European Science Policy Briefing

Consensus conference on the theory and practice of research assessment

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Foreword

The scientific process depends on effective and reliable assessment systems. At a time when there is a demand for increased accountability in science, the system of peer review itself should also be subject to review and analysis. This is especially true with the increased use of science indicators. It is entirely appropriate, therefore, that ESF, with its commitment to peer review and to high quality scientific endeavours, should be a co-sponsor of this Conference.

The initiative was taken by the late Professor Nino Salvatore, who was a most active and influential participant in many ESF activities, and an Italian scientist of great distinction. We owe a debt of gratitude to him for organising this Conference, whose results contribute to the ongoing debate on the research assessment process. This document results from one of his last activities and provides a small memorial to his far-sightedness.

The report itself, commissioned by Professor Salvatore from and written by ScienceBridge as a record of the meeting, will, hopefully, stimulate further debate and encourage additional detailed studies. In this connection, we need to consider how best to ensure integrity and confidentiality combined with transparency in a system, which is one of the cornerstones of the modern scientific process.

The debate on research assessment will continue in many other fora and I believe that this report is an important contribution to the ongoing debate.

Peter Fricker
ESF Secretary General

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The European Science Foundation acts as a catalyst for the development of science by bringing together leading scientists and funding agencies to debate, plan and implement pan-European initiatives.

Organiser's preface

The evaluation of research activity and the methodology used for this evaluation are among the most important challenges facing the international scientific community. We all take pride in claiming that we only support the "highest quality science" and that such decision-making is independent and not influenced by non-scientific factors. This raises two questions. The first is to ensure the 'quality control' of the process so that it can be seen to operate in a fair and open manner and can provide decisions which will support the best science. The second is to examine the process itself in order that it can be adapted, as appropriate, to changing circumstances. For instance, the pressure on research funding has frequently resulted in very low success rates for grant applications at both the national and international levels. Such success rates have often reduced the peer review process to something of a lottery. Peer review then provides a gross discrimination between good and poor proposals with funding decisions on the former often taken on grounds other than the "absolute" quality of the science. There are also changes occurring in the way in which we carry out our research with a greater emphasis on the team or group, on large facilities or on a combination of both. In other words, are we evaluating the person and the idea, or the team and the facility? Furthermore, science and its peer review system are conservative. So how receptive are we to new ideas? As far as peer review is concerned, if those involved in peer review are the "gatekeepers" of quality, then who watches the "gatekeepers"? Finally, although assessment of quality (particularly in basic sciences) is an

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- G7 Working Group on Research Assessment
- Ministero dell'Università e della Ricerca Scientifica e Tecnologica
- US National Science Foundation

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- European Science Foundation
- Istituto Nazionale di Fisica Nucleare
- Stazione Zoologica 'Anton Dohrn'
- Università di Napoli "Federico II"

essentially qualitative process, we increasingly seek to look at methods of quantification and other "objective" aids. The use of such "devices" as citation indices needs to be incorporated with discretion. They are not an automatic panacea for problems which may arise in the peer review process.

Such issues are of concern to research funding agencies globally and the G7 Group of Heads of Research Councils have reflected this concern by establishing a Working Group to study the issue. The Capri Conference arose from this initiative and enabled the G7 Working Group to meet in parallel and to draw on the discussions taking place in the Conference.

The results of the Consensus Conference have been put together by an independent team of science writers, ScienceBridge (who are responsible for this report), to provide an integrated view of the wide-ranging and disparate discussion on research assessment practice and to provide a platform from which other studies on the practice of peer review assessment and evaluation may be taken forward.

Section 1: Introduction: research assessment and evaluation

During 7-9 October 1996, at Anacapri on the island of Capri, a distinguished group of international scientists, research administrators and science policy experts gathered together to discuss the theory and practice of research assessment. Over the three days of the conference, participants discussed many of the major issues facing science in the late twentieth century - from the pros and cons of peer review to the career progression of young researchers.

Many of the issues have in the past been hotly debated. Instead of providing individuals with an opportunity to restate their own points of view, the Capri conference adopted a rather different approach - one based on discussion and reasoned agreement. Its format was that of a consensus conference, whereby participants formed small expert groups to discuss various relevant issues before congregating in front of all delegates to put forward their conclusions. Eventually, what emerged was a reasonable consensus on the participants' views on the best practices for research assessment and evaluation - with just a few areas of disagreement.

Why should such a conference be necessary? As outlined by Professor Salvatore in his introductory address, and as documented extensively over the past few years, the practice of science faces a number of challenges in the late twentieth century. Researchers in every discipline have to face up to these challenges and, where necessary, move with the times. The societal, political and geopolitical environment in which science is conducted has been transformed in the past 50 years, and scientists are increasingly aware of the need to examine their practices in light of these fundamental shifts.

International relations

One of the most significant factors has been the internationalization of science. Research has always been a cooperative venture, often involving collaborations across borders. This is now becoming an even greater feature of science, partly because of improved communications (such as intercontinental travel, effective telephone and fax systems, and more recently e-mail and the Internet), partly because of relative political stability, and partly because the scale of some research endeavours demand multiple international participation.

Nowhere is this effect more marked than in Europe, where the evolution of the European Union has created a new 'super-community' bounded not by national borders but by the framework of Europe-wide governance, legislature and others administrative structures. From a scientist's point of view, perhaps the most important of these are the European bodies that support science. Many new opportunities exist for researchers to attract funding support not just from within their own country's funding agencies, but also from these centralised European sources.

However, just as a single market and other aspects of the European economic and political alliance call for a certain consistency of practice across member states, so the allocation of research funds among European nations must involve some standard procedures.The standards expected for the conduct of scientific research are therefore likely to become established across the whole community. Any country that is unable to demonstrate its commitment to these standards is likely to find itself at a severe dis-advantage when funding allocation decisions are made. Conversely, a clear sign that a country both appreciates the need for high standards of conduct, and is taking steps to implement them, is likely to lead to an increased likelihood of increased investment through European funding programmes.

Although it is not the only important element of scientific conduct, research assessment and evaluation are increasingly important cornerstones of the scientific research endeavour. If these processes are carried out successfully, the chances of competing in international arenas are significantly increased. Any country that wants to compete for funds internationally needs to check that its procedures meet international standards and, if they do not, to take steps to introduce procedures consistent with best international practice.

Changing nature of science itself

Increasingly, there is a trend towards concentration of research in large research groups, often centred around specialist laboratories and major research facilities. Evaluation and assessment may be taking on different roles in looking as much at the group, the facilities and programme management as at the idea and the individual. This may also have the effect of eliminating the 'crazy' idea which does not conform to current established theory. These trends need to be taken into consideration as factors in research assessment.

Other drivers of research assessment and evaluation

Other factors are also encouraging a greater awareness of the need for effective research and evaluation, particularly societal and economic changes. Until comparatively recently, the idea that scientific research could - or indeed should - be objectively analysed and judged would have seemed fanciful. With the possible exception of research in industry, scientists have been used to a large element of autonomy in deciding to whom research funds should be allocated, through the processes of peer review. The major if not only criterion has been scientific excellence, as judged by a researcher's peers. The scientific problems explored were largely decided by the researcher's own interests - 'curiosity-led' research.

Input from other sources, it could be argued, was not a significant factor. The areas to be explored were rarely, if ever, influenced by non-scientists. In addition, whether research was likely to spawn practical advances - such as improvements in healthcare, or an exploitable product that might contribute to national prosperity - was not as high a priority as the opinion of peers on the merits of a proposed research programme. A researcher's main function, by this model, was to improve our understanding of the natural world.

Nonetheless, an unwritten social contract did in effect exist between researchers, who spend considerable sums of public money, and the general public, in large part the source of those funds through taxation. The contract was based on the assumption that the results of research would ultimately provide benefits to the general populace, such as better healthcare, industrially exploitable products, and additional national wealth.

Undoubtedly, this arrangement worked. The great wealth of Western industrialized nations this century has been largely based on the exploitation of science and technology. Many of the discoveries of basic science have spawned immensely successful industries; for the most part, we live longer and are healthier than ever, as advances in medical understanding and treatment have improved healthcare and disease prevention.

But times change, and for a number of related reasons the contract underlying the public funding of science is being re-examined. The reasons reflect both shifts in the nature of public attitudes - not just to science, but to authority and received wisdom in general - and in the economic climate in which the Western world and especially Europe now finds itself.

Public attitudes: the need for accountability

In general, people are now more willing to voice opinions and to organise themselves in order to exert pressure on authorities. They increasingly want to know that central funds are being used effectively and for the benefit of society. They want to be sure that benefits will accrue from this research. Exactly how has research benefited health, quality of life and wealth in the past and how might it in the future? Scientists cannot ignore the need for accountability.

In effect, the investment model has come to predominate over the exploratory model: science is funded by governments in part because it will provide practical returns, not necessarily because it helps us to understand the natural world. Fortunately for scientists driven by intellectual curiosity, the desire to improve understanding often provides rich commercial spin-offs. But, in an atmosphere of public accountability, such spin-offs increasingly have to be demonstrated, as indeed, does basic research. But demonstrating 'pay-off' is far from simple.

