological research and need to be renovated as soon as possible to ensure that research students obtain adequate training.

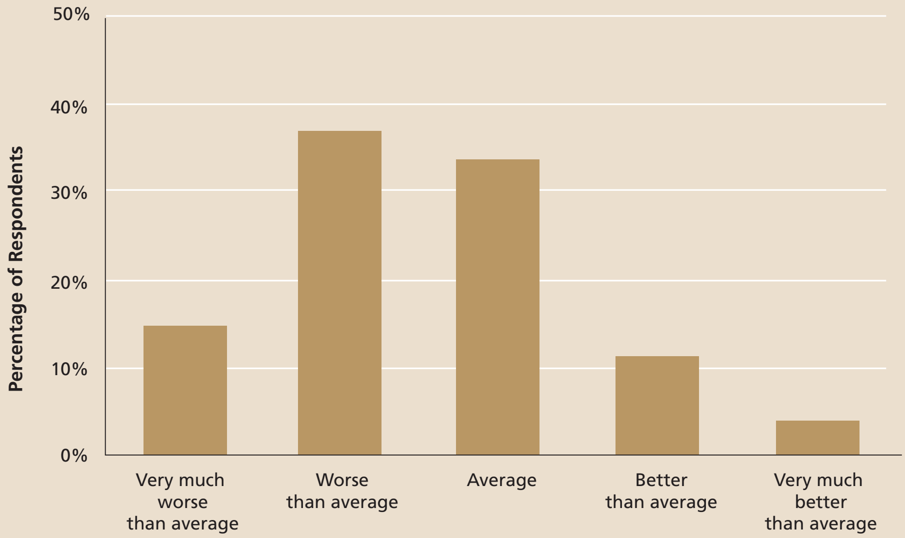
3.4.5.1 Core facilities

As part of our questionnaire survey, leading researchers were asked to compare their research group, centre or department to others nationally and internationally, as regards access to 'large-scale' research equipment.[33]

The majority of the researchers indicated that there is indeed a serious problem concerning access to large-scale facilities. **Exhibit 34** shows the responses obtained when Irish biotechnology researchers were asked to compare their situation with other international research groups. The Exhibit shows that over half of the researchers believe that their own position vis-à-vis large-scale equipment is worse or very much worse than equivalent departments in Europe or North America. Respondents who had only previously worked outside Ireland (N=24) were more critical of the current situation: only 8% considered access to be better or very much better than average, compared to 30% of respondents who had only previously worked in Ireland (N=17).

[33] The question is based on the assumption that respondents will have good working knowledge about the resources and conditions of leading groups both in Ireland and overseas – a not unreasonable assumption in view of the large incidence of overseas visits and overseas research links .

Exhibit 34 *Access to large scale equipment compared with other international research groups (N=81)*



The visits to different departments confirmed this analysis. The panels felt that the most glaring gap in the structure of academic research was the severe lack of core facility services. This gap was not limited to weaker areas of Irish research (e.g. functional genomics technology platforms), but involved also other services such as modern microscopy, X-ray crystallography, DNA sequencing and genotyping, and structural biology. Similarly, funding of improved transgenic animal and gene knock-out facilities is needed to supplement the rather small facilities that presently exist.

Modern crystallography requires access to accelerator beam lines, but the "nuts and bolts" of growing crystals and interpreting data can be done locally; beam line access can be arranged at several international facilities.

One of the problems has been an historical lack of funds to purchase such equipment. The situation in this area appears to have improved over the last few years[34] but at the time of the visits the infrastructure for large scale equipment still appeared relatively poor by modern European and North American standards.

While the lack of funds to purchase expensive equipment is a partial explanation, there appeared to be other problems as well, such as insufficient expertise, lack of positions for skilled support staff, and cultural problems in sharing technology platforms.[35] Although a number of the groups have plans to acquire expensive equipment they do not have any plans to collaborate with other departments to pool funding. In this respect, it was evident that there is a tradition of equipment belonging to departments rather than to the university – a natural response to the historical lack of funding for research which can foster competition rather than cooperation across and even within institutions.

34 Largely as a result of funding through the Programme for Research in Third Level Institutions.

35 For example, one university Department is using a confocal microscope abroad rather than one in a neighbouring Department because of difficulties of access.

On a more positive note, the development of research centres (e.g. the Conway Institute) indicates that some departments are more progressive in their attitude. The Dublin panel members strongly supported the concept and implementation of the centre, which will contribute to breaking-down departmental barriers and arrange researchers around and within core facilities. The panel saw this willingness to change as an indication that attitudes to sharing equipment are changing.

3.4.5.2 Buildings and laboratories

Some of the buildings and laboratories visited were old and already very crowded. As one of the panel remarked during a visit to a postgraduate lab

> *The group has a new building plus refurbishments in progress, which is just as well: we were shown a really awful lab for some 20-30 Ph.D. students (i.e. all together and not in their research groups) which must be the worst I have ever seen, would certainly have put me off science for life and was like something out of a Victorian school… dreadful!*

During the site visits, it became evident that some universities are suffering from a lack of space for development. In the case of TCD this is proving to be a serious limitation with regard to starting programmes to fill out existing gaps in expertise and/or to commence entirely new activities.

Several groups mentioned that they have no room for expansion and, on this ground alone, are expected to have problems in developing their future functions and absorbing a significant increase in funding. It may well be that a significant overhaul in the current structure of the universities is required, in order to enable the use of the SFI funding in a fashion that best benefits Irish biotechnological research.

More generally, this has serious implications for the research community. It looks likely that some restructuring of the ways by which research is conducted at the universities is needed, in order for them to be able to absorb SFI funding effectively. In a number of cases this is likely to mean that departmental boundaries need to be dissolved, at least for the purpose of organising research activities. It will also require a change in approach such that multidisciplinary experience and research activity are promoted and developed.

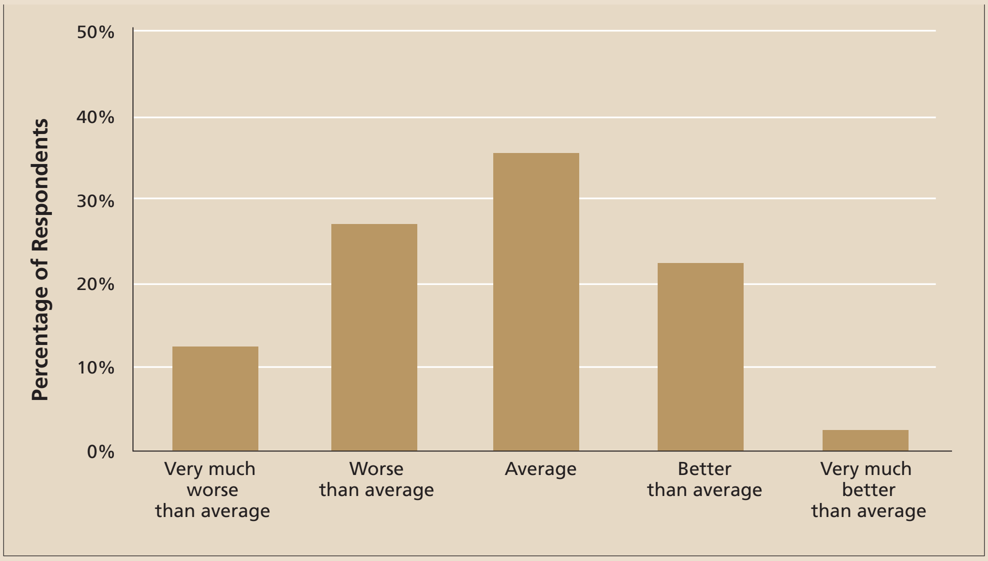
3.4.6 Access to information

Of the several gaps that exist in terms of research resources and capabilities, the one that was discussed repeatedly by researchers was a lack of access to electronic journals. The panels confirmed that this is the case, with library services being poorly maintained in at least some of the departments visited.

The science community has online access to a limited number of electronic journals and there did not appear to be any coherent policy concerning subscription to journals and electronic libraries. A number of the departments we visited admitted that foreign students and members of staff from overseas are still using online access from their previous institutes because of the poor quality of the coverage in Ireland.

In terms of library and information systems, the questionnaire survey shows that over 40% of respondents rated their own position as worse than average internationally. Again, respondents who had only previously worked outside Ireland were more critical of the current situation: only 17% of these considered access to be better or very much better than average, compared to 41% of respondents who had only previously worked in Ireland.

Exhibit 35 *Access to information / library facilities compared to other international research group (N=81)*



Progress in modern biotechnology is moving fast, and a lack of rapid access to the latest publications puts Irish scientists at a significant disadvantage vis-à-vis most researchers in the US and Europe. Printed journals are often out of date by the time they arrive at a lab or library and the handful of copies purchased are not sufficient for the needs of the many students, post-doctoral fellows and staff that ought to be using them.

3.4.7 The organisation of research

Given the size of the population (~3.5 million), the number of universities, institutes, centres, etc. in Ireland is comparatively high. The panels expressed surprise at the diversity in the research coverage of individual departments, and how often the fields covered were duplicated in other departments and institutions (with no obvious lines of communication between each). The panels believe that the breadth of activities has prevented some departments from developing a critical mass of research and one of the panel members described this scattered coverage as "a desperate approach to developing critical mass in biotechnology".

Despite the quality of the researchers, most of the departments we visited lacked the necessary critical mass and focus to compete internationally. It was noteworthy that the few departments that had managed to create critical mass in particular areas and had systematically developed mutually reinforcing areas of competence, achieved higher bibliometric ratings and were generally considered by the panels to be more competitive. The ability to compete with the rest of Europe appears to be hindered by the fragmented nature of the research areas covered by most departments.

There appear to be two main underlying causes for the fragmentation of research efforts

- A strong emphasis on teaching which requires departments to have staff to cover all the areas they teach
- The lack of overhead funding which would give the departments the opportunity to build critical mass

Universities are proud of their teaching tradition and most academics spend a large proportion of their time teaching. The panel agreed that the best way to develop research was to build on the enthusiasm of researchers. However, they argued that there is a need for departments to create coherent research strategies that allow them to develop a comparative advantage in one field of research. Departmental staffing appears to be driven by teaching rather than research needs - the current emphasis needs to change if Ireland is to develop world-class research centres. At the moment, too many of the departments are attempting to cover too broad a range of research in their area.

Historically, none of the national sources of funding has provided an overhead component in research grants.[36] The lack of overhead funding has prevented departments from acting strategically and using central resources to build up capabilities and develop economies of scale in key areas. At the same time, the generally low level of research project funding has meant that successful members of staff are in a strong position to defend their own areas of research, even if there is little overlap with the work of others in the department. To put it bluntly, historically departments have had to take any research funding they could get regardless of whether it was in a core area of research.

3.4.8 Department strategy and leadership

In a number of cases, the tradition of academic independence (and the lack of department level funding) seems to have made it difficult for department heads to develop and implement department level strategy. The panels commented that:

> *With regard to future plans, it was troublesome that several departments did not seem to have coherent plans for their future. However, some departments did present well thought-out visionary plans, including construction of new facilities with multidisciplinary expertise.*

In particular, the quality of departmental leadership appeared to be variable. Some department heads clearly had the vision, purpose and support from members of staff needed to lead their departments through the period of structural change in Irish research. In other cases departments appeared to lack leadership and it appeared that the heads of department had little authority over their colleagues and that their role was not strategic but rather administrative.

3.4.9 Intellectual Property Rights (IPR)

As in other countries, there are conflicting pressures on academics to either protect IPR (and generate funding revenue for themselves and to contribute to a department's future research) or to publish research results and thus contribute to their scientific reputation and chances of promotion. The panels were surprised at the range of schemes that were operated in different universities and the variations in incentives this has provided for the inventor to protect their IPR. Every university appeared to have a different policy on IPR – some were very progressive, whilst others effectively provided disincentives to protect IPR.

A number of the units that were visited expressed concerns about the service that was available for intellectual property rights issues. For example, the departments complained that there is

36 We understand that SFI will be the first national source of funding to include an overhead component in its funding.

often little help in filing patents, or evaluating the potential of an invention. These services are not easily accessed.[37] Generally, there is a perception that these centres suffer from a shortage of professional personnel and a lack of expertise in regulatory issues pertaining to biotechnology in Ireland and within the European Union.

3.4.10 Academic pay and promotion

The panel commented that whilst the funding for post-graduate researchers was comparatively low, the overall level of remuneration for university staff is relatively normal by European standards.

However, the regulations regarding promotion within the university seemed to vary considerably and often did not seem to reflect the changes in Irish tertiary education and research in the last decade. Some universities appear to maintain a rigid and old-fashioned university structure (geared primarily for teaching) which hinders the development of fast-paced modern research.

3.5 External threats to the science base

3.5.1 Public support for science

Some panel members expressed a concern that Irish science may lose the support of the Irish people. Several different researchers reported that school students are not taught science until they reach the age of twelve.[38] As this generation of children grows into adulthood they may bring with them a lack of understanding of – and support for – science.

In an age of competing demands for funds, science may lose out if the public is not made aware of the value of research. Moreover, the adult population should be made aware of the benefits that come from biological research.

Several departments reported having fewer and less talented students apply for admission. Without a reputation for doing first-class research and the incentive of a stable career in research, Irish scientists will become discouraged and the brain drain will increase, thus reducing Ireland's competitiveness in biotechnology.

3.5.2 Loss of EU funding

Ireland has been very successful in winning awards from the EU and this has been an important source of support of the Irish research community (see section 3.4.1) in basic R&D. Ireland's industrial performance in recent years means that Irish researchers may no longer be as sought after for EU consortia.

In addition, there is an increasing trend for the EU to support research based solely on quality criteria and without considering the geographical distribution of the consortia. As a result, EU funding may reduce in the short term while SFI and other agencies seek to raise the quality and strength of basic research in biotechnology.

37 This perception varies strongly from department to department even within the same university.

38 Irish children are not currently taught science until the age of 12, but this is due to change in the 2002-2003 academic year with the introduction of science in the primary school curriculum.

3.6 Important research areas for the next 5-10 years

The analysis of biological and medical problems will in the future require even more complex technologies. This is exemplified by the current progress in genomics, proteomics, bioinformatics and structural biology, to name but a few.

A strong basic research infrastructure is needed for biotechnology in what is essentially post-genomics or functional genomics. Although there are still important issues such as comparative genomics and human genotyping to be pursued under genomic studies, the main thrust will entail expanding work under functional genomics.

The following areas or disciplines will be important in the development of biotechnology in the next 5–10 years and represent areas that Ireland should consider developing:

- Functional genomics and proteomics[39]
- Structural biology (particularly protein-protein and protein-nucleic acid complexes) / structural genomics
- Bioinformatics[40]
- Developmental biology / developmental genetics / stem-cell research
- Pharmacogenomics
- Green biotechnology
- Nanotechnology

In addition, tissue engineering will play an important role for the health system. Cell and developmental biology will also play important roles in plant and mammalian studies from cells to whole organisms and there is a growing interest in Systems Biology to study whole organism function.

Most of the areas identified as important for the future are not currently well developed in Ireland. The biotechnology research community appears still to be focused primarily on topics that were important in the last decade. At the moment Ireland lacks any large-scale capability in any of the up-coming fields and the situation is likely to remain the same unless there is extensive investment in technology platform services. This requires not only purchase of expensive equipment but also training personnel – both academic and technical – to provide the services. Large-scale genotyping, haplotyping and SNP analyses will be needed, and will have to be supported by well-planned bioinformatics services. It is also highly likely that the use of biobanks will play an important role in future human molecular genetics, especially as it applies to complex genetic diseases.

Some steps are being taken to overcome these defects, such as recruitment of a developmental geneticist to TCD Genetics and prioritising the development of pharmacogenetics at the Conway Institute.

Some researchers expressed an interest in developing all the post-genomic/proteomics techniques that fit with the department's ongoing research. This would increase fragmentation and it is important to remember that some of the approaches discussed above will become available from specialist service providers.[41] In some cases, institutions should consider purchasing services, rather than building in-house facilities. Some of the functional genomics/proteomics approaches require

39 This will include the subdivisions of proteomics, structural genomics, bioinformatics, metabolomics, physiology and functional determinants and assays.

40 Bioinformatics will play a central role in Systems Biology and most of the other important areas of post-genomic biology.

41 This has already happened for protein sequencing, oligo synthesis or gene cloning, raising of antibodies etc.... methods that 15 years ago were presented as necessary "in house" techniques are now routinely subcontracted out to specialist service providers.

a distinct change in the scientists' mindset as well, and this may be difficult to achieve until the requisite service is in place and available at an affordable price.

The panel members stressed that there is already a diversified research community in Ireland and that it would be inappropriate for Ireland to attempt to compete in all the research areas discussed above. They argued that investment in core facilities should be accompanied by a reduction in the range of research areas.

3.7 Panel views on future investment

The panel members believe that the research community, as currently constituted, can not effectively absorb the level of funding anticipated over the next five years. Considerable investment needs to be made to improve the infrastructure and raise baseline capabilities before the community can begin to improve significantly its performance in world-class research.

3.7.1 Developing research capabilities

Ireland needs to establish a large-apparatus fund where allocations are based on the collective needs of the research base as a whole, rather than on an institutional or departmental basis.