Economics: the need for priorities

Accountability has become a significant feature in part because of the change in economic circumstances experienced during the past couple of decades. With expanding economies, countries could afford generous and expanding science budgets; with stable or only slowly growing economies, and novel drains on resources - particularly from welfare programmes or social security - the amount of money devoted to science comes under increasing scrutiny.

Since scientific discovery continues to open up new areas to explore, yet budgets cannot rise commensurably, decisions have to be made about what areas of science should receive funds and which should not. In addition, the type of research funded has to be examined. Can basic research, with no promise of near-term financial benefits, be afforded in a world of restricted financial freedoms? Should research funds be concentrated on research with more obvious commercial exploitation possibilities?

These factors lead inexorably to difficult choices, and call for reasoned and evidence-based approaches to decision making. Such decisions have to be made at different levels. Most significant is the decision whether to fund research at all - some highly successful economies have exploited international research without ever fully developing their own research capabilities. Then there are decisions about the areas of research to fund; should a moderate-size country invest in, say, space science, given its enormous expense? Are collaborative ventures feasible? Furthermore, there is the issue of the type of research to fund - often put, unhelpfully, (or 'naively') as "pure" or "applied".

And, of course, decisions have to be made about the individuals and groups who might be carrying out this research. Scientists find themselves in an increasingly crowded and competitive marketplace, where even excellent proposals may not secure funding often owing to a combination of underfunding and overdemand. Research funders have to identify the individuals they believe will make best use of scarce research funds. How can such individuals be identified? How useful are track records in identifying them?

For appropriate and reasoned decisions to be made, information is needed, and this inevitably demands an assessment of likely success and an evaluation of past success. Assessment and evaluation of research have thus become key factors in the strategic planning of governments and major research funders throughout much of Europe and the industrialized world.

Methods

'Research Assessment', part of the title of the Capri conference, is therefore concerned with the acquisition of information to improve decision making. As mentioned above, decisions must be made at different levels, and for different purposes; thus the type of information needed varies according to the situation under review. The terms 'assessment' and 'evaluation' are often used interchangeably, but it is useful to distinguish the two, and to discuss other factors that affect the type of information that should be sought. Assessment is generally used to describe the initial scrutiny of research proposals; evaluation is more usually applied to information-gathering systems employed during or after a research project, programme and so on. Both activities are essential to evidence-based decision-making, and both were considered at the meeting. Participants had to consider a number of factors that could influence the type of assessment or evaluation procedure used.

Type of research

The type of research is also a potentially important factor. Some research is funded simply to improve our understanding of a biological or physical phenomenon; some is funded to develop a commercial product or for social objectives. Success criteria could be quite distinct in the two cases, since they have quite different objectives. Similarly, research in industry laboratories may be rather different from research in academic institutes. Many terms have been used to try to describe these different types of research - 'pure', 'curiosity-led', 'basic' on the one hand, 'applied', 'industrial', 'goal-directed' on the other - but as participants at the meeting agreed (see page 10), it is difficult to use these terms unambiguously and appropriately. Clearly, though, the term 'research' covers a variety of activities. Nor, is there a single simple model that defines the relationships between these terms for all circumstances.

Aggregate level of research

In addition, the level at which assessment and evaluation methodologies can be applied is also highly heterogeneous. Evaluation can be applied to individuals, projects, programmes, funding agency portfolios of research schemes, government strategies and so on. Decisions at all these different levels may require different types of information, and will certainly be based on a variety of inputs, implying a need for a range of methodologies.

Timing

The timing of evaluation is also important. *Ex-post* evaluation, that undertaken after a research project or programme, might be the obvious approach, but at what stage after completion should it be undertaken? Too soon and it fails to capture all relevant information; too late and it can no longer inform decision making. If decisions have to be made about renewal, *ex-post* evaluation is not appropriate, calling for interim evaluation or continuous monitoring. All such information can inform *ex ante* assessment, such as setting of new research priorities or goals.

Methodologies

As for methodologies, discussions at the conference focused extensively on peer review, and how it should be properly operated. There is a general consensus in the scientific world - fully endorsed at this meeting - that peer review is absolutely central to progress in science. It may have its problems, but a better mechanism has yet to be demonstrated. Assessments are traditionally qualitative. Nevertheless, possibilities exist to support peer review with additional objective data. These include indicators such as:

- output indicators (scientific papers, books and so on)
- impact indicators (citations, esteem measures - such as honours, awards and so on)
- performance indicators (outputs in relation to input - financial, labour and so on)
- activity indicators (interface with industry, international cooperation and other indirect measures)
- socio-economic indicators (patents, new products and their impact on society and the economy)
- management indicators (teaching, administrative success and related measures).

Much discussion at the conference centred on the possible use of alternative indicators, for possible use in conjunction with peer review. Publication-based indicators - citation analysis and journal impact factors in particular - formed a recurring theme.

The consensus conference

The consensus conference is a relatively new phenomenon, designed to draw out areas of general agreement among interested parties. The concept has been widely used in several countries, particularly in Scandinavia, where mechanisms exist for consensus meetings to provide information that feeds directly into national policy making. Consensus conferences have many advantages. For example, key players actively participate in the process, rather than acting as passive observers. Ideas can be discussed and modified, and agreed by reasoned consultation and through objective, open comment. The open airing of non-attributable opinion can also encourage creative free-thinking from individuals, who may be stimulated or inspired to re-examine their own standpoint in light of reasoned argument in a non-confrontational environment.

From active participation also comes the concept of ownership of results: since participants were involved in drafting the conclusions, they are likely to feel more committed to implementing proposals or continuing the process of discussion. Ideally, the outcomes should be agreed, and therefore third-party observers or downstream users of information will be assured that the views promulgated are agreed and representative - adding important value to the information generated.

Of course, debate about issues as important as research evaluation, and with such a committed audience, will undoubtedly reveal areas of dissension.

However, this may have the advantage of highlighting issues where more research is needed, or where a wider consultative process could be initiated. Nevertheless, some issues will be such that consensus is impossible, and participants can ultimately agree to differ. It is also important to identify the underlying issues of disagreement.

In Capri, this relatively new approach was brought to bear on the topic of research assessment. Participants formed groups to discuss a number of key issues in this area: in all, nine groups discussed important points in three main areas: research assessment by academic research institutions and by grant-giving agencies; performance indicators for the objective evaluation of scientific research; and research assessment in the career of investigators. These topics were discussed in plenary sessions and some general conclusions presented from each of the nine working groups.

Areas of disagreement were identified, and often resolved with further discussion and after alternative perspectives were put forward. After two days' extensive discussion, the following pages summarize what emerged as the key consensus conclusions - and provide an insight into what can be achieved in a mutually supportive and cooperative consensus conference environment.

Consensus Conference on the Theory and Practice of Research Assessment

Anacapri, 7-9 October 1996

Working groups

A. Research assessment by academic research institutions and by grant-giving agencies

A1. Grant allocation policy

A2. Fundamental or basic research *vs* applied or finalised research

A3. Evaluation of research activity of general *vs* specific interest

B. Performance indicators for the "objective" evaluation of scientific research

B1. What are the key criteria for evaluating basic science?

B2. Performance indicators

B3. Performance indicators for research project evaluation

C. Research assessment in the career of investigators

C1. Start of career and career advancement

C2. Teaching and organisational abilities

C3. Special topics in career advancement

Section 2: Making choices

The first three working groups addressed issues concerned with the need to make difficult decisions. The restricted financial environment of the 1990s means that important decisions have to be made about the allocation of funds to support research endeavours. At the highest level, this means choosing between, say, physics and biology. Within these fields are numerous competing disciplines, each eager to secure support. Individual funding agencies are faced with more applications than they can possibly fund. Some mechanism is needed to decide between competing causes - for, however good each individual or application is, the funds are not available to fund all deserving causes.

As the three Working Groups discussed, many factors influence these decisions about the macroallocation of research funds. Whoever is responsible for making the funding decision has to decide what areas of research to fund and what type of research to fund - basic research of little immediately identifiable value to the citizen but of great potential future importance, or more goal-directed research, geared more towards identifiable short-term benefits?

The decision-making process, the meeting concluded, will depend on the mission and objectives of the funding body itself. The nature of these may well vary from agency to agency. When the body is the government, political factors are likely to influence decision-making, and local issues may also impinge on allocation policies, especially in the case of national and local funding of institutions, facilities and projects.

The research community can influence the higher-level macroallocation decision-making process by providing information that facilitates informed decision-making. The mechanisms for the transfer of this information should be open and transparent and formalized, so the integrity of the process can be maintained. Other stakeholders - individuals or bodies who use research findings in some way - should also be involved in a multilateral dialogue, so the views of a full range of interested parties can be heard.

Allocation decisions are also likely to be based on a desire to support the most able. When it comes to assessing the quality of research, peer review remains the fundamental tool of assessment, though other inputs may provide additional useful information.

Allocating funds

In most Western countries, Working Group A1 considered that, research is funded by a number of agencies, such as government, independent agencies, charities and industry. Each of these different types of organisation has its own purpose, mission and motivation, and hence is likely to make decisions on the basis of criteria it has developed for itself - although these will, of course, often coincide, as in the desire to fund excellent research.

In its consideration of macroallocation issues, the working group concluded that the decision to allocate funds to particular fields at a national level must be at least in part a political one; only an overarching publicly accountable body such as the government is empowered to make such decisions on behalf of the populace. However, though a political decision, it should not be a merely politician's decision: it must be an informed decision, whereby all relevant factors are taken into account and a reasoned and justifiable conclusion reached. The onus is on the politicians to develop a stable framework of priorities, in line with a country's financial wherewithal and societal priorities, while the scientific community develops and delivers programmes of research in line with this framework.

Choices to be made

The decisions are not simple, and many factors need to be considered before reasoned decisions can be made. The group noted that many balances have to be struck - between emerging fields and established fields, between curiosity-driven or basic research and user-oriented or applied research, between long-term potential and short-term realities, and between “expensive” science (for example, space science or high-energy physics) and “cheaper” science (such as in parts of the social sciences), although, first and foremost, decisions must be based on scientific excellence.

An additional factor, becoming more significant in the current climate, is relevance to other aims and objectives of the funding agency. The group also concluded that there is little to be said for funding areas simply because they have been funded in the past. They must continue to justify themselves through the peer review system. However, looking at track records may provide useful information to inform decision-making.

Key features

The working group went on to discuss other significant factors. To the principles of accountability, excellence and relevance can be added equity - the systems must be fair - as well as transparency: the system must be seen to be fair. Moreover, there is, of course, a need for extensive dialogue, between government, research organisations (funders, academic bodies, universities and so on) and long-term users (such as industries, national health and defence services, and others). The flow of information should be based on an informed, intelligent, inclusive debate focused on the medium to long term, through a broadly based network of parties. Feedback from the review process to applicants is an essential part of the process both for its own sake in assisting in a process to improve applications but also as a further aspect of transparency and accountability.

What else must be borne in mind? The group next considered the drivers of research, which include both ‘needs pull’ - the desire to attack a social problem, for example, or a disease - and ‘science push’: what opportunities are emerging as the frontiers of science are pushed ever further back? For a country, the feasibility that scientific progress may be made and the capacity of the country’s scientists to deliver are important factors, as is the capacity of users to absorb new research and exploit new research findings; a country may be strong in research in a scientific field but its public policy institutions or industry may be poor at exploiting innovation commercially or for public good. Particular research areas may also complement each other in a country or between countries.

In terms of the practicalities of funding, awards should be made on a competitive basis, following an assessment of costed programmes wherever possible. The key factors here are excellence, relevance and track record - evidence of the capacity to deliver what is proposed. In the decision-making process, a broad range of expertise is valuable, and the use of international experts highly desirable, so globally recognized standards and comparisons can be applied. Finally, whatever evaluation procedures are used, periodically these procedures must themselves be evaluated.

National priorities

No country can be scientifically strong in all areas of research. How should macroallocation decisions be made when the choice is complicated by variations in research strength? The principle favoured at the meeting was one of building on excellence: strong areas deserve to be supported. The decision of whether or not to support weaker areas is more complicated, and likely to be influenced by such factors as: the funding organization’s goals and responsibilities; whether the weak area is emerging or dying; whether support will provide spin-off advantages elsewhere; and whether strengthening that area is a national priority. Nevertheless, there is much to be said for being selective and strategic, rather than trying to provide each field with just enough to keep it alive. This may mean accepting that, in some countries, some areas of science will end up disappearing.

Points of consensus

- **Evaluation systems to support grant allocation at the national level should be driven by explicit criteria:**
  - Excellence (support the best)
  - Relevance (consider national priorities)
  - Equity (system must be fair)
  - Integrity and transparency (avoid conflicts of interest; system must be seen to be fair)
  - Capacity to deliver (consider national skills base)

- **Macroallocation is a political decision, but must be an informed decision, whereby all relevant factors are taken into account and a reasoned and justifiable conclusion reached.**
  - Develop transparent mechanisms of multilateral dialogue to inform decision-making

- **Areas should not be funded simply because they have been supported in the past**

- **Concentrate on areas that are strong; build on excellence**

Accept that weaker areas may disappear

- **Awards should be made on a competitive basis, taking into account**
  - Excellence
  - Relevance
  - Track record (the capacity to deliver)

Non-consensus

- **Should weaker areas receive special treatment, for example if they are deemed to be of national importance?**

Basic research or applied research - or both?

While working group A1 examined the distribution of funds across scientific disciplines, working group A2 set out to examine the complementary question of the assessment and evaluation of different types of research. Can similar principles be applied across the board, or do different types of research demand different approaches? The group rapidly ran into a problem of terminology, in deciding what types of research were being considered.

That there are different types of research is not in doubt. Some research is aimed primarily at understanding more about the natural world; some is geared towards identifying properties or making discoveries that have a clearly marketable value. Some research is carried out because an investigator is driven by curiosity, or the desire to understand a particular problem; some forms part of a commercial organisation's strategy to develop a new product with a defined series of properties. What is less clear, however, is how these different types of research should be categorised, and what labels could or should be applied to them.

A continuum of research

It was generally agreed that there is no longer a strict division between 'curiosity-driven' research on the one hand, which has no specific identifiable commercial goal and is usually carried out in a university setting, and 'applied' research on the other, with a definite specified endpoint, clear commercial aim and, often, an industrial location. Instead, the group concluded, it is perhaps more meaningful to consider the process in terms of a continuum, but not a linear relationship. The matter is of more than merely semantic importance, because when choices are made, they will often pay attention to the type of research being proposed. Applying a common evaluation method may be difficult because it is potentially feasible, in theory at least, for different types of research to be evaluated in quite different ways. Indeed, what we expect from pure research and applied research will not be identical in every respect. For example, one outcome of pure research is the creation or maintenance of an academic 'culture' in which scientific excellence can thrive, and, in turn, can improve and stimulate teaching. A successful evaluation system should include this factor as an important outcome for research in an academic setting.

Expected outcomes

However, the working group concluded that one would not necessarily expect generically different outcomes from research at either end of the spectrum, and thus there should be no qualitative difference in assessment methods. There are, of course, likely to be differences in emphasis and quantitative differences, in particular in terms of the returns on research investment. Goal-directed research is more amenable to direct measurement based on meeting specific needs, and is much more likely to be judged in term of its ability to meet pre-set specific objectives; pure research may have initial specific goals, but adherence to these goals is not as key as in directed research (a point picked up by working group B3). Basic research is not generally expected to deliver practical advances in the short time - though it sometimes does, particularly in the emerging field of molecular genetics; its benefits tend to accumulate over longer timeframes. Thus evaluation of basic research should take place over longer time periods. Governments need to be realistic about the period necessary for identifiable results to become evident.

A question of balance

Most countries maintain some kind of balance between pure and applied research, or investigator-initiated and goal-directed research. The former fosters an environment of intellectual curiosity and creativity in the scientific community; the latter is a top-down approach that may provide a better-defined outcome. Both kinds of approach are needed, since they are complementary in their roles. Ultimately, it was felt that the long-term returns from basic research should not be compared directly with the more immediate returns from applied research.

The process of evaluation is complicated by the fact that the links between discovery and commercial exploitation of discovery are poorly understood. Rather than analysing the process simply in term of the dichotomous view of pure and applied research, it would be beneficial to try to understand better the dynamics of the process. This would help us to appreciate what the preferred outcomes were for the different types of research, and thus facilitate the development of evaluation systems that could be used more effectively to examine the success or otherwise of such research. As it is, if one is attempting to develop systems for comparing different types of research, the criteria used may be inappropriate for one or more of the types of research, or the indicators used may not capture the full benefits from research.

Points of consensus

- **There is no longer a strict division between 'pure' research and 'applied' research**
- **A continuum of different types of research exists, with 'pure' research and practically orientated research at the two extremes**
- **There should be no qualitative differences in assessment methods for different types of research**
- **There will be quantitative differences in different situations:**
  - the returns expected on research investment will be greater for applied research
  - non-commercial sector research has a greater input into the academic 'culture'
- **Research at the 'pure' end of the continuum should be judged over longer timeframes; the long-term returns from basic research should not be compared directly with the more immediate returns from applied research**
- **Countries need to maintain a balance between pure and applied research**
- **A better understanding of the process of scientific innovation is needed, to help develop evaluation systems based on the expected returns from different types of research**
- **Inadequate evaluation systems may not capture the full benefits of all types of research**

International and local perspectives

A third issue, in addition to the distribution of funds between fields and their allocation to particular types of research, is that of national priorities and local needs within those nations; this was the territory of working group A3.

Science is a global activity. Scientists from countries on every continent exchange information and share experiences; researchers move from lab to lab around the world, with few barriers. The accumulated body of knowledge generated by science is added to daily by an international community bound by common methodologies and driven by similar ideals. Yet the exact nature of the scientific enterprise differs subtly from country to country, and many nations have their own key scientific objectives, problems to be addressed and national priorities. Within countries, regions commonly have specific issues to address or local circumstances that feed into the decision-making process. Working group A3 discussed how can these factors be incorporated into the mechanisms for deciding on the allocation of research funds?