Ireland also needs to increase the number of post-doctoral research posts and the recruitment of Irish nationals or other scientists from abroad. This will help to supplement the capabilities of the existing research community and help it to develop expertise in the use of new technology platforms. As one of the panel members commented:

> *In general, the existing human resources and infrastructure in the leading departments we visited would not be able to absorb future funding for biotechnology effectively. However, with careful selection of the best groups for large-scale support, perhaps to foster interdisciplinary groups and energetic foreign recruitment based on competitive salaries and potential facilities, a plan could be created to establish world-class research in several places and in several subjects in Ireland.*

In order to create real development potential the panel members argued for a more integrated approach by funding authorities regarding the investments being made in the Irish research system. Access to a range of funding is an important feature of mature science systems because it provides stability and funding for a diverse research environment. However, the panel members argued that if Ireland wishes to manage a fundamental change in its research base in the next few years it will be important to make sure that the allocation of resources is properly co-ordinated.

3.7.2 The initial impact of SFI

The recruitment of high-profile investigators has been an effective way to jump-start the research community and it may have been an effective way to demonstrate the sincerity of SFI in establishing an internationally competitive research community in Ireland. The panel commented that the first round of awards had raised the attention of the international community and has begun to change the image of Irish research.

In Ireland, however, SFI's initial wave of support created several significant problems. Several departments showed considerable resentment at the fact that a chosen few are "parachuted' in and given so much. That may lead to a schism in the research community that would reduce communication and co-operation and hinder the current efforts to leverage a critical mass of world-class research.

These types of comments are perhaps to be expected in any situation in which funding is concentrated on a few individuals. Furthermore the resentment is difficult to explain since the majority of the first wave of PI grants was awarded to leading Irish researchers who have been in the system and who are usually regarded as leaders in their field. In addition, even if PIs are recruited from abroad, they will need to recruit some local post-docs and PhD students.

To prevent resentment and accusations of awards being made on the basis of "old boys' networks" it is important to ensure that the selection process is as transparent and accountable as possible and to ensure that those individuals who receive funding demonstrate the results of the investment.

SFI funding represents a unique opportunity for Irish researchers and the panel considered that one of the biggest threats to future funding for research would be the dissipation of SFI funds in sub-critical projects.

The panel members were not briefed on the detailed reporting mechanisms of SFI awards. However, they suggested that sizeable awards should be accompanied by some increased accountability for the unique opportunity that is being offered and that it will be important for SFI to track the mid-term performance of their investments to identify areas for improvements.

3.7.3 Opening up the range of awards

Ireland needs both post-doctoral research assistants (working for a group leader) and post-doctoral research fellows with their own funding sources.

Although the first round of SFI grants was focused on leading researchers, the key to improving Irish research in biotechnology lies in making research in Ireland an attractive career. In that respect it will be important to create adequate facilities and career opportunities to attract and retain first-class researchers (from Ireland and abroad) at senior and young levels to establish a strongly competitive situation for future SFI support. It is also important for the morale of the Irish science community to open up some of the SFI funding to younger investigators (including those who do not have tenured positions) to allow gifted researchers to "shake up" the current university system.

The recent introduction of the Young Investigators awards goes some way to addressing this issue, but more should be done to improve funding opportunities for non-tenured researchers.

3.8 Biotechnology summary

Given the conditions under which Irish scientists have had to work in the past, the standard of Irish biotechnology research is surprisingly high with ambitious self-starters and a number of high-quality Principal Investigators to build on. The independence and individualism fostered by the previous system needs to be tempered by the modern needs of 'big-biology' for co-ordination and collaboration, especially in the context of the substantial funding for biotechnology being provided.

The main conclusions of the biotechnology baseline study are that Irish biotechnology research at the time of the baseline assessment is not competitive enough to enable distribution of SFI funds to existing groups and departments only, using traditional quality-based peer-review processes. New structures for research programmes, better technology platform services and organised graduate training are required for Irish biotechnology research to close the gap with other countries.

- The bibliometric assessment and the panel visits identified two world-class research departments and a handful of research departments that are capable of becoming world-class in the next five years
- Irish research in areas of modern and developing areas of biotechnology is sub-critical. The community lacks sufficient resources to compete at an international level with leading groups
- Both the research community and the panel of experts indicate that access to modern research equipment and services is well below that of research groups in leading European countries and North America
- There are plans to increase access to facilities but, with a few notable exceptions, these do not seem to encourage departments and universities to share resources. The low level of funding has created an environment in which departments do not have a culture of sharing resources
- The research areas covered by Irish biotechnology researchers are fragmented and there are simply not enough researchers active in areas of modern biotechnology to create the critical mass needed to compete internationally. In addition, the average size of research groups appears to be too small and to have too few post-doctoral level researchers
- The research base suffers from a lack of career structure and incentives for post-doctoral researchers to stay active in research in Ireland. This will become increasingly important if Ireland is significantly to increase its research capabilities
- National research grants have been too small properly to support researchers and PhD students. The size of the grants has limited Irish research from developing capabilities and from attempting long-term and more intensive research efforts. In addition, research grants have not included overhead components, which has prevented departments from making strategic decisions on research resources
- Departmental recruitment appears to be driven by a teaching logic (i.e. the need to cover all subjects in undergraduate teaching) rather than attempts to build up core research capabilities. There is a lack of strategic resources at the departmental level and also a lack of experience of managing expanding research groups
- More than other countries, Ireland has relied on the quality of its PhD students to provide much of the research effort. Although the quality of PhD education is internationally competitive, other countries are investing in providing PhD students with broader research skills through graduate programmes
- The current IPR arrangements vary from institution to institution and there does not seem to be a national policy for supporting the protection of IPR that results from university research. In some cases there are few incentives for researchers and departments to address IPR issues
- As the SFI funding programme accumulates successes in attracting skilled personnel, it is accumulating an obligation to support this structure in the future. The sooner the Irish science community is assured that there is indeed continuity to this funding the better. Should there be no continuity to the SFI funding, then Irish research in biotechnology will face a major crisis and risk losing many of the top scientists to foreign universities
- The bibliometric performance of researchers considered for the baseline study appears to be above the world average. However, this has been in slow decline over the past few years

3.9 Recommendations of Biotechnology Panel

The panel recommended

- Increased support fund for large apparatus. This should be based on inter- and intra-institutional proposals and include a component for maintenance and operation by skilled technicians.
- Provide incentives to break down institutional barriers and bring the research base together in inter-university research centres. In addition, SFI could facilitate restructuring within universities to create research units with critical mass.
- Improving the human resource base with numerous post-doctoral positions (including repatriating Irish researchers and recruiting researchers from abroad) and ensuring that there are better defined career paths for post-doctoral researchers. Since there is a certain amount of delay in recruiting and developing new post-doctoral positions, there would be considerable short-term benefits in providing some relief from the heavy teaching loads of most Irish Principal Investigators.
- A programme for research grants for principal investigators capable of employing multiple post-doctoral research assistants and PhD students on a single project of 4-5 years duration
- A smaller programme for research grants accessible to post-doctoral researchers who do not have tenure. This should provide opportunities for researchers to develop their experience of managing research
- A programme to establish some structured Graduate Schools (graduate programs) in the fields of biotechnology and biomedicine to ensure that doctoral students get world-class graduate training. This will be particularly important for the development of the areas where new competencies are particularly needed i.e. in the area of functional genomics and proteomics
- Exchange programmes for Irish post-doctoral fellows to allow them to develop new techniques (particularly in the context of ensuring that the skills to operate large-scale equipment are developed ahead of installation).

4 Baseline Assessment of the Public Research System in Ireland in the area of Information and Communication Technologies

4.1 Demographics

The identified ICT research base in Ireland constitutes 325 principal investigators and their teams. These researchers are distributed across 67 distinct departments or research groups within a total of 12 institutions. The number of identified researchers and departments / groups within each institution is set out in **Exhibit 36** below.

Exhibit 36 *Researcher Nominations – Final set used for ICT bibliometrics*

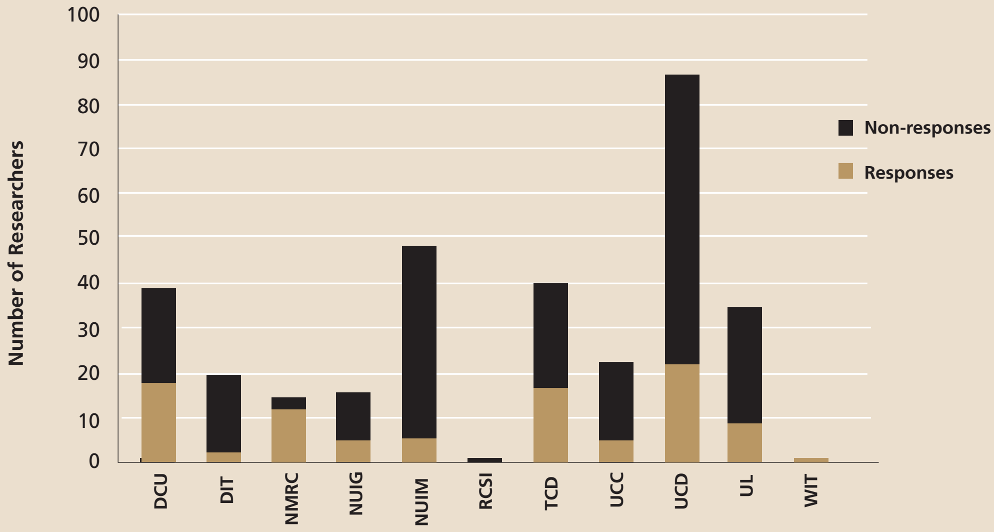
	ICT	
	Number of Departments or Research Units	**Number of Principal Investigators or equivalent**
Dublin City University	7	39
Dublin Institute of Technology	7	20
NMRC	-	15
NUIG	5	16
NUIM	5	48
RCSI	1	1
Trinity College Dublin	11	40
University College Cork	6	23
University College Dublin	18	87
University of Limerick	7	35
Waterford Institute of Technology	1	1
Total	**67**	**325**

The distribution of ICT respondents across the different institutions represented in our survey is presented in **Exhibit 37**. A total of 97 ICT researchers[42] completed and returned our questionnaire - a response rate of 30%. The response rate for the Dublin Institute of Technology and the National University of Ireland, Maynooth are particularly low, whilst the response rate for NMRC is particularly good.

[42] With the exception of UCD the nominations were clearly broken down between Biotechnology and ICT. We categorised UCD nominations based on researchers' publication profile.

Less than 14% of the respondents are women, and, although this is low, it is consistent with the overall situation in research in Ireland and elsewhere.[43] (16% of all Irish senior lecturers are women, and women are generally under-represented in ICT)

Exhibit 37 *Responses to the researcher questionnaire survey*

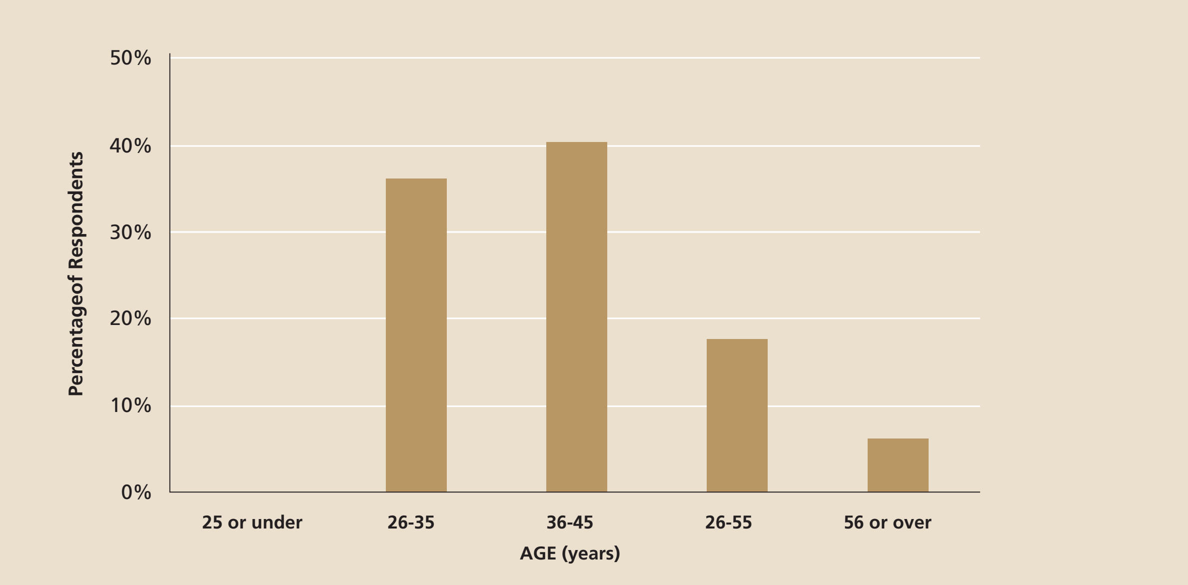


The age profile of survey respondents presented below **(Exhibit 38)** shows that over 75% of the respondents[44] are under the age of 45. Based on this data there are no obvious problems concerning the age of the research base. However, we lack information on the age profile of non-respondents and have been unable to test whether the age profile presented below is representative of the ICT population as a whole.

43 Osborn, M, et al., 2000, Promoting excellence through mainstreaming gender equality: A Report from the ETAN Expert Working Group on Women and Science, European Commission, Research Directorate-General.

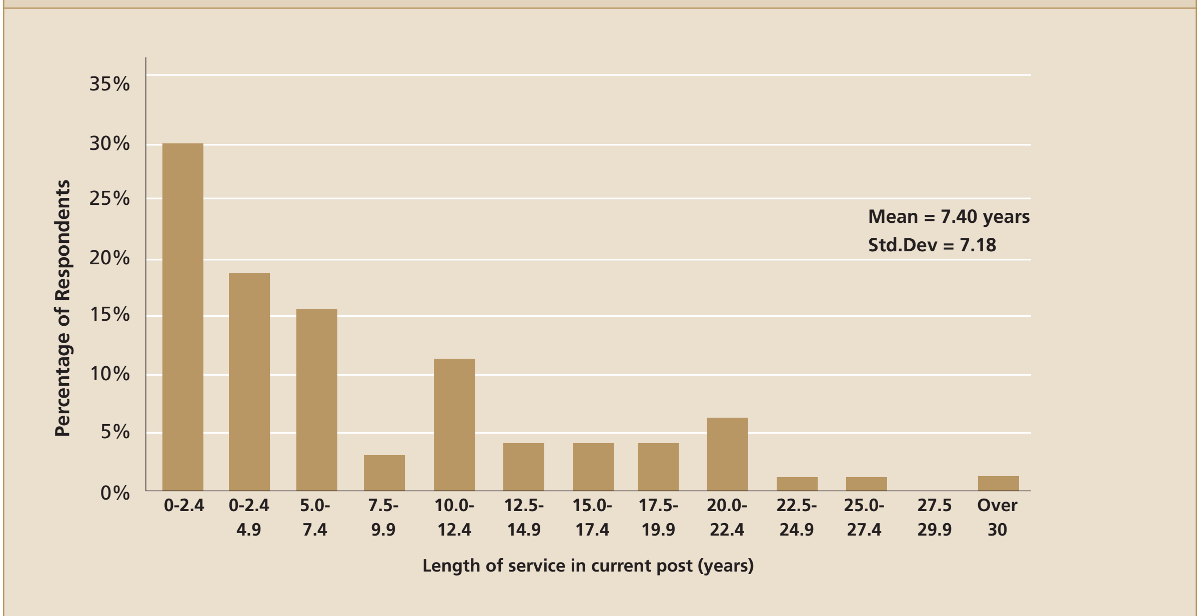
44 We asked Deans of Research to nominate researchers of PI level or equivalent and as a result we would expect the age profile to be biased towards older researchers and were surprised to see such a "young" population.

Exhibit 38 *Age profile of ICT Researchers (n=97)*



The baseline survey also asked respondents to indicate how long they had been in their present positions, and to list their previous positions. **Exhibit 39** below presents a histogram showing the length of service of ICT researchers. 64% of respondents from the ICT research communities have been in post for less than 7.5 years and 30% have only been in post in the last 2.5 years. This reflects the age profile discussed earlier and confirms the mobility of the research base and the fact that there are significant opportunities for researchers to be promoted.[45]

Exhibit 39 *Length of service profile of ICT Researchers (n=97)*



45 The data presented includes promotion within departments

Over 85% of respondents held PhD degrees and some of those who did not held equivalent qualifications, so the number of 'doctoral level' qualifications is around 90%.

It is more difficult to explore the seniority of the respondents, given the diversity of their titles and positions (reproduced in **Exhibit 40** below). Over half the respondents were lecturers, college lecturers or statutory lecturers. Relatively few were post-doctoral fellows or post-doctoral research assistants.

Exhibit 40 *Positions held by respondents (N=97)*

	Responses	%
Professor, Head of School / Department	11	11%
Assistant Director	3	3%
Associate Professor, Senior Lecturer	12	12%
Lecturer/College Lecturer/Statutory Lecturer	57	59%
Senior Research Scientist / Group Director	8	8%
Research Manager/ Research team leader	2	2%
Postdoc	2	2%
Other	2	2%
Total	**97**	**100%**

4.2 Irish Research Performance and Coverage

This section is based on the publication performance of Irish researchers, their responses to our questionnaire survey and the comments of the panel members.

The performance of the researchers identified in the baseline study is at, or slightly above, the world average. However, this may simply reflect a positive bias in our sample. The panel[46] confirm the broad strengths identified by the bibliometric indicators and point to some weaknesses in terms of Irish performance in different ICT areas.

4.2.1 National-level research publication performance

The overall publication performance of the researchers identified within this baseline study was calculated by computing the five-year 'impact'[47] for their publications in the period 1991-2000.[48] The analysis presented in **Exhibit 41** shows the citation rates for publications produced by Ireland's ICT researchers compared to the average citation rates for all articles in the same

*[46] For further information on the panel please refer to **section 2.2.3***

[47] 'Impact' is measured in terms of citations (excluding self-citation). Most citations to published work occur shortly after publication so it is standard bibliometric practice to count only citations for the five years following publication and to present this as aggregated data.

[48] See pages 10 and 11 for a full discussion.

subfields. The exhibit shows that the impact of senior ICT researchers nominated to our study[49] is very slightly above the world average, and that performance has fluctuated in the last five years. However, there is a potential positive bias in our sample in that our data only covers researchers of Principal Investigator level, whereas the world average is based on researchers at all levels.

Exhibit 41 *Publication Impact of Baseline Researchers*

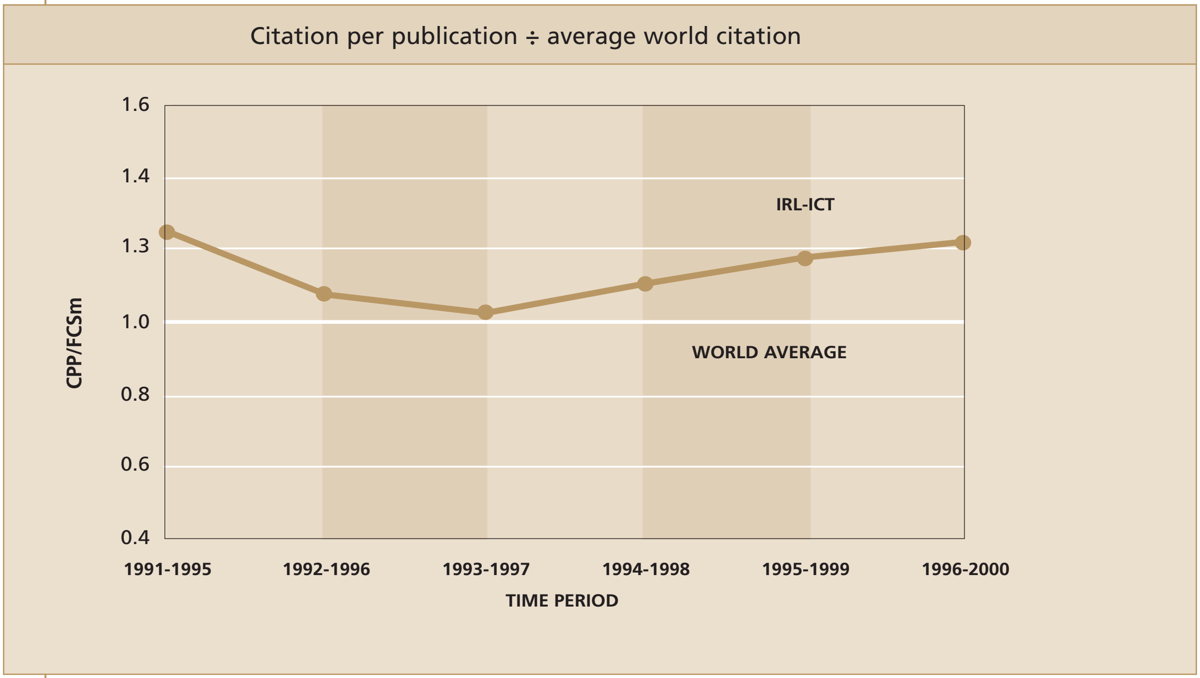


Exhibit 42 presents the same data, broken down by sub-period. In all sub-periods, the impact of ICT publications matches the average impact of the journal it publishes in. ICT researchers are fairly selective about the journals in which they publish and tend to select journals with an impact of about 11% above world average.

The analysis shows that publications of Irish ICT researchers are cited well above the main world reference values. For ICT, the 2,582 publications were cited 12,014 times in 1991 – 2000.[50] The impact of the ICT papers is competitive with that of their journal set, and significantly above the level of the world average.

The output of the ICT researchers (as captured by the Science Citation Index) increased by 32% between 1991 – 1995 and 1996 – 2000 and the volume of citations increased by 35%.

49 The bibliometric assessment was carried out based on a selected group of Irish researchers. Although these account for a good proportion of Irish publications they are not a representative sample.

50 Excluding self-citations.

Exhibit 42 *Bibliometric statistics for Irish ICT publications, 1991 - 2000*

Time Period	Papers	Citations	CPP*	Pnc**	CPP/ JCSm***		CPP/ FCSm****		JCSm/ FCSm****	Self Citations
1991 - 2000	2,584	12,014	4.65	42%	1.05		1.17	+	1.11	29%
1991 - 1995	1,114	2,503	2.25	59%	1.09		1.24	+	1.14	35%
1992 - 1996	1,207	2,382	1.97	57%	0.93		1.07		1.15	38%
1993 - 1997	1,260	2,366	1.88	57%	0.95		1.02		1.07	37%
1994 - 1998	1,344	2,701	2.01	56%	1.00		1.10		1.10	35%
1995 - 1999	1,439	3,140	2.18	56%	1.06		1.17	+	1.10	34%
1996 - 2000	1,470	3,389	2.31	56%	1.09		1.21	+	1.12	32%

A '+' ('-') symbol immediately after the numerical value indicates that the impact of the research unit's articles is significantly above (below) the average citation rate of the journal set.

* CPP: The average number of citations per publication. Self-citations are not included.

** Pnc: The percentage of articles not cited during the time period considered, excluding self-citations.

*** CPP/JCSm: The impact of a research unit's articles, compared to the average citation rate of the research unit's journal set.

**** CPP/FCSm: The impact of a research unit's articles, compared to the world citation average in the subfields in which the research unit is active.

***** JCSm/FCSm: The impact of the journals in which a research unit has published (the research unit's journal set), compared to the world citation average in the subfields covered by these journals.

Further detailed analyses show that Irish ICT achieve the predicted number of papers among the top 5% most frequently cited papers in their sub-fields. This shows that ICT publications are competitive within the 5% most frequently cited papers in their subfields. Furthermore, it confirms that the impact score of all ICT papers is representative of the overall research effort and not due to a few exceptional papers.

4.2.2 Institution-level research publication performance

Exhibit 43 provides a breakdown of the research publication performance by institution. It shows that nearly all units perform at a level close to, or above, the world subfield average.

Over the ten year period, TCD performs considerably and significantly above the international level and two third-level institutions exceed the world subfield average by 20%. In the trend-analysis (based on overlapping 5-year citation sub-periods) we note some decline in impact for two units to a level below 80% of the world subfield average, while the 5 year impact of the University of Limerick increases to the world subfield average, and that of National University of Ireland Maynooth and University College Dublin increases to at least 20% above the world average.

Exhibit 43 *Research Publication Performance by Institution*

Institute	P	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citations
DCU	295	1,329	2,082	4.51	40%	0.87		1.15		1.32	36%
DIT	127	676	948	5.32	33%	1.07		1.14		1.07	29%
UCC	171	682	916	3.99	37%	0.97		1.28		1.32	26%
UCD	745	3,389	4,891	4.55	43%	1.06		1.14		1.07	31%
NMRC	216	870	1,186	4.03	40%	0.94		1.09		1.16	27%
GAL	99	243	345	2.45	43%	0.81		0.81		1.01	30%
MAY	244	1,239	1,899	5.08	51%	0.90		1.10		1.22	35%
TCD	627	4,142	5,417	6.61	35%	1.45	+	1.56	+	1.07	24%
UL	149	337	477	2.26	52%	0.77		0.77		0.99	29%

The data indicate that National University of Ireland Maynooth and Dublin City University tend to publish in journals with an impact at least 20% above average. Other departments publish in journals with an impact that is competitive with the world average.

4.2.3 Research publication performance by sub-field

Exhibit 44 presents an overall picture of the areas in which Irish researchers are involved by comparing the performance of the key researchers nominated for the baseline study against the world average in a number of sub-fields associated with ICT.[51] In five of the eight main sub-fields in which Irish researchers publish, impact is high and the graph shows that Irish ICT researchers publish across a broad range of sub-fields.

- Three physics sub-fields all achieve over 140 publications and a high citation impact
- Engineering, Electrical & Electronic is the most important sub-field, with nearly 200 papers, and an average citation impact
- Output in computer science fields tends to be small in volume, but the impact is high in Computer Science, Artificial Intelligence, and slightly above average in Computer Science, Interdisciplinary Applications. In three computer science sub-fields, Computer Science, Theory & Formal Methods, Computer Science, Software, Graphics, Programming, and Computer Science, Information Systems, impact is below average

[51] A subject category, for example 'Computer Science', refers only to a combination of journals, and not to an institutional or departmental affiliation. As a consequence, it is not unusual that publications in one subject category have been contributed by members from several research units within one institute.

Exhibit 44 *Cognitive orientation: publications by subfield 1991-2000*

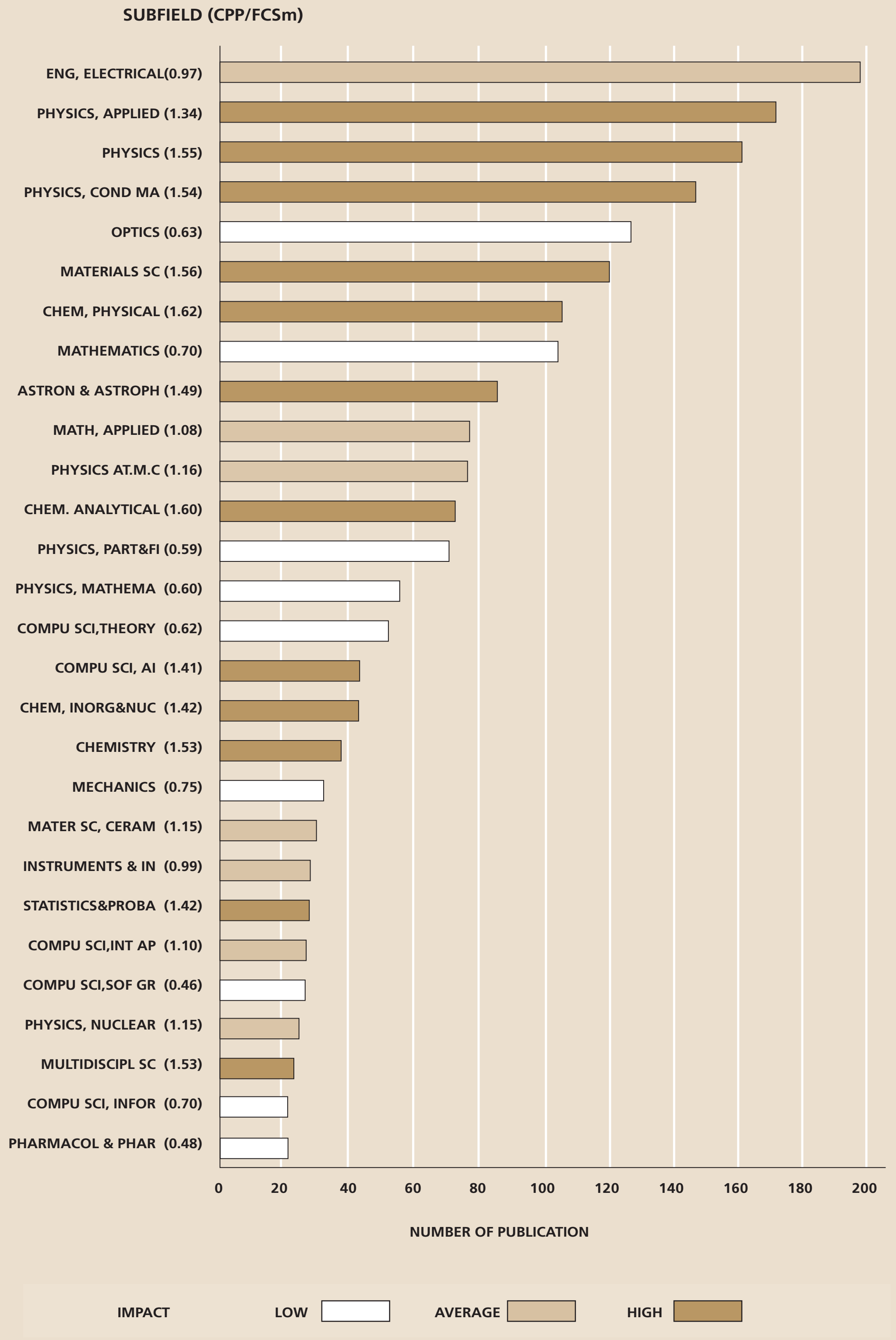


Exhibit 45 presents the research publication performance for each university and institute in the most important sub-fields in terms of publications. The profiles highlight a certain amount of fragmentation in terms of research coverage but confirm that Irish research is internationally competitive in a number of research fields. (See page 10 for explanation of symbols in the Exhibit)

Exhibit 45 *Research profiles of Irish research institutions*

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citation
Dublin City University (DCU)												
CHEM, INORG&NUC	36.8	12%	208.0	329.0	5.65	31%	0.97		1.54		1.59	37%
CHEM, ANALYTICAL	34.5	12%	314.8	481.7	9.13	15%	1.09		1.59		1.46	35%
CHEM, PHYSICAL	33.3	11%	90.9	191.0	2.73	51%	0.61		0.76		1.24	52%
ENG, ELECTRICAL	22.9	8%	28.2	54.1	1.23	45%	0.48	-	0.61	-	1.27	48%
PHYSICS, APPLIED	20.1	7%	96.3	123.8	4.79	28%	0.71		0.94		1.32	22%
PHYSICS, COND MA	16.8	6%	57.6	89.7	3.44	56%	1.09		1.04		0.95	36%
OPTICS	11.6	4%	41.2	78.1	3.56	43%	1.08		0.98		0.91	47%
CHEMISTRY	10.8	4%	117.5	180.8	10.93	9%	0.68		1.59		2.33	35%
COMPU SCI, AI	9.2	3%	20.5	22.4	2.22	63%	0.54		1.02		1.89	8%
COMPU SCI,THEORY	9.2	3%	2.5	4.9	0.27	87%	0.35		0.30		0.85	49%
BIOTECH & APPL M	8.0	3%	18.5	30.5	2.31	44%	0.92		0.54		0.59	39%
ELECTROCHEMISTRY	7.7	3%	34.8	68.8	4.54	24%	0.74		1.02		1.38	49%
PHYSICS, AT,M,C	6.1	2%	41.5	96.5	6.82	22%	0.93		0.74		0.80	57%
Dublin Institute of Technology (DIT)												
PHYSICS, COND MA	22.1	17%	115.7	171.8	5.24	33%	1.18		1.00		0.85	33%
OPTICS	16.7	13%	59.3	85.2	3.56	18%	0.81		0.72		0.89	30%
PHYSICS, APPLIED	14.6	11%	80.0	151.3	5.49	11%	0.66	-	0.93		1.40	47%
MATERIALS SC	12.8	10%	38.3	54.2	2.99	53%	0.88		1.16		1.31	29%
CRYSTALLOGRAPHY	10.5	8%	18.0	23.0	1.71	48%	0.55		0.49	-	0.88	22%
ENG, ELECTRICAL	8.5	7%	21.2	48.5	2.49	20%	0.83		0.78		0.95	56%
POLYMER SCIENCE	7.7	6%	9.3	16.7	1.22	52%	0.30	-	0.32	-	1.08	44%
CHEM, PHYSICAL	7.4	6%	46.8	59.9	6.31	17%	1.21		1.15		0.95	22%
PHYSICS, AT,M,C	7.3	6%	83.3	108.3	11.36	0%	1.66	?	1.52	?	0.91	23%
PHYSICS	6.0	5%	180.0	198.0	30.00	50%	2.13		3.64		1.71	9%

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citation
NUI, University College Cork (UCC)												
ENG, ELECTRICAL	29.0	17%	66.6	91.6	2.30	45%	1.12		1.21		1.08	27%
MATH, APPLIED	24.3	14%	96.8	129.7	3.98	25%	1.61		2.22	+	1.38	25%
OPTICS	21.8	13%	65.0	94.5	2.98	31%	1.11		1.08		0.98	31%
PHYSICS, APPLIED	12.8	8%	76.3	102.8	5.95	12%	1.05		1.66		1.59	26%
PHYSICS	10.3	6%	82.0	116.2	7.94	48%	0.99		1.53		1.55	29%
STATISTICS&PROBA	9.0	5%	25.0	28.3	2.78	56%	0.49		1.35		2.73	12%
COMPU SCI,THEORY	6.8	4%	8.3	10.1	1.23	65%	0.85		1.09		1.29	17%
CARD & CARD SYST	6.3	4%	108.3	121.0	17.11	0%	0.75	?	1.41	?	1.89	10%
COMPU SCI, AI	6.3	4%	5.0	5.3	0.80	52%	1.00		0.78		0.78	5%
National Microelectronics Research Centre (NMRC)												
ENG, ELECTRICAL	54.7	25%	84.3	125.3	1.54	50%	0.71		0.75		1.06	33%
PHYSICS, APPLIED	22.9	11%	44.3	63.9	1.93	49%	0.40	-	0.48	-	1.20	31%
CHEM, ANALYTICAL	20.3	9%	132.3	165.7	6.51	20%	1.01		1.33		1.32	20%
CHEM, PHYSICAL	13.0	6%	227.0	315.8	17.46	17%	1.79		2.50		1.40	28%
PHYSICS, COND MA	10.9	5%	17.7	33.9	1.62	41%	0.48	-	0.33	-	0.69	48%
MATERIALS SC	10.1	5%	22.0	26.8	2.18	70%	1.22		1.20		0.98	18%
INSTRUMENTS & IN	9.7	4%	10.8	15.9	1.12	53%	0.68		0.96		1.41	32%
PHYSICS, AT,M,C	8.5	4%	50.5	82.3	5.94	38%	0.87		0.82		0.94	39%
OPTICS	7.8	4%	11.7	15.0	1.51	59%	0.77		0.66		0.85	22%