As emerged elsewhere at the meeting, the working group felt that, even when local issues were under consideration, scientific quality is of over-riding importance, and that peer review was the best way in which this quality could be evaluated. Poor quality science, wherever it is conducted and for whatever reasons, is never worth supporting. However, while research quality is a necessary condition it is not a sufficient condition; the 'relevance' factor previously discussed becomes an additional factor of significant importance. Local issues are, almost by definition, part of the 'needs-pull', and most existing evaluation mechanisms are not well suited to judge how societal needs are being met.

Involving stakeholders

In these kinds of targeted or local challenge, a key step is to involve stakeholders in the evaluation process. A typical example of a local issue, mentioned at the meeting, might concern the effects of pollution in the Bay of Naples, and how the problem might be tackled. One way to involve stakeholders would be to establishment local 'task forces', consisting of appropriate scientists and those with a first-hand understanding of the local issue; in the Naples example, this might include marine authorities, representatives of the fishing industry, leisure interests, local government officials and so on.

Task forces would be in a position to identify relevant researchers and research specific to the local situation, and to assess the societal relevance of the research activity. Coordinated evaluation of research quality (by traditional means of peer review) and societal relevance by a multi-stakeholder task force would be likely to achieve a more balanced approach. The research would, in theory, be more likely to meet its societal objectives, and stakeholders involved in the process would share 'ownership' of the results and outcomes.

Of course, some stakeholders may not be committed to the process or may not be sufficiently well-informed of the issues. Some participants recounted experiences in which non-scientists had been involved, to provide a local perspective and input, but had not contributed in any meaningful way. Nevertheless, as a general principle, local user representation was judged by participants to provide valuable inputs to shape research directions and ensure the ultimate success of locally driven research-based endeavours.

International expertise

Although practical problems may be of great local importance, underlying basic science should be seen in a broader, often international, context. In this case, a broad range of expertise should be used in the appraisal of the basic research connected to or underlying a local problem. In practice, this is likely to mean international participation in the peer review process: few countries have the range and depth of expertise to be able to peer review all their research activities satisfactorily. As was reiterated several times at the conference, an international perspective provides an important global 'benchmark' and ensures an unbiased and knowledgeable spread of opinion is obtained, which is essential even for projects based on local issues.

Indeed, the working group discussed whether the cultural background in a country or region could influence research assessment or evaluation. Given that peer review is a human activity, the nature of the groups carrying out peer review was regarded by participants as likely to affect the procedures. Furthermore, for most European countries and most scientific disciplines, there is not the critical mass of specialists nationally to develop sufficiently diverse peer review groups. All these factors favour the creation of genuinely multi-national evaluation panels, which would be valuable for all but the most specific local problems.

Points of consensus

- **Science is an international activity, but its conduct differs subtly from country to country**
- **Nations have their own key scientific objectives, local problems to be addressed and national priorities**
- **Within nations, scientific approaches are necessary to address issues of regional importance**
- **Even if a specific local problem needs to be addressed, it is important to ensure that mechanisms are available that select only projects of the highest quality.**
- **Research quality is a necessary condition, but not a sufficient condition; other stakeholders should be involved too**
- **Local user representation provides valuable inputs to shape research directions and ensure the ultimate success of locally driven research-based endeavours.**
- **Few countries have the range and depth of expertise to be able to peer review all their research activities satisfactorily; an international perspective provides an important global 'benchmark'**
- **Multi-national evaluation panels are valuable for all but the most specific local problems and provide a perspective that can overcome national cultural differences**

Points of non-consensus

- **Whether international panels, in most cases, are always necessary or, at the very least, highly desirable**

Section 3: Evaluating performance

Having considered the principles of evaluation and assessment in the first series of working groups, participants then turned their attention to the practical application of these principles. The three working groups that addressed the practicalities of research evaluation drew out a number of features essential for an effective and efficient system.

Once again, peer review was agreed to be the most powerful approach currently available. Nevertheless, it became clear that quantitative performance indicators are being used operationally by evaluators, and are proving to be a useful source of additional objective input. One of the most controversial possibilities discussed was the use of performance measures based on researchers' or research institutes' outputs of scientific papers. There was consensus, however, that sensitively handled publication-based indicators could provide valuable supporting information about the quality of research.

Of the measures considered most explicitly, citation analysis drew more support than evaluation based on journal impact factors - the history of which was described at the meeting by Eugene Garfield, the inventor of the Science Citation Index and father figure of the bibliometrics field. Citation analysis is based on the number of citations a published paper receives; a journal impact factor is a measure based essentially on the average number of citations each paper in a journal receives in a given time period. Although Garfield's intention was to develop a system to aid the retrieval of scientific information, the methods he and his colleagues developed have also proved extremely useful in the evaluation arena.

However, the Science Citation Index is not a perfect tool for evaluation work. On balance, high citation rates probably mean that a piece of research has had a big impact on other scientists. It does not mean, however, that the research is necessarily of high quality or socially useful.

The use of publication-based indicators, it was agreed, had to be carried out with a number of caveats in mind - a point emphasized by Dr Garfield in his introductory address. In particular, they must be used carefully, critically, transparently, competently, and as an adjunct rather than a replacement for peer review. Bibliometric-based evaluation of research might thus be described as the next most useful tool after peer review, its main advantage being its manifest objectivity: it calls for little in the way of human interpretation. But the tools can easily be misused in the wrong hands, and often call for sophisticated statistical handling, for example to ensure that like is always compared with like in evaluation methodologies.

Peer review: potential problems and possible solutions

The advantages and drawbacks of peer review have been endlessly debated in the literature. The conclusion, if one can be drawn, is that for all its disadvantages, peer review (like democracy) is not perfect but remains the best system available and there is no convincing evidence to the contrary. This position was reinforced by the discussions in working group B1.

Low success rates

Unfortunately, the success rate for grant applications in most industrialized nations is currently very low, with demand far outstripping the capacity of funding bodies to supply. With low success rates, it was felt, there is a danger that the peer review system begins to resemble a lottery: if only some 10 or 15 per cent of applications are funded, the number of excellent applications is almost certain to exceed the sums of money available to the funding agency. It then becomes difficult to judge the reasons why one excellent application gets supported but another excellent proposal does not. Moreover, in this kind of climate peer review will tend to favour low-risk proposals, where the likelihood of good outcomes from the research is high, rather than daring but risky applications.

Some of these problems could be overcome or ameliorated if the success rate of applications were to be increased. At least two mechanisms could be envisaged to achieve this goal. First, the amount of funds available could be increased. Although in the current economic climate it is increasingly difficult to argue for more funds - indeed, it is more usual to try to avoid budget cuts - the case should be argued with the appropriate authorities - perhaps as part of the dialogue discussed in working group A1.

Second, the number of applications could be reduced. The advantages of this approach would include reduced frustration in the academic community - writing grant applications is a labour-intensive business, and absorbs time that could be spent more constructively at the bench. In addition, the process of peer review imposes an extremely heavy load on senior scientists who are duty-bound to contribute to peer review evaluation and assessment. No agreement was reached about whether referees should be paid or released from other academic duties; nevertheless, it was accepted that refereeing is a duty that scientists have to fulfil for a certain time period during their careers, even if that sometimes imposes a heavy burden on their time.

One possible mechanism to reduce the number of applications going on to peer review would be prescreening of applications. After much discussion, it was concluded that prescreening by a funding agency was only appropriate in a limited number of circumstances and with a specific set of published criteria, such as the appropriateness of the topic to the agency's funding programme, the completeness of the application and its adherence to the agency's guidelines.

Furthermore, pre-screening was felt to be most appropriate for goal-directed research programmes. For curiosity-driven basic research, any screening would have to be based on criteria of scientific excellence. This again calls for some type of peer review mechanism, which might be able to identify applications of low scientific quality at an early stage, facilitating more careful selection of the remaining high-quality proposals. However, although this might lead to increased confidence in the procedure, it would not by itself increase the success rate.

To this end, it was suggested that potential applicants could be better informed about the criteria used by referees when assessing proposals. This could conceivably lower expectations among applicants and perhaps even reduce the number of applications received. In addition, there is some evidence that eliminating calls for proposals and their rigid deadliness reduces the number of applications, presumably because researchers do not rush to complete hasty applications by a particular date.

Features of peer review

Although the working group did not have time to review critically all the features of peer review, it did draw out some general conclusions. With regard to the issue of anonymous versus open peer review, it was generally felt that anonymous procedures were more appropriate. While open peer review does have its advantages - for example, referees are more directly accountable if identified and therefore are likely to be more motivated to act responsibly - anonymous reviewing of basic research is more likely to lead to objective results, since reviewers could be frank and honest and not swayed into attempting to curry favour with the scientists whose applications they were assessing and publication of the names. Identification of referees used in past assessments and evaluations by funding agencies may represent a possible compromise. Nevertheless, the procedures themselves must be transparent: everyone should know how their application is to be assessed and the criteria being used; if they do, they are more likely to have confidence in the system and in the conclusions reached. Transparency also implies feedback so that criticisms can be addressed, future proposals improved and, where necessary, injustices challenged.

In any case, all members of a peer-review committee must be active scientists. This is essential because aspects of the review process must be to consider both the applicability of the research methods proposed to the research problems, and the innovation contributed by the applicant.

Finally, the working group discussed whether pre-existing resources should be a factor in the assessment of research proposals. The general agreement was that, in principle, these factors should not be taken into account during assessment of individual grant applications in terms of the quality of ideas. However, it is appropriate for funding agencies or universities to take pre-existing resources into account in their considerations regarding the feasibility of proposals.

In conclusion, the group decided there was no suitable alternative to peer review, but when funds are limited, peer review procedures can tend towards lotteries and to favour low risk research. Possible solutions would be to seek ways to increase funds for basic research and to assess peer review procedures critically.

Points of consensus

- **Only expert scientists can evaluate and select research proposals on the basis of the commonly agreed criterion of excellence**
- **With low success rates, the number of excellent applications is almost certain to exceed available funds**
- **Success rates could be increased by:**
  - Increasing funds available to science
  - Decreasing number of applications
- **Prescreening is feasible only under extremely limited circumstances**
- **Clearer expositions of assessment criteria might reduce number of applications**
- **Eliminating calls and their deadlines may reduce the number of applications**
- **Anonymous peer review is more appropriate than open peer review**

Points of non-consensus

- **No agreement was reached about whether referees should be paid or released from other academic duties**

Performance indicators

As session B1 illustrated, no-one challenged the value of peer review. It is an essentially subjective judgement. It is also more suited to qualitative than quantitative measurement. Moreover, in periods of intense competition, it is clearly advantageous to have an additional source of information other than personal opinion, to help inform rational and balanced decision making. Are there any performance indicators available that are more clearly objective and quantitatively based? Such questions were discussed by working group B2.

Objective performance indicators can be categorized into a number of areas:

- publication-based indicators, based on either journal impact factors, citation analysis or papers in international refereed journals;
- the number and size of grants held;
- tutorial and training activities;
- any patents lodged;
- membership of editorial boards and scientific bodies;
- prizes and invitations;
- links with industry and ability to meet societal needs.

Of these, publication-based indicators are perhaps the ones most widely used at present.

Publication-based indicators

The working group concluded that publication-based indicators can potentially be used for evaluation at different levels, such as the performance of institutions, the assessment of grant applications or evaluation of their progress, or to inspect the track record of individuals. It was agreed that such indicators play a key role in evaluating research institutions as well as single groups within institutions. They can also be useful in assessing grant proposals, but should be applied carefully, and only as an aid to decision-making, and applicants should be made aware of the procedures being used by evaluators. Publication-based indicators can be valuable for screening of candidates for fellowships and other positions, but should not be used in isolation. The group emphasized that publication-based indicators should only be used in scientific disciplines in which publications are the major output from research.

It was agreed that publication-based indicators may bring three major advantages to evaluation procedures: they can be simple to use, provide a degree of objectivity, and are transparent. Nevertheless, their use does have several disadvantages. The problem of multi-author papers is often not satisfactorily addressed (without any correction, all authors get equal credit, irrespective of their actual contribution to the research), and the number of such papers in the scientific literature is increasing. There is also a danger that publication data may be used mechanically, without any thought being given to their purpose or meaning. In addition, they cannot be used to compare performance of individuals from different scientific fields without adjustment, which can be difficult to achieve.

It is possible to add value to publication-based indicators, by correcting the raw data to take account of various confounding factors. The problem of multi-authorship can be addressed by paying attention to statistically significant data, and analysing the entirety of an individual's list of publications. Reviews and methods papers, which tend to attract large numbers of citations, should be weighted appropriately. The group felt, however, there was no need to adjust for the fact that an individual was working in a currently 'fashionable' area of research, other than to ensure that he or she is being compared with other scientists in the same field.

The possibility also exists that an individual may be undervalued by publication-based indicators. Corrections for multi-authorship may have this effect, again emphasizing the importance of taking into account an individual's entire record. For those who work in a geographically limited area, the intrinsic merit of the project should be considered especially carefully. And if someone is working in an unfashionable research area, account should be taken of previous achievements.

Impact factors

The possible use of journal impact factors was also scrutinized. Impact factors refer primarily to the importance of a scientific journal, as judged by the frequency with which they are cited by other journals. Their major advantage is that journal impact factors provide an indicator of current performance of an individual or institution. If an individual is consistently getting his or her papers accepted for publication in high-impact journals, it is likely that their current performance is high. By contrast, citation-based measures are much less immediate: to enumerate the number of citations a researcher's papers has gathered, several years have to elapse before sufficient citations accumulate for a valid assessment to be made. The impact factors of journals in which a scientist publishes therefore represent only a proxy measure of performance - in effect, a shortcut to assessing current performance.

The bigger drawback of impact factors, however, is that they are dominated more by the citation characteristics of different scientific fields than by scientific excellence. Thus, journals in molecular biology tend to have high impact factors, while those in, say, geoscience, typically have lower impact factors. This does not imply that molecular biology papers are 'better' than those reporting geological research; rather, geologists simply list fewer references in their papers than molecular biologists. This makes it crucial that, when journal impact factors are being used, molecular biologists should be compared only with molecular biologists and geologists with geologists. Comparisons are not valid across different fields using impact factors. Equally, the research groups with the highest impact factors are not necessarily the most outstanding researchers in the country.

Other indicators

As well as publication-based indicators, the group concluded that other performance indicators could also be considered. These included the number and value of grants received, and the number of patents held. While these indicators were appropriate for all levels of evaluation, some could be used only to evaluate individuals. These latter indicators include prizes and invitations (to write reviews, give lectures and so on); contributions to other scientific activities (such as representation on editorial boards, academic societies, contributions to the organization of scientific meetings, and participation in the processes of peer review); and the amount and success of tutorial and teaching activities. In conclusion, the working group agreed that an individual's performance could to an extent be determined by his or her publication record, but a number of other relevant indicators could justifiably be said to contribute to the overall evaluation.

Points of consensus

- **Publication-based indicators can potentially be used for evaluation at different levels**
  - To monitor the performance of institutions
  - To assess grant applications
  - To assess individuals' track records

  However, they are best used and weighed by a knowledgeable scientist in a given field only, as performance indicators do not offer parameters for mechanistic evaluations.
- **Publication-based indicators are valuable for screening of candidates for fellowships and other positions, but should not be used in isolation**
- **There is a danger that the use of publication data may become mechanical, with little thought being given to their purpose or meaning**
- **Reviews and methods papers, which tend to attract large numbers of citations, should be weighted appropriately**
- **The impact factors of journals in which a scientist publishes represent only a proxy measure of performance, a shortcut to assessing current performance.**
- **Indicators facilitate a more objective evaluation within a given field but not across disciplines**
- **As well as publication-based indicators, the use of other quantitative performance indicators could also be considered**

Monitoring and evaluating individual projects

Sessions B1 and B2 examined mechanisms for evaluation, concentrating on peer review, publication-based indicators and, briefly, other possible indicators. In practice, the finest level of research evaluation is carried out at the level of an individual project. Working group 3 addressed the issues specific to the assessment and evaluation of research projects; it is at this level that funding agencies would like to ensure that all work is of the highest calibre, and that its investment reaps the anticipated rewards. Can performance indicators be used at this critical level and, if so, how? What types of information can the use of performance indicators provide? The group attempted to answer these and other key questions.

Major points

Not surprisingly given the content of the other working groups, the group independently drew out many of the same conclusions - good evidence that the conference was drawing out genuine consensus views. As a starting point, the working group agreed that research project monitoring and evaluation is a useful tool for decision makers and the scientific community. It has several benefits:

- most obviously, it can be used to measure the management of research being carried out and its ongoing feasibility;
- ongoing evaluation during a research project can be used to examine the direction in which research is heading - and can thus enable steps to be taken to redirect research efforts, to ensure that work is proceeding in such a way as to produce useful results;
- and it provides an indication of the likely future success of researchers, which might be important in, for example, decisions to renew support.

This group was also keenly aware that project evaluation must be carried out correctly if it is to provide meaningful and useful information. Thorough evaluation requires a multifaceted approach, and performance indicators should only ever be considered as one tool to be applied to project evaluation. The role of publication-based performance indicators was considered at length, and the group's conclusions essentially recapitulated those of working group B2 - again illustrating the harmony of views.

Clearly, then, performance indicators have an important role to play in research project evaluation. If they are to be successfully applied, however, the group noted that some thought needs to be given to the context within which they will be used. As working group A2 discussed, the type of activity labelled 'research' can differ significantly in different contexts, and the development of performance indicators needs to bear in mind this multiplicity of contexts. For example, different indicators are likely to be needed for mission-orientated and basic research. The point of time in the project and its scale must also be taken into account. Finally, the objectives of the funding agency itself will help to shape the nature of the indicators used.