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citation
NUI, University College Dublin (UCD)												
PHYSICS	75.3	10%	605.3	788.3	8.04	30%	1.36		1.24		0.92	23%
MATHEMATICS	70.5	9%	56.5	101.5	0.80	62%	0.79		0.74		0.94	44%
ASTRON & ASTROPH	64.5	9%	691.5	980.5	10.72	17%	1.30		1.61	+	1.24	29%
ENG, ELECTRICAL	40.3	5%	68.4	103.9	1.70	54%	0.76		0.75		0.99	34%
CHEM, PHYSICAL	29.5	4%	425.0	580.5	14.41	15%	1.98	+	3.40	+	1.72	27%
PHYSICS, PART&FI	29.3	4%	74.6	113.8	2.54	45%	0.30	-	0.34	-	1.12	34%
OPTICS	29.0	4%	65.4	109.5	2.25	38%	0.55	-	0.56	-	1.01	40%
PHYSICS, AT,M,C	26.8	4%	161.5	295.5	6.04	35%	1.13		1.25		1.10	45%
MATH, APPLIED	25.8	3%	27.5	47.0	1.06	63%	0.85		0.52	-	0.61	41%
PHYSICS, MATHEMA	22.8	3%	81.3	127.3	3.56	26%	0.94		0.73		0.77	36%
COMPU SCI, AI	19.8	3%	51.0	66.0	2.58	46%	2.15		2.22		1.03	23%
MATERIALS SC	17.7	2%	76.7	113.0	4.34	31%	1.57		2.57		1.64	32%
CHEMISTRY	16.0	2%	123.0	223.0	7.69	31%	0.76		1.75		2.29	45%
CHEM, ANALYTICAL	14.0	2%	178.0	233.8	12.71	2%	1.58		2.12	+	1.35	24%
National University of Ireland, Galway (GAL)												
OPTICS	15.3	15%	40.5	55.0	2.64	28%	0.77		0.49	-	0.64	26%
ASTRON & ASTROPH	12.0	12%	28.0	43.0	2.33	25%	0.45	-	0.53	-	1.19	35%
MATERIALS SC	11.2	11%	32.3	51.3	2.90	39%	0.82		1.25		1.52	37%
COMPU SCI,INT AP	9.7	10%	24.0	29.0	2.48	55%	2.13		1.39		0.65	17%
MECHANICS	9.3	9%	8.0	17.0	0.86	46%	0.67		0.44	-	0.66	53%
National University of Ireland, Maynooth (MAY)												
ASTRON & ASTROPH	41.8	17%	649.1	906.1	15.52	14%	1.61		2.29	+	1.42	28%
PHYSICS	40.0	16%	81.5	190.0	2.04	54%	0.32	-	0.34	-	1.06	57%
MATHEMATICS	29.5	12%	16.0	32.0	0.54	78%	0.48	-	0.62		1.30	50%
PHYSICS, MATHEMA	26.0	11%	30.3	88.2	1.17	76%	0.43	-	0.33	-	0.76	66%
PHYSICS, PART&FI	23.3	10%	42.6	88.4	1.83	52%	0.31	-	0.32	-	1.03	52%
OPTICS	10.7	4%	5.8	15.5	0.55	55%	0.26	?	0.13	?	0.50	62%
ENG, ELECTRICAL	9.8	4%	17.8	28.5	1.81	41%	0.84		0.81		0.96	37%
PHYSICS, NUCLEAR	7.3	3%	10.6	19.7	1.46	44%	0.34	-	0.36	-	1.07	46%

Category	P	%	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	Self Citation
University of Dublin Trinity College (TCD)												
PHYSICS, COND MA	100.4	16%	909.4	1,177.0	9.06	20%	2.24	+	1.81	+	0.81	23%
PHYSICS, APPLIED	85.9	14%	708.4	917.3	8.25	15%	1.43	+	1.75	+	1.22	23%
MATERIALS SC	57.3	9%	301.9	395.2	5.27	38%	1.73		2.11	+	1.22	24%
CHEM, PHYSICAL	27.2	4%	173.8	247.0	6.40	26%	1.19		1.13		0.95	30%
PHYSICS	22.0	4%	657.0	760.0	29.86	27%	2.76		4.29		1.56	14%
PHYSICS, AT,M,C	21.3	3%	165.8	203.9	7.80	26%	2.04		1.53		0.75	19%
PHARMACOL & PHAR	20.2	3%	58.3	73.0	2.89	19%	0.86		0.49	-	0.57	20%
ENG, ELECTRICAL	19.0	3%	138.3	175.0	7.28	45%	3.57		2.97		0.83	21%
OPTICS	18.8	3%	65.1	93.0	3.46	41%	1.00		0.94		0.93	30%
PHYSICS, PART&FI	17.5	3%	142.0	181.5	8.11	26%	1.25		1.65		1.32	22%
MATH, APPLIED	14.5	2%	27.5	57.5	1.90	52%	0.76		0.83		1.09	52%
ENG, BIOMEDICAL	13.3	2%	16.8	40.9	1.27	60%	0.58		0.44	-	0.75	59%
COMPU SCI, AI	10.9	2%	9.7	22.3	0.89	57%	1.24		0.92		0.74	57%
COMPU SCI,THEORY	10.9	2%	8.8	14.4	0.81	47%	0.52	-	0.69		1.32	39%
University of Limerick (UL)												
MATER SC, CERAM	25.0	17%	47.0	94.0	1.88	44%	0.65		0.81		1.23	50%
ENG, ELECTRICAL	22.3	15%	10.5	29.7	0.47	80%	0.36	-	0.20	-	0.56	65%
MATERIALS SC	13.3	9%	8.8	13.8	0.66	64%	0.42	-	0.26	-	0.62	36%
MATH, APPLIED	8.1	5%	7.3	8.8	0.90	56%	0.62		0.50		0.80	17%
COMPU SCI,THEORY	7.8	5%	1.2	1.2	0.15	89%	0.27	-	0.44		1.63	0%
STATISTICS&PROBA	7.6	5%	47.8	50.1	6.30	40%	1.05		1.86		1.77	5%
CHEM, PHYSICAL	6.0	4%	32.0	41.5	5.33	33%	0.82		1.01		1.23	23%
PHYSICS, APPLIED	6.0	4%	16.0	23.5	2.67	33%	0.80		0.65		0.82	32%

Our data highlights the different research profiles of the nine main universities and institutes.

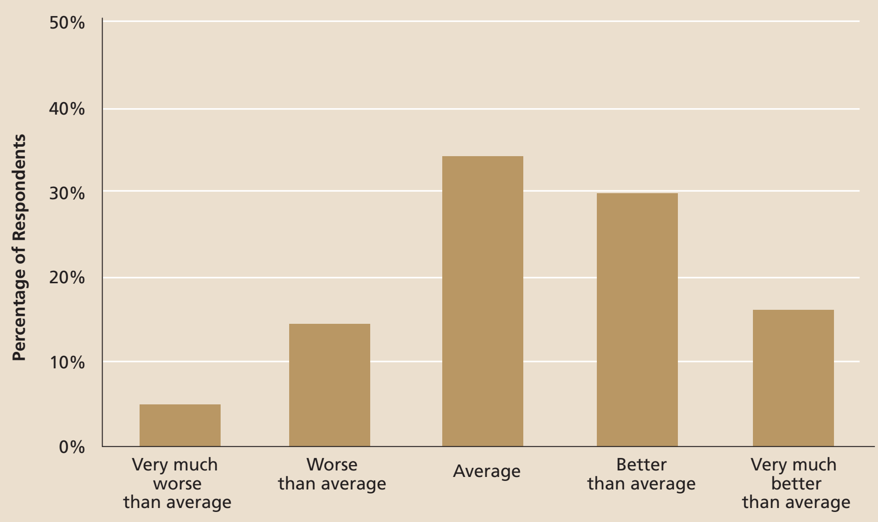
- DCU has a strong focus on chemistry and its three main chemistry sub-fields account for about 35% of its output
- For DIT, UCD, and TCD, Physics, General or Physics, Condensed Matter are the main sub-fields. These two sub-fields and Materials Science, General yield high impact scores for TCD

- Engineering, Electrical & Electronic is the largest sub-field for UCC and NMRC. Astronomy & Astrophysics is the largest subfield for MAY, generating a large share of its impact, and the second ranked sub-field for GAL, after Optics. This sub-field is also important for UCD, showing a high impact
- UL focuses on Materials Science, Ceramics and Engineering, Electrical & Electronic
- If we look more specifically at Mathematics and Computer Science sub-fields, Mathematics, Applied or Mathematics, general are among the main sub-fields for UCD, UCC (with a high impact score for Mathematics, Applied), MAY, TCD, and UL. Computer Science subfields figure for DCU, UCC, UCD (with a high impact for Computer Science, Artificial Intelligence), GAL, TCD and UL

4.2.4 Self assessment

Exhibit 46 presents the responses of researchers when asked to rate the ability of their department to perform high-quality basic research compared to international groups performing research in similar areas. Only 20% of respondents considered their performance to be worse or very much worse than the international average, and 46% considered their performance to be better or very much better than average. This contrasts with the overall results of the bibliometric study. On the whole, the research panels disagreed with the results of this positive self-assessment.

Exhibit 46 *Ability to perform high quality basic research – International comparison N=94*



4.2.5 Interpretation of bibliometric indicators

The expert panels were asked to comment on the bibliometric indicators presented in the previous sections. Some of the peers felt that the bibliometric studies failed to properly capture the output and performance of applied departments, particularly in Electronic Engineering and Computer Science. In contrast to other disciplines, technology changes can have major impacts within the period of journal publication. As a result, publication at leading conferences is more important than in journals and some journals have problems receiving sufficient quality papers.

One panel member commented particularly on the problems of using bibliometrics to assess Computer Science Departments:

> *The bibliometric study indicates a low output and a low impact. This may be due to several reasons. First, as with all CS departments, publications tend to be in the cutting edge conferences rather than journals. (I confirmed this by looking at individual publications lists). Second, the large increase in faculty over the last few years may not have appeared in the output yet. I would expect their metrics to improve considerably over the next few years.*

The first issue raised by our panel member could partially have been addressed if the bibliometric team had had access to full publication lists for all researchers.[52] The second issue highlights the importance of involving panel reviews in future assessments in order to overcome the relative delay in achieving bibliometric impact.

4.2.6 Other Types of Output

The baseline questionnaire asked respondents to provide data on other types of 'outputs' from their work, including patents and non-academic, industrially-oriented publications. Almost three-quarters (74%) of respondents reported no patents whilst 11% indicated at least one patent.

Respondents reported having produced 921 industrial publications in the period 1991-2000. The distribution of responses is heavily skewed because one respondent accounted for over half of the publications. 51% of respondents had not produced any industrial publications, and 85% had produced less than 10 industrial publications.

4.3 Irish Collaboration Patterns

In the past, low levels of national funding have pushed Irish scientists to seek funding from the EU and abroad and the system has encouraged an entrepreneurial attitude to gaining access to facilities that are not available in Ireland. Previous studies[53] in Ireland have confirmed the relatively strong participation in international networks by Irish scientists.

Our bibliometric analyses confirmed the strength of international networks as evidenced by the fact that (with the exception of UL) publications produced jointly with other national or international institutions represent at least 50% of the total output for all Irish researchers. The ability of Irish researchers to draw on foreign resources or to collaborate with research groups abroad is impressive, ICT researchers contribute substantially to international scientific networks and many receive an important part of their impact from publications that are internationally co-authored.

The bibliometric results presented in **Exhibit 47** distinguish between three types of research collaborations

- Publications with only one address were assigned to 'no external collaboration'

52 This would permit analysis of citation in ISI journals to conferences that are not covered by ISI. The advantages of the method used in this study is that it permits comparison of the average departmental publication with the average citation rates achieved for researchers which publish in the same journal (i.e. the bias is the same for researchers which publish in those journals).

53 Arnold, E. and Thuriaux, B. 2001, The contribution of basic research to the Irish national innovation system, Science and Public Policy, April 2001
Guy, K., Tebutt, J. and Stroyan, J., 1999, Evaluation of the Operation and Impacts in Ireland of the EU's Fourth Framework for Research and Development: a report to Forfás, Technopolis: Brighton.

- Publications with multiple addresses, all from the same country, were assigned to 'national collaboration'
- Publications with at least one address outside Ireland were marked with collaboration type 'international'

The shading indicates whether the impact compared to the world subfield average (CPP/FCSm) is 'relatively low' (<0.80), 'average' (0.80 - 1.20) or 'relatively high' (>1.20).[54]

The survey also asked respondents to indicate previous positions held, giving the name of the institution, the country in which it was located, and the duration. **Exhibit 48** shows that 48% of respondents indicated that they had spent a period of employment outside Ireland.[55] Over 26% of respondents who provided details had not worked in Ireland previously.

54 Low numbers in categories for some research units invalidate statistical tests. Nevertheless, our experience shows that the present labeling is usually meaningful.

55 This figure may underestimate the true proportion, given that only limited space was given to record previous positions.

Exhibit 47 *Impact analysis for Irish ICT research and institutes by types of collaboration (1991 – 2000)*

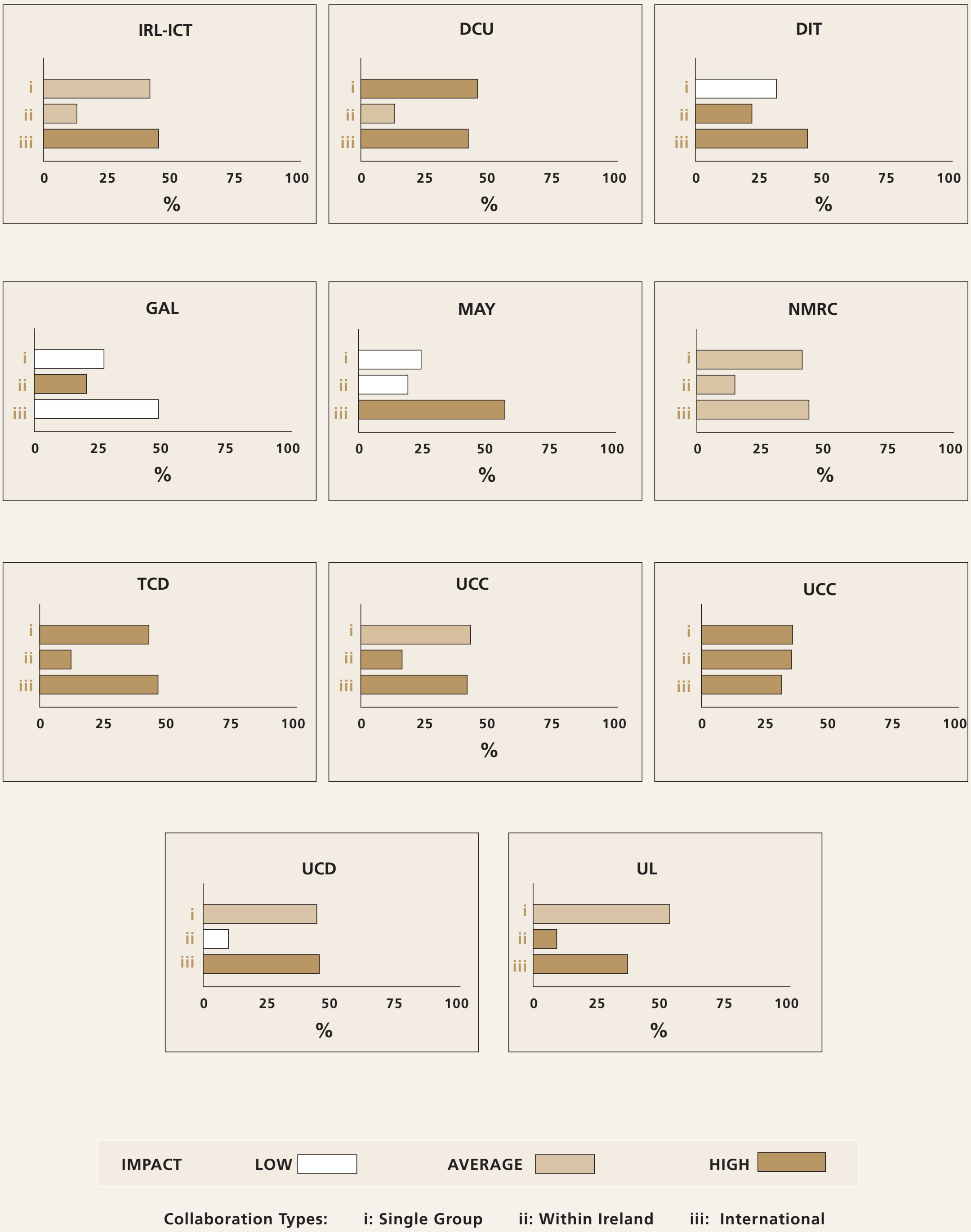


Exhibit 48 *Extent of previous experience abroad (N=94)*

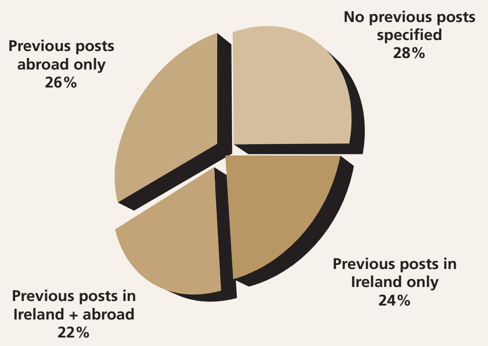


Exhibit 49 shows that the United Kingdom and the United States of America, unsurprisingly, top the table and account for 52% of all international experience. There are also strong links to the German research community.