Although performance indicators are likely to be designated largely by the body funding the work, the working group concluded that under some circumstances, researchers themselves could contribute suitable indicators. This would help to ensure that the most appropriate indicators were used, and that stakeholders could understand the value of the evaluation and were committed to the process itself.

Flexibility

The use of performance indicators should not be an end in itself, but as provide a tool to monitor and influence performance, and it was felt at the meeting that an over-rigid application of such measures might fail to take into account the value of serendipitous discoveries. Much discussion centred on the concept of flexibility, particularly with regard to the extent to which a project's original goals have been met. In general, it was felt that ultimate value for money was more important than achievement of original objectives; if a new line of enquiry presented itself early in a research project, and this avenue promised to be more fruitful than the originally specified goals, then a researcher was justified in pursuing this line of enquiry. The evaluation of this project should not necessarily treat this deviation as a failure. The serendipitous discovery of penicillin is a good example of a shift in direction that ultimately provided exceptional benefits to society. Hence any system of evaluation should be flexible enough to cope with reasoned deviations from initial objectives. This point is particularly but not exclusively relevant to basic research, and may be less appropriate for more applied science, and the nature and objectives of the funding agency concerned will also have to be borne in mind.

Credibility

For a system to work effectively, the group agreed that participants must have confidence in the mechanisms being used and in the usefulness of the information generated. In turn, confidence demands transparency - hence the criteria used for evaluation must be widely known, credible, and accepted by all stakeholders. As in other sessions, some discussion revolved around the concept that referees and proponents should be allowed to interact openly. While this might have some advantages - referees would gain an increased understanding of the proposed research and the transparency of the process would be increased - the approach could also lead to conflicts of interest and potentially to harassment of referees. There was also a suggestion that open procedures would mean that reviewers could provide advice on how research programmes could be organized, but others felt that advice on proposals or strategic development of research programmes was different from critical reviews, and the two should be kept distinct. Overall opinion was in favour of preserving anonymity of reviewers, though some felt that, under certain rare circumstances, open procedures would be more suited.

The time for evaluation

Further discussion centred on the time at which evaluation should take place. For some, assessment and evaluation were considered to be part of an ongoing process, providing a measure of continuity throughout the lifecycle of a project. This would begin with *ex ante* assessment and objective setting, through continuous monitoring of work in progress, through to *ex post* evaluation of achievements. This is particularly useful when decisions have to be made about renewing research projects. As for who should carry out these various tasks, the working group agreed that there is value in having some overlap between *ex ante* assessment and *ex post* evaluation committees; although it is worth bringing in experts who can provide a fresh perspective, it is also valuable to have a certain proportion of reviewers who are already familiar with the work being done. A fresh perspective might also be particularly useful, however, for evaluations carried out towards the end of a research project.

The development of appropriate indicators, tailored to the type of research and funding agency involved, is clearly a time-consuming process, and one that must be done carefully and competently if it is to generate useful intelligence. Thus, despite mounting pressures to develop and apply performance indicators, the benefits must be weighed against the dangers of creating excessive and unnecessary bureaucracy.

In conclusion, the group decided that monitoring of research achievements is a valuable exercise. Mid-term and *ex post* evaluation can be used to assess quality, redirect research if necessary, and assess future research activities - it may, for example, reveal emerging new technologies or fields that warrant greater research endeavour. Flexibility is important, especially for basic research, so investigators can if necessary modify their objectives midway through projects. Finally, the human element in evaluation and interpretation of results cannot and should not be ignored.

Points of consensus

- Thorough evaluation requires a multifaceted approach, but clearly performance indicators have an important role to play in research project evaluation although they are only one tool among many used in project evaluation
- Researchers may themselves be able to contribute suitable indicators
- Ultimate value for money is more important than achievement of original objectives
- Evaluation of a project should not necessarily treat deviations from original objectives as a failure
- Criteria used for evaluation must be widely known, credible, and accepted by all stakeholders
- Assessment and evaluation may be considered part of a continuing process, providing a measure of continuity throughout the lifecycle of a project
- There is value in having some overlap between ex ante assessment and ex post evaluation committees, though fresh perspectives are useful too
- Ongoing monitoring may reveal emerging new technologies or fields that warrant greater research endeavour
- The human element in evaluation and interpretation of results should not be ignored
- Despite mounting pressures to use performance indicators, the benefits must be weighed against the dangers of creating unnecessary bureaucracy

Points of non-consensus

- Peer review: anonymous reviewing was generally favoured, but some expressed support for procedures in which there is an open interaction between reviewers and those being reviewed

Section 4: Research assessment in the career of investigators

Research is conducted by individuals, albeit working in groups where, it might be hoped, the whole is greater than the sum of the parts. Thus, if high quality research is to be produced the calibre of the research investigators must be equally high. This means that assessing the quality of researchers is an important element of assessing any research project application for funding.

The issue, however, is more complex than this, for, in many publicly funded research establishments, researchers are required to contribute to the teaching of students. Thus there is a debate about whether teaching and research should continue to co-exist in the same institutes or whether they should be separated with teaching restricted to universities and research concentrated in specialist institutes. Within the present system (which is likely to continue in many places and could be seen to exist contemporaneously with specialist teaching and research units) the balance of teaching and research skills required by researchers remains an issue of debate.

In addition, the role of industrially based scientists in the development of any field cannot be ignored and the ability to be mobile between academia and industry with the consequent gains for the advancement of scientific knowledge are important issues.

A consensus on the benefit of sectoral mobility is easily reached. However, discussions on the benefit of mobility between disciplines is more contentious, even though advances are sometimes made when a problem is examined from the diverse perspectives provided by different disciplinary bases.

The final set of three workshops therefore addressed the career development of researchers, the personal and intellectual qualities required and how these might be measured. The relative importance of these qualities is likely to change over the lifetime of a researcher as they move from graduate researcher to head of an institute and may be different between academe and industry.

Assessing researchers early in their careers

Working group C1 agreed to define the start of a researcher's career as the first postdoctoral appointment and focused on this stage of development rather than entry into doctoral training as it was felt that it was at this point at which a career could really be said to begin. Indeed, it was felt that the first postdoctoral job opportunity in research really proves the research ability of potential researchers. This was given as one reason why the post should not be permanent.

Key characteristics of successful young researchers

At this early stage of any career, past record cannot be taken as an indicator of future research potential. A list of key characteristics essential to any scientific researcher was therefore developed. At the plenary session these were presented to the conference and a consensus was reached. The listed attributes are:

- the ability to identify and solve problems;
- the ability to motivate oneself and others;
- research vision (i.e. the ability to turn problems into researchable questions);
- previous academic achievement;
- being a team player;
- having good judgement;
- some degree of mobility; and
- some appropriate experience.

Having established the characteristics needed to "join" the scientific research community, the discussion moved on to consider how the possession of these attributes might be assessed in the young researcher.

Assessment of key characteristics

Interviewing young candidates for academic posts (which involve undertaking some research) was agreed to be the optimum method but it was recognised that the number of applicants and their geographical locations might necessitate some degree of pre-selection, although pre-selection was to be avoided if possible. By asking the researcher to present their proposed research programme it is possible to gain an insight into their possession of the required attributes. References and recommendations are seen as an important part of the assessment process at this stage in the research career. Indeed, some participants (a minority) felt that analysis of references from known researchers was a sufficient method for assessing the research ability of young researchers.

The working group also posed the question of using objective tests and examinations as part of the evaluation of young researchers. However, these methods of assessment should be introduced generally.

Quantitative performance indicators

It was agreed that publication-based indicators are valid as long as their limitations are understood and taken into account in the final decision-making process. As in the measurement of performance of established researchers and institutions (Section B) citation analysis was seen as a useful aid to, but not as a substitute for, personal judgement of young researchers. The specific citation analysis conducted (and there are different approaches) must be made clear to all involved in the evaluation process and it is important that the analysis must be transparent. If citation analysis is only to be one of the inputs into the decision-making process any discrepancy between the results of the citation analysis and the final funding or job application decision must be capable of being justified explicitly. This introduces an element of accountability into decision-making and keeps the process more transparent.

Nevertheless, concerns were expressed about the methodologies used and their possible misuse. Hence transparency and objectivity in the assessment methods and processes used by grants panels was a theme which ran throughout the conference and a firm consensus was reached on their importance.

Peer review

Peer review is central to the assessment of the majority of research proposals in most developed countries. Its conduct and shortcomings are therefore at the core of any discussion about how to judge both the competence of researchers and their ideas. Working group C1 concluded that peer review was important and necessary in the assessment of careers and, in recognition of the problems, set out some guidelines for its use with respect to assessment of individual research scientists.

Points of consensus

- **Key characteristics needed by the good researcher:**
  - the ability to solve problems
  - the ability to motivate themselves and others
  - research vision
  - academic achievement
  - being able to work in a team.

- **Methodologies by which these characteristics could be judged:**
  - interviewing candidates
  - obtaining references
  - having the candidate present their ideas in person.

- **Citation indices and impact factors when assessing individual careers are valid as long as their limitations are taken into account in the final funding decision.**

- **Peer review (including using foreign peers) in the assessment of researchers is crucial to the process.**

- **All members of a peer-review committee must be active scientists, and any discrepancy between the results of the citation analysis and the final decision must be explicitly justified.**

Assessing teaching and organisational abilities

The relevance of different skills, in particular the balance between teaching and research ability, varies depending upon the post for which a candidate is being considered. For example, when applying for a position in an industrial environment, past teaching records may be of marginal interest to the assessors, while in a research institution teaching methods would be of some importance. However, for academic positions in the kind of university department where teaching is a core element of the job, past teaching record must be considered seriously.

Working group C2 agreed that beyond formal teaching ability, that is delivering lectures, taking tutorials and such like, researchers also need to have skills in generally coaching and training their junior colleagues. These skills, it was felt, can be developed at the post-doctoral stage of the career.

Even in industrial settings the training of young researchers is significant and of importance to the businesses which employ them. Nevertheless, the ability of researchers to contribute to the training of young researchers is perhaps more significant for those working in academic institutions.

Young investigators are able to contribute at an early stage in their career to the training of students even though their teaching abilities might yet be limited. There is, however, a danger that PhD students and other young researchers can be exploited by senior researchers and there must be systems and structures in place to be sure that young investigators are receiving the necessary training and support.

Much can be learned through teaching others and teaching while researching enhances the quality of the teaching (and questions raised by students may enhance the research). The working group agreed that teaching and research activities are inter-related and best not separated into different establishments. Consequently, evaluation systems should consider performance on both activities together.

Measurement of teaching ability

Given the acknowledged importance of teaching ability it is essential to consider how teaching ability (present and future) could be measured in the higher education context. These concepts are currently very weak and clearer indicators are required.

The publication record and career achievements of former students can be helpful in the objective assessment of university staff, (the citation performance of students has been found to be closely correlated with that of their supervisors). Evaluation of teachers by students and the writing of teaching (text) books also have a role to play in the assessment of teaching ability. Nevertheless, it was felt that teaching ability as measured by these criteria should be seen as a secondary criteria when considering the selection and advancement of individuals during their career as scientists.

The changing balance of skills over the lifetime of a researcher

Over the course of a career the balance between teaching responsibilities and research and managerial responsibilities will change, even if the researcher remains in the same institution. The change in balance needs to be borne in mind when assessing a researcher at different careers stages.

Later in a career the ability to organise the research activities of other researchers becomes more important if natural career advancement has led to the candidate becoming head of a laboratory, institute or research group. The working group discussed what skills are needed for the effective management and organisation of research.

Organisational skills

Working group C2 reached a consensus that considerable weight should be given when assessing an individual's career to an investigator's ability to organise the conduct of research in all its aspects, from defining the problem to obtaining funds, recruiting researchers and evaluating results. These abilities can be readily and objectively assessed by accepted procedures and should be an important factor in evaluation throughout the career of an investigator. Moreover, organisational ability is an important quality for an accomplished scientist and this is of great value in all research environments from basic to applied, in universities and in industry.

Participation in the wider scientific community

Senior scientific researchers may also be involved in the wider aspects of running and managing science at the local, national or international level. This involves participating on review panels for grant giving and involvement in science policy decisions more broadly. These types of activities are essential to the greater life of the scientific community, and are usually only undertaken by established scientists but it is difficult to evaluate them objectively when assessing an individual's career or contribution to science.

Points of consensus

- **The relative importance of teaching abilities in different research environments varies and whilst the ability to teach is central to the university academic, it is much less important to the researcher in industry.**

- **Teaching ability might be more objectively measured by:**
  - publication record
  - the success of former students
  - writing text books
  - evaluation by students

  BUT
  - research ability remained the most important criterion

- **Training is distinct from formal teaching or lecturing and post-doctoral staff have a role to play in training.**

- **Managerial abilities become more important as the career of the successful scientist develops.**

- **It is essential for experienced and successful researcher to contribute to the broader scientific community.**

Assessing researchers with diverse careers

The key issue addressed by working group C3 was the importance of interdisciplinary working and mobility between industry and academe. How eclectic should a career be? Was a varied career more beneficial (to the researcher or to science) than one focused on one field or in one type of environment? If a researcher moved across boundaries how could their career be judged? Other special topics considered worthy of discussions were the role of personality of leading researchers and the effect of fierce competition for funds on career paths.

Single discipline study versus interdisciplinary development

A positive contribution can be made to research groups by individuals with similar backgrounds as well as those with complementary competencies derived from working in a different environment or scientific field. When researchers bring similar expertise to a group which already has people with similar skills it needed to be recognised that they would, in some sense at least, be competitors on a personal level. However, competition between researchers can have a positive benefit to the research unit.

Some institutions may recruit personnel to enhance or broaden the skills of the research group or to help it to enter a new field. This would result in an improvement of flexibility and in the introduction of new techniques and approaches which might be at the forefront of the discipline. Many areas of scientific research are becoming increasingly interdisciplinary and thus need the addition of new blood from other fields of enquiry.

When considering the issue of movement between scientific disciplines the different stages of a career should be regarded separately. Various arguments were rehearsed but depending upon the area of study and the individual concerned, policies for individuals may easily become self-evident.

One school of thought argues that young scientists at the beginning of their careers should be free to explore different fields before developing a solid base in a specific area. This argument suggests that in order for young scientists to develop their own creativity, and ultimately their scientific personality, a degree of freedom is essential. The important goal is to develop new talent by nurturing initiative and creativity so that scientists rather than technicians are produced. An alternative argument is that young scientists need the discipline and guidance which results from some specialisation early on in their career. Without this they may lack structure and rigour in their future work.

When considering established scientists some are convinced that they should invest their energies in building in one area of competence. Others would argue that senior researchers who move to an established unit working in a complementary field should be able to create new interests in their own areas of work within the group thus enriching the whole research process.

Some of the greatest developments recently have come from interdisciplinary work. It is important to realise that there are dangers in over-specialisation and, moreover, the boundaries between disciplines are becoming more fluid. Cross-fertilisation by scientists moving across fields can be important for scientific development but the researcher needs to be able to demonstrate potential competency in their proposed new field. Such mobility should not be the result of an inability in the original area of study.

The role of personality

The personality of the group leader is an important aspect of the career development of young researchers. In Europe, it was argued, young investigators are often not allowed sufficient freedom due to the organisation of the academic or research institute and the funding system. An increase in the number of PhD positions might help to overcome, at least in part, by providing more opportunities for young researchers.

Absolute and relative assessment

Within an environment of limited funding for research projects, when many proposals rated excellent are still unable to obtain funds, competition for jobs and funds is fierce. Applicants therefore have to face both absolute and relative assessment criteria. Absolute assessment takes place against objective criteria set out for applicants; for example the need to have specific knowledge or skills. Relative assessment takes place between the candidates who fulfil all the objective evaluation. Relative assessment takes place after the objective evaluation if more than one candidate fulfils the objective criteria.

It was agreed that absolute assessment is important when recruiting for a highly defined role, where the skills required can be clearly specified. Relative assessment is more appropriate for posts which might be considered more “open” in nature, where the recruiter wants to appoint someone with potential to develop the work of the research group.

Criteria for the two stages of assessment differ and more criteria can be added at the stage of relative assessment in order to be able to identify a “winner”. However, in all cases the criteria for assessment should be clearly defined in advance and must never depart from the need for scientific excellence.

Assessing the value of mobility between industry and academe

The relationship between those employed in industry and those employed in academe is evidently different between countries and possibly between fields of science. In general, mobility from university to industry is more common than movement in the opposite direction, even later in the career, but the frequency with which established researchers move between the two environments is generally low. This tends to result from variations in cultural backgrounds and perhaps the different currencies used by the communities, where publication is significantly more important to the career of the academic researcher while commercial success is more valued by industrial employers. It is in the interests of all that the boundaries between the two scientific communities should be reduced and mobility in both directions encouraged, particularly movement from industry into universities.

The implication for assessment methods is that previous experience gained in industry should count positively when candidates are being assessed for academic positions, provided that they have made significant scientific accomplishments during their career to date.

During the plenary session the debate begun by working group C3 was widened to consider the impact of the changing priorities of governments (who are the main funders of basic scientific research). Policy shifts mean that researchers now need to:

- be flexible;
- have transferable skills applicable to a range of scientific environments and fields;
- have non-research skills such as:

- the ability to organise and manage research projects;
- the ability to manage other researchers' work;
- the capacity for entrepreneurship.

There is, nonetheless, a lack of mobility between the various working environments and between disciplines and both the industrial and the academic research communities are conservative. It needs to be recognised that such non-flexibility is not necessarily good for the future of science or of the scientific community.