Exhibit 49 *International posts of respondents*

	Number of previous posts abroad	Share of previous posts abroad
UK	25	32%
USA	16	20%
Germany	13	16%
France	6	8%
Netherlands	4	5%
Switzerland	3	4%
Australia	2	3%
Italy	2	3%
Japan	2	3%
Romania	2	3%
Czech Republic	1	1%
Denmark	1	1%
Israel	1	1%
New Zealand	1	1%

4.3.1 Academic Links

The questionnaire responses regarding academic links presented in **Exhibit 50** confirms the international outlook of Irish researchers and shows that over two-thirds of all academic links are international in nature. It is particularly noticeable that Irish researchers nominated the UK more frequently than other Irish contacts outside their institutions.

Exhibit 50 *Countries with which respondents reported academic links*

Country	Number of times cited	%
UK	56	20.8%
Ireland (other institutions)	45	16.7%
Germany	32	11.9%
France	31	11.5%
USA	29	10.8%
Italy	13	4.8%
Belgium	8	3.0%
Switzerland	7	2.6%
The Netherlands	7	2.6%
Spain	6	2.2%
Sweden	6	2.2%
Portugal	5	1.9%
Finland	4	1.5%
Australia	3	1.1%
EU (multiple links)	3	1.1%
Austria	2	0.7%
Canada	2	0.7%
Czech Republic	1	0.4%
Denmark	1	0.4%
Greece	1	0.4%
Hungary	1	0.4%
Israel	1	0.4%
Japan	1	0.4%
New Zealand	1	0.4%
Norway	1	0.4%
Poland	1	0.4%
Trinidad	1	0.4%

Exhibit 51 shows that the most commonly cited links were collaborative projects (including EU funded projects) which account for 67.6% of links described by respondents. The other significant type of linkage is that mediated by the exchange of staff or students between two academic institutions. This accounts for 17.5% of links reported by the ICT community. Links mediated, or driven by, the need to share equipment, facilities, account for 3.6% of those reported by ICT respondents. Finally, teaching links other than the exchange of students (including external examining) account for 2.7% of those reported by ICT respondents.

Exhibit 51 *Type of academic links*

Type of Link	No of times cited	% of total
EU and Other Collaborative Project	342	67.6
Other 'Network' link (e.g. COST)	11	2.1
Exchange of staff or students	91	17.5
Sharing of facilities or equipment	19	3.6
Sharing of materials	6	1.1
Teaching or training link	14	2.7
Other	27	5.2

4.3.2 Industrial links

The industrial links of Irish ICT researchers have a somewhat less international flavour than the academic links (**Exhibit 52**). Again the UK is the most common overseas country to have links reported by respondents, followed by France and Germany.

Exhibit 52 *Countries with which respondents reported industrial links*

Country	Number of times cited	%
Ireland (only)	74	40.9%
UK	23	12.7%
France	24	13.3%
Germany	16	8.8%
USA	11	6.1%
Denmark	6	3.3%
Ireland plus other	5	2.8%
Belgium, Italy, Netherlands	3	5.1%
Greece, Spain, Switzerland	2	3.3%
Austria, Sweden, Finland, Norway, Hungary, Portugal	1	3.6%
International companies	1	0.6%

Collaborative research projects again prove to be the most frequent type of industrial links. Also significant are links via consultancy and contract research (that is, company funded research carried out in the respondent's institution rather than collaboratively). These are more significant than exchange of staff or students for ICT (11.5% versus 8.0%). Again the sharing of equipment, facilities or materials, and teaching or training links, are also significant sources of industrial links.

Exhibit 53 *Type of industrial links*

Type of Link	No of times cited	% of total
EU and other Collaborative Project	293	67.6
Consultancy or Co. Funded Research	50	11.5
Exchange of staff or students	35	8.0
Sharing of facilities or equipment	11	2.5
Sharing of materials	7	1.6
Teaching or training link	12	2.7
Other	25	5.8

4.3.3 Research coverage

The panel divided the research departments they visited into three categories: basic ICT disciplines like physics and mathematics, electrical engineering and computer science departments. As a generalisation, they largely confirmed the results of the bibliometric assessments and argued that Ireland is

- Average in computer sciences[56]
- Average to strong in Electronic Engineering sciences, but with a fair amount of fragmentation in research coverage
- Strong in basic sciences: mathematics and physics

Much of the exciting research in ICT is at the edges of several disciplines, but there appear to be few cross-disciplinary topics. The panel attributed this to the traditional "department" structure, which is a barrier to forming these links. The panel members confirmed the relative strength of Irish research in the more fundamental parts of ICT, in the microelectronics area and rather strong activities in media technologies in Computer Science Departments. In between these there are considerable gaps.

4.3.3.1 Computer Science

The investment in Computer Science research in Ireland seems to have been relatively low, given the growth of the ICT sector. In fact, given the low level of research funding in the past, these departments did remarkably well. It seems that growth in the CS departments has been based mainly on student numbers rather than national research strategy.

[56] We are not advocating that Mathematics departments transform themselves to do ICT research but we would like to stress that the relatively strong publication performance of these departments is often in areas that are not relevant to SFI's mission.

The strongest computer science departments appeared to be located in the Dublin area. Other departments had one or two groups of international standard. It is important to stress that this does not mean that they do not have the potential to evolve. The computer science departments are all either relatively new or have been subject to rapid recent expansion and have yet to establish themselves as major research units. The current investment in these departments could bring great rewards in the ICT research sector.

The computer science departments are not the strongest from a purely scientific perspective. However, from an industrial development perspective, they are in the short-run the strongest candidates for funding because they work in areas that are of interest to industry. Additionally, they are interested in, and used to, co-operating with industry.

There appeared to be relatively little fundamental ICT research in Computer Science - industry collaborations and funding seem to dominate and drive research with the result that much of the research is very applied. Departments have very good industrial contacts and a strong will to participate in the enhancement of the industrial activity in ICT in Ireland.

4.3.3.2 Electrical Engineering

The general area of electronics has some major strength in areas such as microelectronics, optoelectronics, circuit design,[57] digital signal processing and nanotechnologies. There is a strong research community in terms of number of researchers, scope of coverage and resources which seems to be well represented in most universities.

However, the world-class research that is being conducted is very fragmented with the added problem of duplication of effort amongst universities leading to borderline critical mass in most areas. Even the best departments lacked a coherent coverage and focus of research topics. In particular, there seems to be a duplication of effort in microelectronics and optoelectronics device fabrication between NMRC, TCD, and DCU along with a duplication of expensive facilities. It is difficult to see how small groups of researchers in small departments can acquire the huge sums of money to continue to develop world-class research. There is a need to consolidate and to compel departments to collaborate with researchers at other centres.

4.3.3.3 Basic ICT disciplines: Physics and Mathematics

From a purely scientific perspective, the panels regarded the research performed in the basic physics and mathematics disciplines as the strongest.

There is a world class activity in magnetism and magnetic materials, in optronics, and in basic materials physics. However, the most interesting materials from an ICT perspective (silicon and silicon-related materials) do not seem to be very well covered.

At TCD Mathematics Department, the High Performance Computing Centre works mainly with basic physics problems outside the ICT sector, but is redirecting its activity to this field. Similarly, a number of other mathematics departments appear to be doing research that is only loosely related to ICT research.[58]

[57] This may be related to the fact that a number of international semiconductor manufacturers have a strong presence in Ireland.

[58] We are not advocating that Mathematics departments transform themselves to do ICT research but we would like to stress that the relatively strong publication performance of these departments is often in areas that are not relevant to SFI's mission.

4.4 Strengths and Weaknesses of Irish ICT Research Base

The panel members argued that the main strengths of the ICT research base are

- Motivated and highly professional academic staff at the universities dedicated to teaching and education ensuring the supply of well-educated and skilled graduates
- High efficiency organisations: It is impressive to see the quality and quantity of output in education and research under the given constraints of low funding and sometimes restricted infrastructure
- Irish research is very internationally orientated through impressive participation in EU projects.

Using the material available to them and the discussions with a range of different departments, panel members identified a number of factors likely to be important in the development of a world-class research community and these are discussed in more detail below

- Sources of research funding
- Structure of research groups
- Time spent on research
- Training
- Infrastructure and equipment.
- The organisation of research and Department strategy
- IPR
- Academic pay

4.4.1 Sources of research funding

The questionnaire survey asked respondents to identify sources of funding for research projects that commenced after 1st January 1995. The responses are shown in **Exhibit 54** and **Exhibit 55**. The Exhibits reveal that although the EC provides fewer grants than national government, the relative size of the projects it funds makes it the dominant source of funding for ICT researchers.

Exhibit 54 *Share of overall funding*

	Number of grants	Total funding (€k)	Average size of award (€k)	Share of awards	Share of funding
National Governmental	226	18,433	81	55%	30%
Non-national Governmental	158	40,071	254	38%	66%
Trust/charity	3	80	27	1%	0%
Industry	26	2,289	88	6%	4%
Total	**413**	**60,872**	**147**	**100%**	**100%**

The role of national government funding seems hitherto to have been a stepping stone to EC funding and as a mechanism to train postgraduate students. The sizes of some of the national grants suggest that it would be difficult to train anything but an MSc student because of lack of continuity. There are few charities providing funding for ICT research and around 5% of the projects were funded by private companies, though it is surprising to see that industrial awards are of a comparable size to national governmental funding.

Exhibit 55 *Funding sources reported in questionnaire responses*

Funding Source	Number of grants	Total funding (€k)	Average size of award (€k)
National Government Department / Agency	**226**	**18,433**	**82**
Forbairt / EI	*155*	*10,747*	*69*
National Government Department	*4*	*235*	*59*
Irish Research Council	*3*	*91*	*30*
HEA	*28*	*5,493*	*196*
Internal funding	*25*	*927*	*37*
Other national	*11*	*941*	*86*
Non-national Governmental	**158**	**40,071**	**254**
EC	*124*	*37,488*	*302*
UK Research Council/university	*12*	*955*	*80*
Other non-national Governmental Organisation	22	1,627	74
Trust/charity	**3**	**80**	**27**
Industry	**26**	**2,289**	**88**
Total	**413**	**60,872**	**147**

Exhibit 56 presents the breakdown of grants by size of awards. The average size of awards is around €147k; 62% of grants are less than €100k; and 83% of grants are worth less than €250k. Of the 11 reported grants worth over €500k, eight are EC grants and only three are from national funding agencies.

Exhibit 56 *Breakdown of grants by size of award*

€k	Number	Share
0-49	167	40%
50-99	91	22%
100-149	43	10%
150-199	23	6%
200-249	24	6%
250-299	20	5%
300-349	20	5%
350-399	7	2%
400-449	7	2%
450-499	4	1%
500+	11	3%
Total	**417**	**100%**

The panel argued that a lack of a substantial national research funding body such as the NSF in the US or EPSRC in the UK, has led to chronic under-funding of research in both ICT and other areas in Ireland over many years.

The lack of programmatic funding in the past means that most departments have funded their efforts in a hand-to-mouth way, mainly via European Union funding. Although this has enabled many departments to do surprisingly well, it seems to have had several negative effects

- European funding appears to have put Irish departments and universities in competition with each other and some centres have "shut out" those not involved. The fragmented funding has led to a fragmented research effort with many departments under critical mass in many research topic areas. In addition, there has been no effective method for different universities to collaborate in their areas of strength
- Reliance on Enterprise Ireland funding has put an emphasis on short-range projects with very specific deliverables. Although a certain proportion of this type of "contract research" is desirable, it diverts quality researchers from being able to tackle long-term basic research on internationally important issues. The panel argued that this had led to the current emphasis on research Masters rather than Ph.D. degrees.

In general, the funding for computing appears to have lagged behind the funding of microelectronics and optronics in Ireland. Computing Departments have been under pressure to focus more on teaching than research.

4.4.2 Structure of research groups

The low levels of funding for fundamental research in Ireland have had a marked impact on the structure of Irish research groups. The results manifest themselves in two ways

- A lack of post-doctoral fellows, post-doctoral assistants, and PhD students
- A lack of continuity in research funding

4.4.2.1 A lack of postdocs and PhD students

A number of Departments visited by the panel lacked a suitable structure to compete with internationally competitive research groups. There is little in the way of career structure for post-doctoral researchers and there have been few incentives to study for PhDs because of the current ICT boom in Ireland.

There appeared to be a lot of talented researchers who need human resources to help perform their research. There are two main gaps in the research base – at the PhD student / research assistant level and at the level of post-doctoral researchers.

In competitive European and US research, group leaders direct the research activity, which is mainly carried out by research assistants and PhD students. They provide input in terms of guidance, research training and feedback without undertaking detailed research work themselves. It is unrealistic to expect Ireland to be competitive using the present system, which requires junior lecturers to teach and carry out international research, supported only by MSc students. The number of post-doctoral assistants in research groups varies considerably within the range of ICT disciplines with international competitive research groups in Mathematics and Computer Science having few post-doctoral assistants (2-4 for a research group of 4-5 academics) and Physics and Microelectronics having relatively more.

In a number of cases, the panel members commented that post-docs appeared to be treated as flexible labour to assist with research projects and seemed to lack the kind of benefits usually provided by Universities, such as pension provisions and health insurance.

The panel members expressed concern about the poor career development opportunities in Irish universities. In particular, this applies to the period of post-doctoral research and training. The lack of funding to support post-doctoral researchers within national funding sources and the lack of a clear development path (i.e. making a transition from being a research assistant to holding their own independent funding as post-doctoral fellows) means there are relatively few incentives for young post-doctoral researchers to remain in Ireland.

4.4.2.2 A lack of continuity

Generally there is little continuity and research projects stand as independent small pieces rather than contributing to an on-going project or vision.

This is partially due to the lack of overheads components in national grants. Departments seem to lack internal research funding to provide continuity to longer-term research projects and the development of pro-active departmental level research strategy.

In addition, as mentioned in **section 4.4.1**, the national funding structure has encouraged smaller and shorter-term projects and the use of two-year MSc research students as the basis for research. The lack of baseline infrastructure funding for Ph.D. students and post-docs has also led to a dominance of project oriented research, with no real possibility for "blue-sky" longer-term research. MSc students have insufficient time to develop expertise in their research topics and to make major contribution to the field. From the point of view of the supervisor, it is difficult to plan a long-term, significant research project based on such fine granularities of very narrow or very shallow research.

4.4.3 Time spend on research

Irish researchers appear to spend relatively little time on research and suffer from high teaching loads.

The responses to the survey presented in **Exhibit 57** indicate that researchers spend relatively little of their time on research (over a third of respondents spent less than 20% of their time spent on research; 90% of researchers spent 50% or less of their time on research).

Exhibit 57 *Proportion of time spent on research (N=97)*

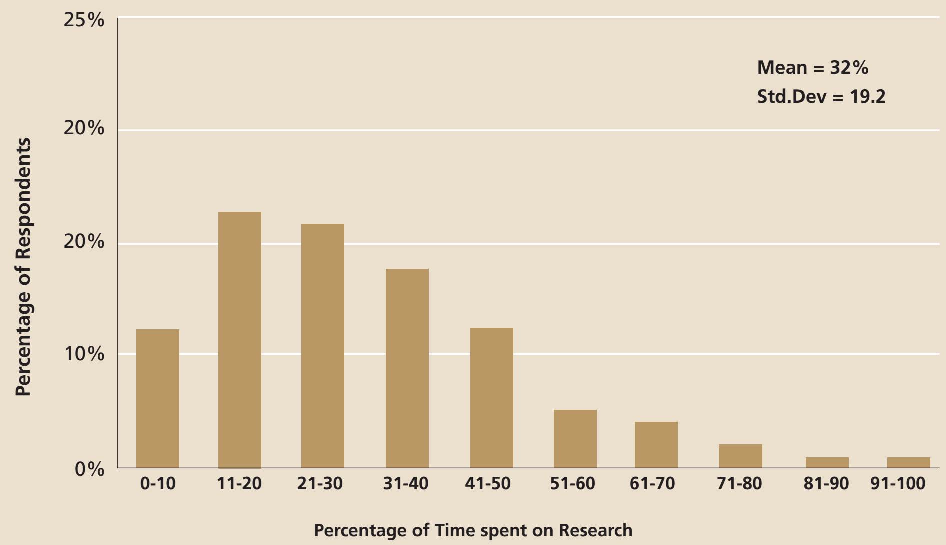


Exhibit 58 and **Exhibit 59** show that Irish researchers have high teaching loads. Half the respondents spent between 40 and 60% of their time on teaching (undergraduate and post-graduate teaching combined).

Exhibit 58 *Amount of time spent on post-graduate teaching (N=97)*

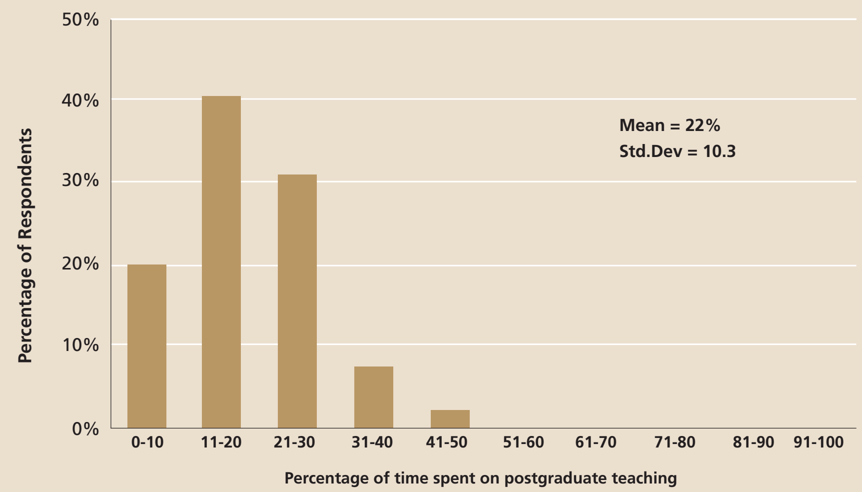
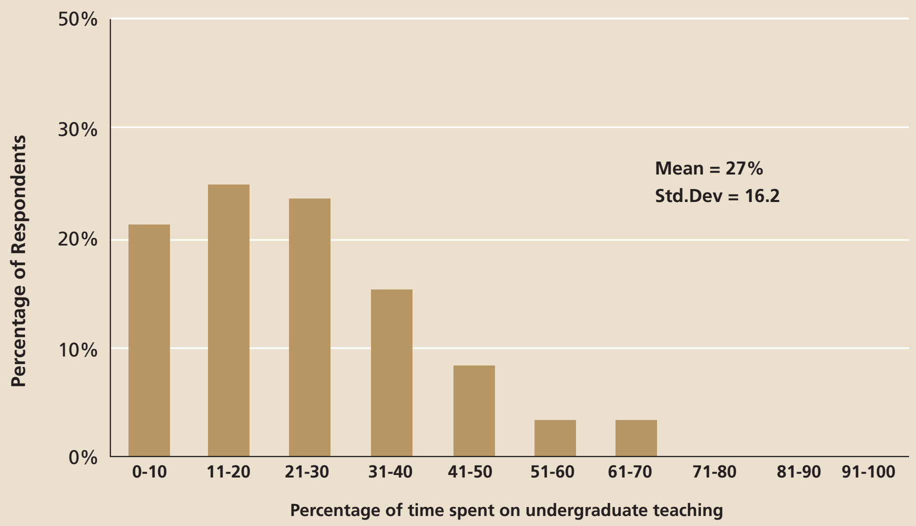


Exhibit 59 *Amount of time spent on undergraduate teaching (N=97)*



The focus on teaching rather than research appears to have been a sound strategy in the last decade and has contributed to the generally high educational standards of the Irish ICT workforce for industry. However, in terms of developing a research base, this strategy has prevented the development of sufficient numbers of high quality PhD research students.

The relatively high teaching loads were confirmed during the departmental visits. Some departments have been rapidly expanding in the last few years and have had to develop on both the research and the education fronts at the same time. However, because departmental income is predominantly linked to the number of students, this can lead to environments where research is seen as the exception rather than the norm and it does not motivate young staff to take part in research. Some of the panel members commented that the staff-to-student ratios appeared high by international standards and that they felt that this would impact on the quality of research. The panel suggested that administration also increases directly with student numbers, producing a double-hit on research time.

The amount of time spent on research reflects the seniority of most of the respondents. **Exhibit 60** shows that administrative functions displace research time for older (and more senior) researchers. We had expected to see disproportionately higher teaching loads for younger respondents but our data suggest that high teaching loads are a normal feature of Irish academic life, irrespective of seniority.

In fact, the problem seems not to be with the number of teaching hours, but rather with heavy loads of undergraduate project supervision and grading of exercises. Whereas elsewhere student projects can be a major contribution to larger and longer-term research projects, researchers in Ireland considered students to be a burden.

Exhibit 60 *Activity of ICT researchers by age of respondent (N=97)*

	Mean % of time spent on			
Age	**Research**	**P/G teaching**	**U/G teaching**	**Other (mainly administrative)**
Up to 25	-	-	-	-
26-35	40%	21%	27%	12%
36-45	34%	22%	23%	21%
46-55	24%	21%	25%	30%
56 or over	24%	20%	22%	35%

Few departments seemed to experiment with solutions of employing senior students to supervise labs or even to do some exercise grading. If the latter is problematic due to coursework being part of the formal assessment, then perhaps they should consider a move away from coursework-based assessment back towards exam–based assessment.

As a balance to the current focus on developing research capabilities, all the institutions visited agreed that a thriving teaching program must go hand-in-hand with high-quality research, and argued against the establishment of "research only" institutions.

4.4.4 Training

The quality of MSc students appeared to be relatively high but there were few PhD students and there did not appear to be suitable mechanisms to provide the 3-4 year projects required for PhD training.

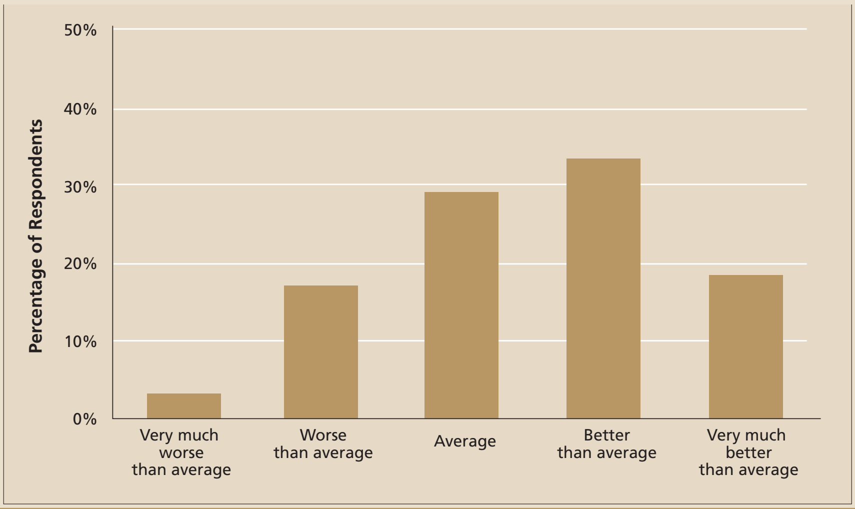
Exhibit 61 shows that 20% of ICT researchers indicated a concern about their comparative ability to train future generations of researchers. Exposure to international research plays some part in shaping response to this question and those with an international perspective are more critical of the situation.

This kind of response can be partially explained by the high quality of undergraduate education in Ireland[59] and by the potential bias that can be expected from supervisors asked to assess the training of their students. Indeed the positive bias was revealed in the responses to a similar question, in which 76% of respondents argued that compared to other **national** institutions their ability to train high-quality undergraduates was above average; only 6% felt they their ability to train high-quality graduates was worse than average.[60]

59 Irish BSc Honours degree are 4 year degrees.

60 Since we are surveying a high proportion of the research base we would expect a more normal distribution.

Exhibit 61 *Ability to train post-graduate scientists compared to rest of world (N=97)*



Post-graduate and undergraduate teaching activities are clearly important in most of the institutions covered by our survey.

Exhibit 62 shows that Irish researchers do not supervise PhD students as frequently as other types of post-graduate degrees – this probably partially reflects the fact that there is little demand for PhDs in the Irish job market. Respondents reported an average of 2.7 PhD completions in the period 1991-2000, though 44% reported no PhD supervision. Respondents also reported an average of 6.5 other post-graduate completions, though again 32% respondents indicated no post-graduate supervision.

Exhibit 62 *PhDs completions: ICT (PhD N=96; Post-graduate N=95)*

Number of advanced degree supervised to completion	Frequency for PhDs	Frequency of other Post-graduate degrees
0	42	31
1	19	8
2	8	7
3	5	8
4	6	11
5	5	1
6-10	9	18
11-20	2	5
21-60	1	7
Total supervised	**259**	**697**

4.4.5 Infrastructure and equipment

With some notable exceptions, the overall finding of our expert panels is that Irish researchers' access to modern equipment and laboratory standards is lower than in other smaller countries with an industrial base that is less dependent on microelectronics.

4.4.5.1 Research resources

As part of our questionnaire survey, leading researchers were asked to compare their research group, centre or department to others nationally and internationally, as regards access to 'large-scale' research equipment.[61]

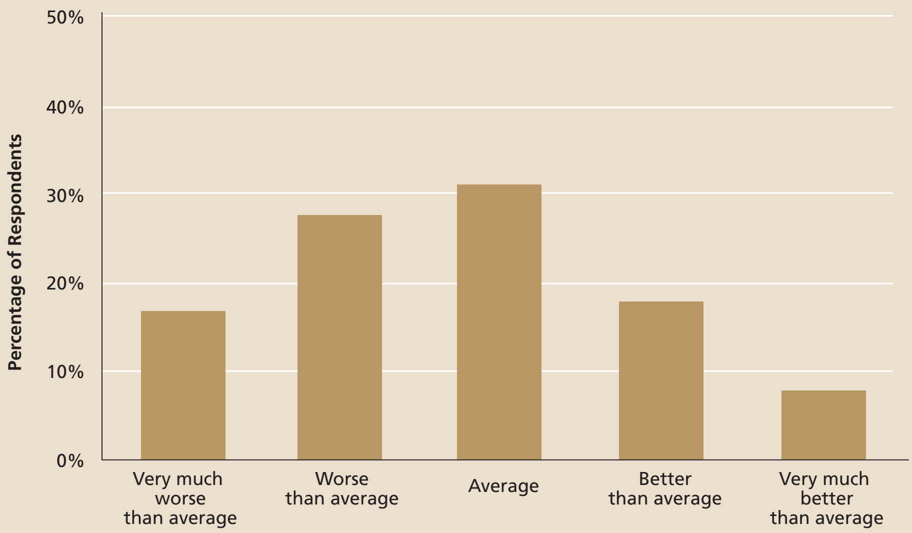
The majority of the researchers indicated that there is indeed a serious problem concerning access to large-scale facilities. The largest gap in infrastructure and the equipment base is in the electronics and electrical departments.

Exhibit 63 shows the responses obtained when Irish ICT researchers were asked to compare their situation with other international research groups. The exhibit shows that 45% of the researchers believe that their own position vis-à-vis large-scale equipment is worse or very much worse than equivalent departments in Europe or North America. Approximately 25% of the respondents in ICT were of the opinion that they had better access to "large-scale" research equipment than did their colleagues in Ireland or abroad.

The Dublin panel members were surprised with the responses. This was because they did not see any up-to-date large-scale installations during the visit except for a rather big computer cluster at TCD in the Hitachi Dublin Laboratory. The microelectronics laboratory at TCD, which in principle is a large-scale facility, was too small in terms of clean room area and the processing equipment was not modern. Other departments suffered from similar problems and at UCD E&E Department the microwave and RF- technology as well as the optics laboratories were 10 years old and need to be renewed. The Panel visiting Cork, Limerick and Galway did not draw as much attention to the issue of up-to-date instrumentation - although facilities can always be improved, the departments at Limerick E&E and NMRC did not appear to be suffering from lack of modern equipment.

61 The question is based on the assumption that respondents will have good working knowledge about the resources and conditions of leading groups both in Ireland and overseas – a not unreasonable assumption in view of the large incidence of overseas visits and overseas research links.

Exhibit 63 *Access to large scale equipment compared with other international research groups (N=91)*



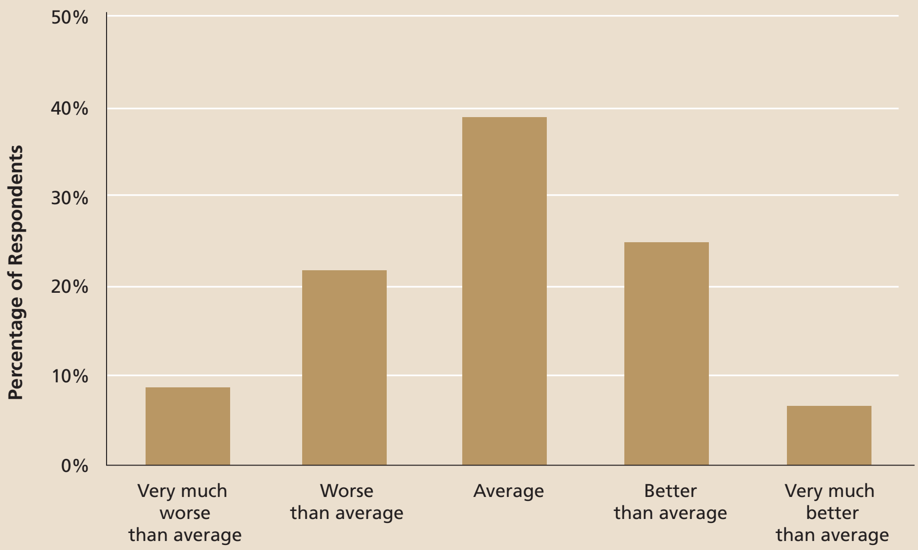
Respondents who had only previously worked outside Ireland (N=23) were more critical of the current situation: 52% of these considered access to be worse or very much worse than average. By comparison, 38% of respondents who had only previously worked in Ireland (N=21) expressed a similar opinion.

The situation in the basic disciplines, physics and mathematics, and the computer science departments is generally much better.[62]

A similar question was asked regarding access to small-scale equipment and consumables. The results presented in Exhibit 64 show a broad range of opinions. There is a significant difference in the responses of those who have only previously worked outside Ireland (N=23): 52% of these argued that the situation was worse or much worse (the comparative figure for those who had only previously worked in Ireland was 14%).

62 The infrastructure is cheaper and computer power is seldom the limiting factor.

Exhibit 64 *Access to small-scale equipment and consumables compared to similar groups internationally (N=93)*



4.4.5.2 Lack of space

During the site visits, it became evident that some universities are suffering from a lack of space for development. In the case of TCD this is proving to be a serious limitation with regard to starting programmes to fill out existing gaps in expertise and/or to commence entirely new activities and seems to have delayed some SFI funded activities.

The panel argued that the lack of expansion space for Dublin universities, particularly Trinity College, is a real impediment to the expansion of research activity. This situation will limit the ability of institutions to respond to new initiatives or to set up new and cross-disciplinary research centres and other efforts that are needed to build critical mass. Unless TCD is able to resolve the lack of space for expansion there are likely to be real delays in launching the work programmes associated with any additional funding.[63]

In addition, the cost of living and housing is a real problem for young faculty, who must then commute, which further eats into productive research time. The cost of living is also high by US standards and some European standards, and this appears to be a serious barrier to attracting high quality researchers from abroad (including attracting Irish nationals back).

4.4.6 The organisation of research and Department strategy

Only a few departments could be said to have critical mass.

Due to a dearth of research funding in the past, many departments lack experienced research leaders who have research vision and who can manage a large research group and at the same time serve as a role model to young researchers. At the department level, there is often little or no real research strategy nor the experience to define one.

[63] TCD needs to overcome this by acquiring new sites within Dublin. This may be an opportunity for SFI to encourage different universities in the Dublin area to build up new infrastructure to create critical mass. However, the time-lag associated with this investment will significantly affect its ability to absorb SFI funding.

There appear to be two main underlying causes for the fragmentation of research efforts

- The fact that student numbers rather than research funding is the principal source of income for all departments
- The lack of overhead funding which would give the departments the opportunity to build critical mass

Historically, the available national research funding sources have been at zero overhead so that the status of research as a source of funding is generally weak and the panel members saw little evidence that departments have experience of managing overhead funding.

The lack of research funding has meant that successful applicants to national and EC grants have been able to develop their own research areas without having to integrate them with the rest of the research carried out by other members of the department. As a result the research coverage of departments lacks depth because of the scattered coverage.

4.4.7 IPR

Some departments lack sufficient awareness of the importance of managing Intellectual Property (IP) in the form of patents or other "packaged" IP and there was a great deal of variance in the support provided to academics to protect their IP.

Policies varied widely amongst institutions, but invariably seemed to involve delays (thus hampering the commercial timeliness of the invention) and were unrealistic in terms of costs, royalties, and ownership.[64]

4.4.8 Academic pay

The panel commented that whilst the funding for post-graduate researchers was comparatively low, and the incentives for post-doctoral research in Ireland were low, the overall level of remuneration for university staff seems to compare favourably with other European countries. It was a topic of complaint in most departments that academic salaries are well below those in the industrial sector. However, this is true in general and it is more realistic to compare researchers' salaries with those of academics in other European countries (particularly their near neighbours in the UK).