Points of consensus

- **Objective criteria must be clearly set out when recruiting staff and these should be applied in an initial screen of candidates.**
- **The qualifying applicants then need to be subject to a process of relative assessment with another set of criteria established at the outset but also with the flexibility for change, should the characteristics of candidates require this.**
- **With respect to specialisation, whilst cross-fertilisation between research environments and disciplines is important for new developments, in general much is to be gained from specialisation within a discipline.**
- **More movement should be encouraged between industry and academe.**

Section 5: Conclusion

The conference successfully considered how to assess projects at the grant application stage, how to evaluate the outcomes of the projects successful in receiving a grant and how to assess and review the careers of individual researchers at different stages in their career.

It was unanimously agreed that the quality of the scientific project and the ability of the proposer to carry out the proposed work were the over-riding considerations to be taken into account when assessing grant applications. Nevertheless, it was acknowledged that some funders would have their own aims and purposes which would be superimposed on the demand for scientific excellence. On the whole, the conference believed that it was essential to build on excellence rather than to prop up areas which were weak or declining.

Consensus was reached on the need to review assessment and evaluation techniques periodically. It was clear to all present that the boundaries between disciplines and between basic and applied science are becoming increasingly blurred. It was easily agreed that all types and disciplines of science could be assessed and evaluated using the same methods.

The techniques agreed to be important in the assessment and evaluation of research projects can to a large extent be applied to the assessment and evaluation of researchers during their career. In addition, the linking of teaching with research in many countries means that assessment of teaching ability should be incorporated in the overall assessment of researchers in universities, although it was recognised that this skill was less relevant to those working in industry.

The central issue of the conference was the peer review process and the conclusion that whilst the system is not perfect, it is the best that exists. Peer review is at the centre of *ex ante* and *ex post* assessment and evaluation of scientific research endeavours. It is used to assess individual scientists in their job applications and in applications for project grants. However, peers are becoming overworked and the grant allocation procedure is in danger of becoming a lottery as ever smaller proportions of applicants are funded.

Delegates argued for the process to be made more transparent by the use of objective measures such as publication records, citation indices, impact factors and the setting-out of criteria for absolute and relative evaluation. The conference debated the anonymity requirement and concluded that it was a necessary safeguard for reviewers.

The peer review process can also be supplemented by evaluation of teaching or training ability using the "success" of past students, student assessment forms and the production of text books. It can be made ostensibly fairer by the inclusion on review panels of reviewers from other countries who have less intimate knowledge of the applicant such that they might be thought to be more objective. More criteria can be added to the demand for scientific excellence, such as the economic value of the research or its "fit" with government policy.

However, in the end, when assessing ideas and/or the ability of an individual researcher or research group, human judgement must intervene. Thus, the final judgement will remain subjective, even if it is the subjective opinion of a group rather than of an individual and even if his opinion is backed-up with quantitative facts. The important factor is the ability to be able to justify the decisions made as a result of the peer review process. This justification will be made easier by reference to objective measures.

Lastly, the conference acknowledged the need to recognise evaluation as a distinct activity in its own right and to broaden and introduce, where necessary, its study into universities.

And finally....

During the three days of the conference delegates covered a vast number of issues. The opportunity to discuss these issues with others working in the area of science policy was invaluable. The participation in the debates of delegates from many European states and from North America and Japan enriched the discussion. Many delegates arrived with preconceived ideas which were challenged or accepted. All benefited from the workshop formats which allowed everyone to air their views and work through their ideas in an intellectually rigorous but supportive environment.

Without full and frank discussion consensus could not have been reached on many of the points. Without the involvement of all the participants from the different communities in reaching the consensus, many of the outcomes from the conference might have been subsequently challenged.

Consensus was reached on one over-riding principle - that the issues under discussion are complex and fundamental. It was therefore unlikely that in three days the problems which have been challenging those charged with the responsibility of evaluating scientific research and researchers for years would be solved. Nevertheless, having spent three days working together, those at the forefront of the field felt that they were moving in a common direction in their search for solutions.

It was agreed by those present that further meetings should be held to review the issues and move forward in the consensus on the methods of evaluation to be used and how these methods should be applied.

Delegates left the conference knowing that there are no easy answers and reassured that others in the field are facing the same issues, and aware that others are addressing these issues in the same way.

Guidelines for peer review

It is essential to avoid any conflicts of interest between the research proposal or proposer and those asked to take part in the peer review process. Those requested to undertake peer review should also be active researchers as one aspect of the review process must be to consider the novelty of ideas and the applicability of the research methods proposed to the research problem. Members of the "user" community could be included as peer reviewers as a way of broadening the review procedures and introducing new perspectives.

A large pool of peers needs to be maintained if the system is to work well, avoiding conflicts of interest and providing expertise across all aspects of the scientific research community. International participation should be encouraged wherever possible and appropriate, to the extent that foreign peers should be included on committees. This is a way of enriching the quality of the peer review process by bringing new and independent ideas to any review panel.

The problems with the peer review process are heightened when success rates for grant applications runs at 10% or 15%. The conference felt that in this situation peer review was reduced to a lottery because so much excellent science was not funded.

Solutions put forward included:

- increase the amount of funds available for scientific research;
- introduce some element of pre-screening;
- inform applicants more clearly about the criteria sought by funders;
- eliminate fixed calls for proposals and their accompanying deadlines.

Pre-screening was not accepted by the conference except by agencies or programmes with very focused goals who could rule applicants ineligible.

Guidelines for using performance indicators

Peer review is a qualitative performance indicator which can be supported by more objective quantitative indicators. Forming an opinion on the excellence of the science is the "easy part" of assessing a project application. Forming an objective view on track record is more difficult because of the problems of perfect knowledge of candidates and personalities.

A number of objective performance indicators in comparable fields which can contribute to ex ante assessment and ex post evaluation were agreed upon:

- non-mechanistic use of journal impact factors;
- citation analysis;
- number and value of grants held;
- patent lodged;
- membership of editorial boards and scientific bodies;
- prizes and invitations;
- organisation of research activities;
- links with industry;
- ability to meet societal needs.

Publication-based indicators are simple to use and transparent but their use can become mechanistic. It is important that indicators are recognised as a tool in assessment but care must be exercised in their application. They are best used by a knowledgeable scientist in any given field. The conference emphasised the need to take account of multi-authorship, over citing of methods papers, review articles, comparisons between different scientific fields and other factors which can lead to misjudgements being made if care is not taken in the use and interpretation of these methods. Publication-based indicators are useful for screening candidates but should not be used in isolation.

Performance indicators bring forward questions which may otherwise have been overlooked and they provide objective justification for decisions.

The conference acknowledged the need for evaluation tools to be targeted at the project to be evaluated. In general, the evaluation crieteria and practices will be set by the funding agency. However, there is scope for the researcher to contribute to the identification of appropriate tools. Crucially consensus was reached on the need for all involved to agree that the evaluation methods were fair and transparent.

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Professor Gaetano "Nino" Salvatore, Full Professor of Molecular and Cellular Pathology at the University "Federico II" of Naples, President of the Stazione Zoologica "Anton Dohrn" in Naples, and a member of EMRC and LESC of the ESF, died suddenly in Naples on 25th June 1997 at the age of 65. He had just returned home from an expert hearing in the Italian Parliament where he had presented his views on the importance of biotechnology.It is typical that he was engaged in the promotion of science and in convincing politicians of its importance in a modern society until the last moments of his life.

An endocrinologist by training, he was best known in the field of biomedicine. Becoming a full professor at the University of Naples at the early age of 33, his drive in setting up innovative research on the biochemistry, molecular biology and pathophysiology of the thyroid gland and the biosynthesis of thyroglobulin made him well known internationally and won him many honours. Among them are the Fogarty Scholar in Residence at the NIH in USA (1977), membership in the Accademia dei Lincei (1992), and Chevalier dans l'Ordre National du Mérite, of France. In addition to his reputation as an innovative and excellent researcher, he was a dedicated academic teacher who cared very much for the best training of students and young researchers. Acting for more than 13 years as Dean of the Medical Faculty of the University of Naples and through his wide international experience, including his own Ph.D. education at the Sorbonne in Paris and his many stays at the NIH, he became Chairman of the national commission for reforming medical education in Italian universities. In 1987 he was appointed as the first president of the famous Stazione Zoologica "Anton Dohrn" immediately launching a programme of rebuilding and enlargement of research facilities reestablishing its position among the leading research institutes in Italy. He was meticulously concerned for the cultural heritage of this institution evidenced in the restoration of the Marees frescoes and the creation of "I Musici dell' Aquarium".

Nino Salvatore was a European scientist par excellence. He was an eloquent and ardent proponent for the need of European collaborations and a strong supporter of the ESF's role as the voice of science in Europe. As chairman of the Biotechnology Committee of the Italian CNR he represented CNR in two of ESF's Standing Committees. His contributions to the planning of research priorities with European dimensions were seminal. Nino was full of energy and of ideas, and was not fond of bureaucratic necessities. He acted spontaneously out of his breadth of scientific and political experience and his profound familiarity with science administration. Being himself very humble, he was most generous to others. The ESF mourns his premature death. But we all remember his enthusiasm for science, his lively presentations which enlightened so often our meetings. We cherish the privilege of having known him.

Werner Rathmayer, *Chairman of the ESF Standing Committee for Life and Environmental Sciences*

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