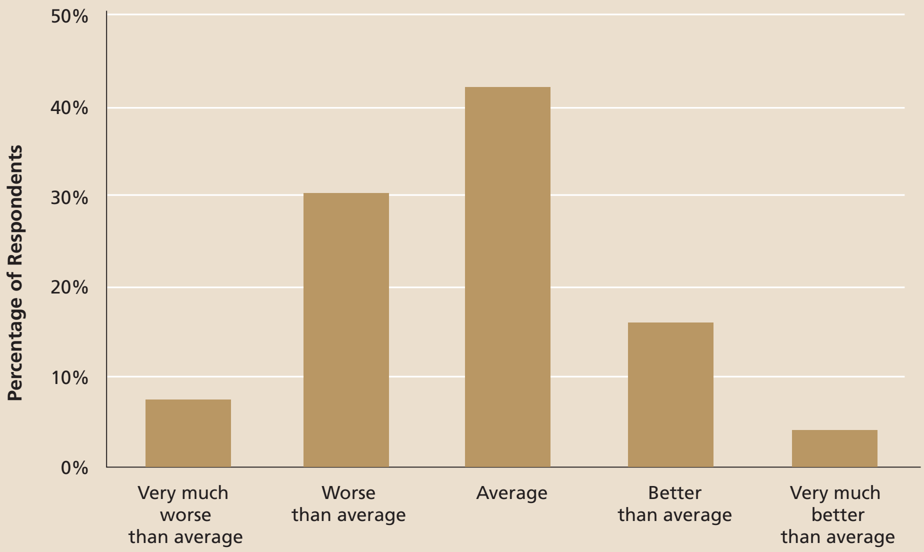
4.4.9 Access to information

In terms of library and information systems, **Exhibit 65** shows that over 38% of respondents rated their own position as worse than average internationally.[65]

64 This was surprising since one of the strengths of small countries is their potential to manage a national strategy for IP resulting from government funded research.

65 There was no significant difference in the responses of researchers who had only previously worked outside Ireland.

Exhibit 65 *Access to information / library facilities compared to other international research group (N=95)*



4.5 External threats to the science base

The panel members identified a number of external threats which included changes in the world economy, lack of sustainability, failure to achieve critical mass, decreases in students in science and engineering, and the co-ordination of national investment in research capabilities.

4.5.1 Change in world economy

Irish industry does not have a strong research culture. Multinationals are mostly doing production rather than research and indigenous companies are often too small to do research. The current basis for investing in ICT research is that there will be an industrial base capable of capturing some of the benefits from Irish academic research – if ICT companies are unable to absorb ICT research this rationale will no longer be valid.

Ireland is exposed to the presence of large multinational companies. The current downturn in the world economy (particularly in the telecoms area) might lead to reduction in manufacturing and a reduction in creation of industrial R&D activities. This may mean that the ICT industry is unable to make use of Irish investments in ICT (either because the industry does not make the investment to exploit the research output and resources created, or because the resources are not sufficiently relevant to the ICT industry).

If there is an upturn in the economic climate in the next couple of years, Ireland may face a severe shortage of research students, academics and researchers in the ICT area.

4.5.2 Declining interest in science

As in other countries, there has been a declining interest in science in secondary and tertiary education. The current research system is heavily dependent on research students and PhD students who are poorly supported and who may not have much incentive for post-graduate research or a career in research.

An upswing in industrial activity combined with an increasing cost of living (particularly in the Dublin area) could push students away from higher research degrees.

4.5.3 Sustainability

Changes in the overall economic situation might lead to substantial cuts in research budgets after the current funding period and make a significant part of the research infrastructure created so far obsolete and, worse, damage confidence in public sector long-term planning.

Large injections of funding, especially when they involve the creation of new research structures and environments, must be continual, otherwise Ireland will be unable to sustain the research community it will have developed over the next 4-5 years. In terms of infrastructure and equipment, there is the possibility that the current investments will be dispersed and fail to create sustainable "large-scale" research environments and thus fail to address the current fragmentation in the Irish research base.

4.5.4 Barriers to recruitment of world-class scientists

To become truly competitive Ireland will need to recruit from an international research community. Current and planned recruitment seems to focus on repatriating Irish scientists but, if it is to benefit from having the best postdoctoral researchers, Ireland needs to address barriers to incoming scientists (e.g. by facilitating work permits, creating a post-doctoral career structure and reducing the differential in overseas research student fees).

4.5.5 Improved co-ordination in national funding

There are strong pressures to fund the existing strong ICT research areas, and to neglect areas that may be critical to the long-term success of the ICT sector and the economy in general.

Strong groups (e.g. NMRC) have been very successful in gaining funding and have very professional management, public relations and lobbying skills to justify the large-scale investment in infrastructure required. In general, the hardware and communications aspects of ICT are strong and well established. On the other side, many computer science departments are relatively new and have been growing rapidly. Even with the strong leadership that many now have, they will find it hard to fight against the more established research bases in hardware and communications.

A fair distribution of resources will require a well-defined national research strategy and a better co-ordination among various research funding agencies and their programmes. There are presently several agencies involved in the development and funding of R&D in Ireland, and the mechanisms for ensuing a coherent, coordinated and balanced development across all research fields are not yet in place. We are aware of ongoing efforts to improve the co-ordination of STI activities within Ireland, most notably the work of the ICSTI Commission, and we hope that these will prove successful.

4.6 Important research areas for the next 5-10 years

The panel identified the following important and emerging research areas

- Wireless and mobile systems and networks, including antennae and propagation
- Sensors and actuators (both devices and networked systems)
- High Performance Computing, and its mathematical and theoretical underpinnings
- Analog and digital VLSI and FPGA systems design (particularly low power implementations for mobile devices)[66]
- Grid and other distributed computing architectures
- Communications system science: Digital Signal Processing, Circuits and Systems, Error Control Coding, Protocols, Optoelectronics communications (not devices), high bandwidth digital systems
- Web-based systems, e-learning, e-commerce
- Distributed storage and knowledge acquisition systems
- Artificial Intelligence and Human – Machine Interfaces
- Medical applications of computing such as: Medical Imaging, Health care informatics and Data mining, Visualisation of data, Genetic modelling and visualisation, Computational drug discovery, characterisation, and analysis

There are fragmented research efforts in all these areas. The challenge will be to coalesce active researchers into pan-university centres that can form viable research entities with critical mass that are industrially relevant and can contribute to the educational mission of Irish universities.

4.6.1 Microelectronics

There is a temptation to attempt to develop state-of-the art microelectronic development and manufacturing facilities in the research and education sector. In practice, such facilities tend to remain significantly behind the commercial state-of-the-art. Keeping microelectronics technology (mainstream CMOS) up-to-date would absorb most of the available funds in SFI.

That is not to say that no investment is required. Microelectronics is, and will continue to be, an important area for Ireland and there is a need for further investment and consolidation of existing work. However, cooperation with the multinationals calls for a world-class know-how in the specific research areas, because the multinationals can buy research services from all over the world. For comparison, the industrial production of semiconductor components in Ireland is many times bigger than in Sweden or Finland but

- Sweden has three microelectronics research facilities with a class 100 clean room space of 1000 m^2 each
- Finland has a large microelectronics research centre in silicon technology[67] with a clean room area of 2500 m^2

Some departments appear to be working far below the critical mass for an up-to-date activity in modern research and education in silicon technology and should consider combining their research groups.

Areas in microelectronics, which could be targeted for investment because of their relevance to Irish industry, are the "alternative silicon technologies". In a broad sense this includes all technologies except for digital CMOS (i.e. analog, integration of passive components, micromechanics, micro-optics and micro-fluidics). This is the basic discipline for sensors, RF, optical switching and biomedical instrumentation.

[66] Note this does not mean device physics

[67] Additionally, Finland has a dedicated facility for three-five research

Another area, which has close links to microelectronics processing, is the design of integrated circuits including digital circuits, digital system on chip solutions and analog and mixed signal designs. In particular, there appear to be opportunities for providing research and training services for Multinationals operating in Ireland.

4.6.2 Computing science

Ireland has a comparatively strong software industry but there has been very little research to support it.

Major forecasts indicate that, in the next ten years, distributed computing (such as small microprocessors, embedded DSPs and mobile and ubiquitous systems with wireless networking) will gain a lot more importance, as ambient intelligence will increasingly find its place in everyday life.

There are a number of sub-aspects

- New computer architectures suitable for lowest power consumption and lowest production cost
- New operation systems managing distributed computing resources allowing for distributed applications
- Software development tools and processes

Other important specific research areas include

- Grid computing
- Healthcare informatics
- e-learning and e-commerce

An area of Irish strength is scientific computing, which appeared in many forms – sometimes appearing as inter-disciplinary scientific computing, or as parallel computing, or as basic applied mathematics. There is potential to create a significant international standing in this area, especially if the various groups could work together and focus on particular application domains.

Some departments lacked capabilities in core and systems-oriented computer science with little research in computer systems, programming language technologies, theoretical foundations of CS, information systems, software-engineering technologies, distributed systems and graphics. These areas provide the basis for computer science as an experimental science and are important, not only for fostering and sustaining basic computer science research, but also for the education of top graduates to serve the ICT sector.

Given the number of specialist MSc and other forms of post-graduate programmes in Software Engineering (SE) there appeared to be little SE research. Where this was supported the research lacked support in software technologies and system building. As a result, continued investment in software engineering is required to continue to ensure high quality and efficient output of software creation and to strengthen the position of Irish economy in the field of software production. This should involve work on new methodologies for development of software, testing and quality assurance.

4.6.3 Communications

As far as the physical layer is concerned, there are already many activities on an international level ongoing on 3G or 4G communication systems. In the short term, catching up with these research groups is neither possible nor appropriate.

The work in this area should be focused on service integration, network management and developing new applications in mobile multimedia streaming and mobile computing. The area of communications software research is important for some of the multinationals and telecom operators in Ireland.

4.7 Panel views on future investment

The panel members believe that the research community, as currently constituted, cannot effectively absorb the level of funding anticipated over the next five years. Considerable investment needs to be made to improve the infrastructure and raise baseline capabilities before the community can begin to absorb the current increase in funding effectively.

Panel members made the following calculations based on the assumption of an even spread of SFI ICT funding over five years (€70 m per year).

- There are up to 20 departments/organisations capable of successfully applying for funding or an average additional annual funding of €3.5 m per year
- Assuming that some of the funding will be used to cover research expenses, overheads and secretarial support, a conservative estimate would be that this would lead to an addition of up to 350 extra researchers (at a level of post-doctoral fellows or higher)
- Since the average group size is small and often constrained in terms of lab space, the sudden increase in SFI may create very real problems (in terms of managing growth) for even the best research groups

Most of the management experience of the current research community is based on surviving a long period characterised by small-scale research activity that is often highly fragmented. There appears to be relatively little appropriate management experience and structures to deal with the current additional injection of funding.

The current research base cannot continue to absorb massive injections of large project-based funding (as in the first round of SFI) and the current shift by SFI to supporting a range of schemes is appropriate. There is a need to expand the research base (along with a change in the research culture) and this must be done from the bottom up. Given the relatively short time horizon, researchers will need to be recruited from abroad.

4.7.1 Developing Departmental capabilities

Some of the panel members argued that the current fragmentation in research coverage at the departmental level should be addressed by providing resources to allow departments to develop and implement pro-active research strategies. At the moment, the lack of core funding prevents departments from prioritising a research strategy.

The panel argued that one of the key issues for Ireland would be to develop and foster cooperation between existing research departments and centres either through virtual centres or through the developments of inter- and intra-university research centres which will have sufficient scale. EU projects fostered collaboration with other countries but not within Ireland and there is a need to break the culture of individuals working on their own little research area in isolation. Collaboration and new research centres are essential for establishing the critical mass needed to focus on interesting problems requiring multi-disciplinary expertise.

4.7.2 Developing the research community

Ireland needs to increase the number of post-doctoral research posts in the leading departments. This will involve the recruitment or repatriation of foreign researchers and will require a substantial investment in developing a career structure and providing incentives for post-doctoral fellows. As one of the panel members commented:

> *There is no real career path defined or accepted within the universities for those who wish to be career researchers. The universities should adopt some common national policy so that junior researchers can hold recognised university positions.*

Under current funding arrangements there is little in the way of research grants that is available to non-tenured staff and researchers who have recently completed their doctoral research. Smaller start-up grants should be made available to create opportunities for post-doctoral researchers and junior faculty members.

4.7.3 Creating structures to provide a bridge to industrial research

In smaller countries there are government supported research institute structures in between the universities and the industry (e.g. SINTEF in Norway, VTT in Finland, TNO in the Netherlands and the Danish Technological Institute). The role of these institutes is to work with slightly more applied problems than the universities and in close co-operation with the industry. These institutes have played a decisive role in renewing the industry structure in those countries. These institutes, like those used for microelectronics research, usually manage the very expensive research environments. They have permanent staff with strong links to universities (usually as adjunct professors). There is no such institute in Ireland, although NMRC, which is part of the University College Cork plays a somewhat similar role. There may be scope to expand this concept in other areas.

4.7.4 The initial impact of SFI

Based on the discussions during the panel visits there is a perception amongst the majority of the university departments that SFI

- Lacks understanding of the scope of ICT research or has not communicated the coverage of SFI funding to the ICT research community
- Has a potential problem with the definition of "fundamental research" as applied to the engineering and Computer Science aspects of ICT. For example, it is not clear what is meant by "fundamental" research in the context of the development of technology (the T in ICT). In the first round of funding, the research community argued that "basic research" has been interpreted to mean "research in Physics"
- Has not supported software systems, communications systems, and their underlying sciences
- Has not properly thought through the effect of the Principal Investigator scheme on universities, in particular that the PI is an SFI and not a university employee
- Has failed to be clear about the continuity of research funding after the end of the current SFI funding period

These kinds of allegations are to be expected in the context of significant changes in the research funding system. However, whatever the truth in these matters, there is a need to address these issues or, more importantly, the perception of these issues so as to develop the trust and respect of the community.

4.8 ICT summary

The main conclusions of the baseline study of Irish ICT research are that:

- The performance of leading researchers considered for the baseline study appears to be at or slightly above the world average. However, the performance over the last few years has varied somewhat and, given that the bibliometric study is limited to leading researchers, there is room for improvements
  - Basic research in Physics and Mathematics is strong and some of this is performed in world class research departments.
  - There are strong pockets of expertise in research in Computer Science and AI but the overall research performance in Ireland is fragmented and some departments lack sufficient critical mass.
  - Research in Microelectronics is strong but fragmented and there is a need to encourage more collaboration / joint ventures between departments, particularly in the Dublin area.
- The bibliometric assessment and the panel visits identified one world-class research centre and a handful of research groups that can become world-class in the next five years
- The education system appears to be concentrating on producing graduates and to a lesser extent, MSc students. In most areas there are insufficient numbers of PhD students compared with leading international research groups. More generally, there are few post-docs and there is a lack of career structure for non-tenured researchers, which will make it hard for groups to attract international applicants
- Funding for ICT research appears to have been overdependent on EC grants and this has prevented collaboration within the national research community. On the other hand, national research grants have been too small to properly support researchers and PhD students. The lack of overhead components has hindered the development and implementation of departmental research strategies
- Teaching requirements have been the main driving force for the recruitment of junior staff in many departments and this has hindered the development of core research capabilities
- There is little support for obtaining and maintaining patents and managing an Intellectual Property portfolio
- There is scope for funding agencies to improve the co-ordination of investments that are being made in the research system
- Continuity of funding needs to be provided in order to avoid reverting to the previous stop-start arrangements which resulted in fragmentation
- More needs to be done to address the declining popularity of science-based subjects in Irish education
- The research community has little experience of managing the kind of strong growth that is expected to result from the current investment in Research. Research leaders should be supported throughout the growth period in order to ensure effective use of resources

4.9 Recommendations of ICT Panel

Panels had the following recommendations for SFI

- There is a need to work with the different Irish universities to develop career structures for PhD and post-doc researchers and to create mechanisms for post-doctoral research assistants to make the transition to managing their own research projects. There needs to be grants for young post-docs as well as for established professors
- Work with universities to develop a national IPR policy for publicly funded research and to ensure that there are appropriate incentives to protect IPR at the level of Researchers, Departments and Universities

- Work with other research funders to develop a coherent overall research strategy to ensure that other research funders cover the more fundamental research disciplines
- Create critical mass by supporting large multi-disciplinary collaborations, including inter- and intra-university real and virtual research centres
- Provide overheads on grant funding to allow departments to support research and develop research strategies
- Provide an interface with industry on behalf of the research base

5 Parameters for the future evaluation of SFI performance

The panel members were asked to comment on the kinds of indicators that need to be used to monitor the impact of SFI and the development of the Irish biotechnology and ICT community.

In one sense it ought to be possible to assess SFI's effectiveness (goal attainment) by holding it accountable to goals. However, at present SFI's mission goals are largely process orientated, and although there are high-level objectives, these are not anchored to quantifiable metrics.

As a result, future evaluations will have to consider the impact of SFI funding on the scientific community and will require data on both the inputs and outputs of the community.

5.1 Inputs

Future assessments of departmental performance should consider tracking the inputs used by research organisations including:

- Sources of funding obtained (industrial, governmental, EU, charity funding). In particular, tracking the total level of funding for research institutions will provide information on the displacement effects of SFI investments
- The structure and staffing of different organisations
- The infrastructure available to the organisation

5.2 Outputs

SFI will be judged by its success in establishing its primary objectives of creating world class basic research groups in biotechnology and ICT with concomitant high quality of research training of graduates for research and industry.

5.2.1 Quality of research outputs

Overwhelmingly the panel members argued that the core indicator for the performance of the research groups would be the quality of the research published in peer reviewed journals and conferences.

For this purpose, SFI can rely on the kinds of bibliometric indicators produced for this study. However, it will be important to ensure that expert judgement is also used so that the impact of publications in conferences and journals outside the ISI database can be understood. This is particularly important in some ICT areas where publication in mainstream journals is the exception rather than the norm. In addition, it will be important to track the performance of Irish publications in leading journals and to track the emergence of Ireland's contribution to the top 5% of cited papers.

Other robust indicators might include

- The number of Irish residents who are awarded membership in honorific scientific societies such as the European Molecular Biology Organisation[68]
- Ability of researchers to attract substantial investments from outside Ireland (e.g. EU or Wellcome grants). As a benchmark, Scotland has attracted over £100m of Wellcome funding, but our survey suggests Ireland had received relatively little
- Changes in the numbers of Irish trained scientists who choose to stay in Ireland to work as researchers in university or industry
- The number of Irish or foreign scientists (post-graduate research students, post-doctoral fellows or sabbatical faculty) who come to Ireland for an extended visit in a laboratory
- The number of International collaborations in which departments take part (a strict definition of what constitutes a collaboration is required)

5.2.2 Training

It is relatively easy to track the production of MSc and PhD students. However, it is hard to suggest measures for the quality of Irish post-graduate training.

One potential metric would be to track the publication impact of these students after they complete their PhD. This will provide some indication of the number of PhD students who remain active within the Irish research system and abroad.

Other potential indicators for the quality of students would be to monitor the track record (secondary education and class of degree) of students applying for PhDs in different areas as this will provide early warnings about the long term "attractiveness" of research as a career path.

5.2.3 Industrial links and industrial performance

Increased funding of ICT and biotechnology and the subsequent improvement in the Irish academic research system are naturally anticipated to lead to the formation of new start-up companies or to other means of commercial exploitation of the discoveries.

However, the panel considered that tracking industrial links should be a secondary measure of SFI's performance and they expect a considerable timelag between the increased investment in fundamental research and future impact on industrial research.

Another important measure of success will be the number of spin-off start-up companies arising in technology transfer from SFI funded activities and also the ability to attract foreign investment in R&D for industrial connections. There is a well-established literature that discusses the types of links between fundamental research and economic activity and this can be used as the basis for quantifying and monitoring these links.

Other indicators to gauge the importance of the university activities to the Irish industry and foreign companies willing to sponsor research in Ireland could include the:

- Number of patents filed
- Amount of royalties generated through IPR
- Level of industrial funding obtained by universities and research institutes

[68] One of the panel members searched for Irish EMBO members and found 2 members with home addresses in Ireland, 15 from Denmark, 7 from Norway, 14 from Finland, 6 from Portugal and 202 from UK. By these standards research workers based in Ireland appear to perform poorly, as a ratio of membership per head of population. In general the highest international recognition has been restricted to Irish workers who leave their country. As a predominantly English-speaking nation, Irish scientists should have an advantage over countries whose scientists have to operate in a foreign language.

5.3 General comments

It is notoriously difficult to establish the impact of research performance on economic growth, but given the rationale for SFI, it will be important to understand the impact of SFI on the competitiveness of the Irish economy in the area of ICT and biotechnology.

The panel members believe that the material gathered in this baseline exercise could form the basis of future performance assessments. However, they highlight the relative inexperience of Irish researchers in taking part in evaluation studies and their relative resistance to taking part in standardised performance assessment.

There are limitations to bibliometric analysis, particularly in research areas that do not publish in journals and conferences covered by ISI. However, it must be recognised that the current indicators are still able to provide some partial information on performance, even in those areas which are poorly covered by ISI if researchers are willing and able to provide full publication lists. In particular the results of bibliometric assessments would benefit from being benchmarked against the performance of leading international groups.

More formal and rigorous research assessment exercises based on expert panels are an expensive option but would overcome some of the problems experienced in this study. Developing a strong assessment exercise will require more active participation by researchers. SFI or other funding organisations will need to provide an incentive to participate in this kind of review and will also need to exercise more serious leverage if it is to collect truly robust standardised data from departments and universities. The set of performance measures should be developed and communicated to the research community early on to ensure that everyone understands the "rules of the game".

Finally, it will be important to have ongoing performance assessments of SFI's investments to ensure that groups that receive funding are held accountable to the rest of the research community for their use of resources.

Appendix A

Definitions of ICT and Biotechnology

DEFINITIONS

These definitions are intended to be indicative rather than exclusive. Should you feel that they exclude relevant areas of research in which you are active, please indicate this in your answer to Q7.

INFORMATION AND COMMUNICATION TECHNOLOGIES

For the purposes of this study, ICT research is considered to encompass the generic areas listed below, including research oriented to specific application domains:

Information Theory and Systems – e.g. System theory and modelling; input, organisation and presentation of information; expert and decision support systems.

Signal and Image Processing – e.g. Computer vision; speech recognition; computer graphics.

Computer Software – e.g. software engineering and reliability; theory and design of operating systems, programming languages and compilers; data structures; artificial intelligence.

Computer Hardware and Systems – e.g. arithmetic and logic structures; processor architectures; integrated circuit design; network theory and design.

Communication Technologies – e.g. broadcast technologies; broadband networks; satellite communications.

Underlying Science for ICT – e.g. optoelectronics; magnetics; nanosciences; communications science; computation theory and mathematics.

BIOTECHNOLOGY

"Modern" Biotechnology involves new DNA techniques, molecular biology and reproductive technological applications. The definition covers a range of different technologies such as gene manipulation and gene transfer, DNA typing and cloning of plants and animals.

For the purposes of this study, "Modern" Biotechnology research is taken to include activities in these areas:

Molecular and Cellular Biology – e.g. virology; microbiology; biochemistry.

(i) Biomolecular Structure and Function

(ii) Biomolecular Processes - Biochemistry of Gene Expression, Metabolic Biochemistry (and engineering)

(iii) Cellular Biology - Cellular Organisation, Signal Transduction

Genetics – e.g. genome mapping; evolution; biodiversity.

Plant and Animal Sciences – e.g. plant and animal reproduction; pathogenesis.

Environment/Marine – e.g. bioremediation; pollution; risk assessment.

Medicine/Diagnostics/Therapeutics – e.g. vaccines; neurobiology; immunology.

Food/Industry – e.g. industrial microbiology; neutraceuticals; food/beverage processes.

Instrumentation/Technology – e.g. bioinformatics; biosensors; nanotechnologies.

Pharmacology/Pharmacognosy

Appendix B

Questionnaire used in survey

Baseline survey of biotechnology and ICT research in Ireland

This questionnaire seeks information about your **Biotechnology** and/or **Information and Communications Technology** research activities, including research links with external organisations. For the purposes of the survey, some definitions of biotechnology and ICT research are given on the following page. These definitions are intended to be indicative rather than exclusive, and should you feel that they exclude relevant areas of research in which you are active, please indicate this in your answer to Q7.

Some of the questions (especially Q8 and Q9) ask for information which you may be able to provide from an existing document such as a research CV. As an alternative to answering these questions, you may return such documents along with the questionnaire (either as an email attachment or by fax) **provided they contain all the information required**.

If you feel there is insufficient space provided to answer any question fully, then please continue your answer(s) in the open-ended text box (Q10) provided at the end of the questionnaire. Please be sure to indicate to which question your response refers.

The information collected in this questionnaire is to be used to generate a picture of the demographics, resources and skills base of researchers active in biotechnology and ICT in Ireland. The publications information requested is to be used to support bibliometric analysis of the publication patterns of the research communities in biotechnology and ICT. All personal data relating to an identifiable individual will be retained by the project team **for these purposes only**, in accordance with data protection principles. No information about identifiable individuals will be passed on to any other party.

You are asked to return the completed questionnaire to the address below, preferably by fax or by email, before **31 st May 2001**.

SFI Baseline Study
PREST, The University of Manchester,
3rd Floor, Mathematics Building,
Oxford Road, Manchester M13 9PL, UK
Fax: +44 161 273 1123

Email: sfi-baseline@lists.man.ac.uk

Help is available from the survey team at PREST. Email **sfi-baseline@lists.man.ac.uk** or telephone Dr Kieron Flanagan, Dr Paul Cunningham or Dr Mark Boden on **+44 161 275 5921**

1 Your details

Department, Centre or Research Group				
Institution or Organisation				
Title		**Name**		
Your Position				
Gender *(M/F)*		**Age** *(please tick one)*	☐ **up to 25** ☐ **26 - 35** ☐ **36 - 45** ☐ **46 - 55** ☐ **56 or over**	
Academic Qualifications				
Telephone Number		**Email**		
Length of Service in current post	years			
	Institution	**Country**	**Position**	**Approximate Dates**
Details of any previous posts held since 1st January 1991				

2 Please roughly estimate the proportion of time you spend on the following activities:

Research %	**Post Graduate Teaching/ Supervision** %	**Under Graduate Teaching** %	**Other** %

3 Please list your current or recently completed research projects in biotech and/or ICT:

Please include any current or completed projects which commenced after 1st January 1995.

Please try to give the approximate value of ***your share*** *of the total funding, and identify the funding source (e.g. EU Framework, Structural Funds, HEA, Basic Research Grants Scheme, internal institutional awards etc.)*

If you require extra space then please use the open text box at the end of the questionnaire (Q10).

Project Name/Details	**Research Area(s)** *(you may want to refer to the areas listed on page 2 for guidance)*	**your share of total project Funding £K**	**Funding Source**

4 Please tell us about your most significant current **formal external research linkages** in biotech and/or ICT

For the purposes of this question, a formal link is defined as one which is governed by a formal agreement, contract or memorandum, or by the transfer of resources. Examples of linkages include collaborative projects, sharing of equipment or facilities ,staff/student exchange or training links, consultancy agreements, company directorships, and so on.

Please remember to give the nameand location of the organisation with whom the link exists.

Academic Linkages:

Name of Linked Organisation	Location (country)	Type of Linkage

Industrial Linkages:

Name of Linked Organisation	Location (country)	Type of Linkage

Other Linkages:

Name of Linked Organisation	Location (country)	Type of Linkage

5a

Please estimate the comparative position of your research group, centre or department in biotech and/or ICT research:

*Please rate the position of your research group, centre or department in relation to similar groups, centres or departments (i.e. conducting research in similar areas) both **nationally** and **internationally**, for each of the research "resources" and "outputs" listed below*

(please tick one in each row)

Research "Resources"		very much better than average	better than average	average	worse than average	very much worse than average
Access to large-scale equipment or facilites	*Nationally*	☐	☐	☐	☐	☐
	Internationally	☐	☐	☐	☐	☐
Access to small-scale equipment or consumables	*Nationally*	☐	☐	☐	☐	☐
	Internationally	☐	☐	☐	☐	☐
Access to library/information services	*Nationally*	☐	☐	☐	☐	☐
	Internationally	☐	☐	☐	☐	☐
Research "Outputs"						
Ability to perform high quality basic research	*Nationally*	☐	☐	☐	☐	☐
	Internationally	☐	☐	☐	☐	☐
Ability to perform high quality strategic or applied research	*Nationally*	☐	☐	☐	☐	☐
	Internationally	☐	☐	☐	☐	☐
Ability to train skilled post-graduate scientists	*Nationally*	☐	☐	☐	☐	☐
	Internationally	☐	☐	☐	☐	☐

5b

Do you have any comments on the adequacy and appropriateness of the resources (financial, equipment, space, personnel) available for research in biotech and/or ICT?

Please identify any cases in which resources act as a significant constraint on your group, centre or department's research in these areas

6 Please use this space to nominate those research groups or individual researchers in Ireland (working in third level institutions or public sector research institutes) who you see as making significant contributions to research in biotech and/or ICT.

Please give details of departmental and institutional or organisational affiliations.

Name of Researcher/Group	Department and Institution/Organisation

7 Please indicate the biotech and/or ICT research areas within which your work is conducted:

Please refer to the set of definitions of biotech and ICT research on page 2. These definitions are intended to be indicative, rather than exclusive, and if you feel an important area of work is omitted, please explain.

8 Please list any awards or prizes received, appointments to Government or industry advisory panels, or other "esteem" indicators relevant to your research in biotech and/or ICT

9a

Please indicate how many of the following "outputs" you have been responsible for between 1st January 1991 and 31st December 2000:

Patents	
PhD Completions	
Other Post-Graduate Completions	
Publications intended for industrial, commercial or policy audiences **Eg: industrial guide books or manuals** **Articles for industrial or trade press** **Reports to policy-makers**	

9b

Your publication profile:

Please provide a list of *all* your research publications published between 1 Jan 1991- 31 Dec 2000.

Please ensure you provide the following *essential* bibliographic information:

First author's name | Year of publication | Journal | Page numbers

As an alternative, pre-prepared research CVs are acceptable *provided they contain the above information.* These should be returned by fax along with the completed questionnaire, or as an email attachment in MS Word format.

10 Please use the space below to provide any other information or comments.

You may continue your answers to previous questions in this space if necessary.

If you do so, please indicate to which question each answer refers.

Thank-you for completing this questionnaire.

Please remember to return it to by 31st May 2001, along with any supporting documents, by email to sfi-baseline@lists.man.ac.uk or by fax to +44 161 273 1123.

Publication List

The 4th Framework Programme in Ireland	April 2001
Commercialisation of Publicly Funded Research *Irish Council for Science, Technology & Innovation (ICSTI)*	April 2001
The Third Report of the Expert Group on Future Skills Needs *Responding to Ireland's growing skill needs*	July 2001
Forfás Annual Report 2000	August 2001
Annual Employment Survey 2000	September 2001
Statement of Outward Direct Investment	October 2001
State Expenditure on Science & Technology, 2000	December 2001
Research and Development in the Public Sector, 2000	December 2001
Key Waste Management Issues in Ireland	December 2001
Annual Competitveness Report, 2001 & The Competitiveness Challenge *National Competitiveness Council*	December 2001
The Labour Market Participation of Over 55s in Ireland *Expert Group on Future Skills Needs*	January 2002
International Trade and Investment Report	February 2002
Biotechnology *Irish Council for Science, Technology & Innovation (ICSTI)*	February 2002
Enlargement of the European Union **Forfás Submission to the National Forum on Europe**	February 2002

Broadband Investment in Ireland	March 2002
Research & Development in the Business Sector 1999	May 2002
Comparative Consumer Prices in the Eurozone & Consumer Price Inflation in the Changeover Period	June 2002
Forfás Annual Report, 2001	July 2002
e-Business: Where we are and where do we go from here	August 2002
Measuring and Evaluating Research *Irish Council for Science, Technology & Innovation (ICSTI)*	August 2002
Legislating for Competitive Advantage in e-Business and Information Communications Technologies	October 2002
A Strategy for the Digital Content in Ireland	November 2002
Annual Competitiveness Report 2002 & The Competitiveness Challenge Report *National Competitiveness Council (NCC)*	November 2002

Functions of Forfás

Is é Forfás an bord náisiúnta um polasaí agus comhairle le haghaidh fiontraíochta, trádála, eolaíochta, teicneolaíochta agus nuála. Is é an comhlacht é a bhfuil comhactaí dlíthiúla an stáit maidir le cur-chun-cinn tionscail agus forbairt teicneolaíochta dílsithe ann. Is é an comhlacht é freisin trína dciomnaítear cumhachtaí ar Fhiontraíocht Éireann le tionscail dúchais a chur chus cinn agus ar ghníomhaireacht Forbartha Tionscail na hÉireann (GFT Éireann) le hinfheistíocht isteach sa tir a chur chun tosaight. Is iad feighmeanna Fhorfáis:

- comhairle a chur ar an Aire ó thaobh cúrsaí a bhaineann le forbairt tionscail sa Stát
- comhairle maidir le forbairt agus comhordú polasaithe a chur ar fáil d'Fhiontraíocht Éireann, d'GFT Éireann agus d'aon fhoras eile dá leithéid (a bunaíodh go reachtúil) a d'fhéadfadh an tAire a ainmniú trí ordú
- forbairt na tionsclaíochta, na teicneolaíochta, na margaíochta agus acmhainní daonna a spreagadh sa Stát
- bunú agus forbairt gnóthas tionsclaíoch ón iasacht a spreagadh sa Stát, agus
- Fiontraíocht Éireann agus GFT Éireann a chomhairliú agus a chomhordú ó thaobh a gcuid feidhmeanna.

Forfás is the national policy and advisory board for enterprise, trade, science, technology and innovation. It is the body in which the State's legal powers for industrial promotion and technology development have been vested. It is also the body through which powers are delegated to Enterprise Ireland for the promotion of indigenous industry and to IDA Ireland for the promotion of inward investment. The broad functions of Forfás are to:

- advise the Minister on matters relating to the development of industry in the State
- to advise on the development and co-ordination of policy for Enterprise Ireland, IDA Ireland and such other bodies (established by or under statute) as the Minister may by order designate
- encourage the development of industry, technology, marketing and human resources in the State
- encourage the establishment and development in the State of industrial undertakings from outside the State, and
- advise and co-ordinate Enterprise Ireland and IDA Ireland in relation to their functions.

Board Members

Peter Cassells	*Chairman*
Martin Cronin	*Chief Executive, Forfás*
Sean Dorgan	*Chief Executive, IDA Ireland*
Dan Flinter	*Chief Executive, Enterprise Ireland*
Paul Haran	*Secretary General, Department of Enterprise, Trade & Employment*
Professor Michael Hillery	*Chair of Manufacturing Engineering University of Limerick*
Rody Molloy	*Director General, FÁS*
William Murphy	*Partner, Tynan Dillon and Company*
Feargal O'Rourke	*Partner, Taxation Pricewaterhouse Coopers*
Professor Yvonne Scannell	*Professor at Law, Trinity College*
Toni Wall	*Managing Director, Wall-2-Wall Ltd*
Jane Williams	*Managing Director, The Sia Group Ltd*