PEER REVIEW

AND THE ACCEPTANCE OF NEW SCIENTIFIC IDEAS

Discussion paper from a Working Party on equipping the public with an understanding of peer review

SENSE ABOUT SCIENCE

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November 2002 – May 2004

Compiled and presented by Tracey Brown, Director
Sense About Science

Contents

Appendices

List of illustrations

Foreword

Few outside the scientific world can be expected to know about the immense effort, and even pain, that is experienced before research is ready to be published as a peer-reviewed paper in a scientific journal. The peer-review process is almost as complicated and unpredictable as the birth of a baby. Yet, as with delivery, it involves analysis, judgement and evaluation – or at least it should.

We believe it is important for the public to understand more about the critical engagement and the checks and balances that help to determine the plausibility of new knowledge (Section 1). This report therefore seeks to provide an outline of the complex way that science enters the public arena (Section 2) and why the time-honoured peer-review process is crucial, though it could be improved and better understood (Section 3).

This report also endeavours to show how things can go wrong. Delivery of 'results' may be premature and a claim can reach the airwaves before adequate testing has been performed. A consequence is that the unsuspecting are presented with untested opinions rather than peer-reviewed conclusions.

Donald Kennedy in a recent editorial in *Science*[1] pointed out that peer review of a scientific paper involves the addition of qualifications and limitations on conclusions. Other forms of communication, by contrast, such as intelligence, news reporting and campaigning, often delete qualifying language and caveats so that scientific conclusions are strengthened and simplified. This tension between the description of experimental findings and interpretation arises for all who aim for clarity and urgency. Yet it is the pursuit of truth that remains fundamental to the scientific endeavour.

This report is for scientists and for all who grapple with the barriers and difficulties arising from new knowledge as societies come to terms with the latest scientific and technological news. It is a discussion paper, written in a cultural context, that makes a more determined case for peer review from a social standpoint than we envisaged at the outset. It is the outcome of a vigorous debate within the Working Party and is published with its full support.

May I take this opportunity to thank all the members of the Working Party for their immensely valuable contributions, many other colleagues who also gave most generously of their time and energies, and most of all Tracey Brown, who has worked tirelessly over the past 18 months in bringing the report to a successful conclusion. She has directed and inspired our wide-ranging deliberations and has brought them together in a comprehensive and comprehensible document. We are further indebted to Dr Bridget Ogilvie and Professor Onora O'Neill for their review of the document. Finally, we are deeply appreciative of the help of Dr Irene Hames for her thorough and thoughtful editing over several drafts.

Professor Sir Brian Heap (Chair)
May 2004

[1] Editorial (2004) *Science*, 303, 1945.

The Working Party

This discussion paper has been endorsed by a sub-group of the Board of Trustees of Sense About Science. It has been prepared by a Working Party on equipping the public with an understanding of peer review. Members[2] of the Working Party are:

Professor Sir Brian Heap CBE FRS (Chair)
Dr Derek Bell
Professor Colin Blakemore FRS
Ms Tracey Brown,
Dr Peter Cotgreave
Lord Drayson
Ms Fiona Fox
Mr Tony Gilland
Professor Stevan Harnad
Professor Sir Peter Lachmann FRS
Sir John Maddox FRS
Professor Peter Main (and Dr Philip Diamond)
Professor Alan Malcolm.

For some periods of its existence or for particular meetings, the Working Party has been joined by:

Professor David Cope (and Dr Peter Border)
Dr Ron Fraser,
Dr Irene Hames
Dr Robert Moor FRS
Mr Bob Ward.

[2] Biographical details are listed in Appendix 5.

Executive Summary

Background

Public discussion is sometimes dominated by debates about the implications of scientific research: what causes Sudden Infant Death? Will genetically modified crops create 'superweeds'? Is the Measles Mumps Rubella (MMR) vaccine linked to autism? Will transgenic pigs help to solve a shortage of organs for transplants? Do mobile phones damage children's brains? What is an optimal dose of fluoride?

Over one million papers about scientific research are published in scientific journals worldwide annually. To get a paper published, scientists submit their research findings to a journal, which sends them out to be assessed for competence, significance and originality, by independent qualified experts who are researching and publishing work in the same field (peers). This is known as 'peer review'. Despite its extensive use and recognition among scientists in assessing the *plausibility of research claims*, in the rest of society very little is known about the existence of the peer-review process or what it involves.

A Working Party was established by Sense About Science in November 2002 to consider how an understanding of peer review might help the public to weigh the relative merits of different research claims. This report of its discussions[3] is for scientists and for the many groups who mediate and comment on scientific information. It also contains a guide to peer review (Section 2) for everyone who is interested in science.[4]

The 'public interest' and peer review

From the outset, the Working Party recognised that scientific peer review has not traditionally been a subject of public interest. In British society today, however, science has become the subject of many wider public and political controversies. More scientific information is being put into the public domain and a growing number of organisations are becoming involved in promoting and discussing scientific research and reacting to new research claims. Scientific evidence is sometimes mixed up in these 'politics of science'. Exaggeration and anxieties about scientific developments often relate to research findings that are regarded by scientific experts as weak or flawed, or that have not been subjected to independent expert scrutiny at all. The promotion of these findings seems to come about because some journalists and opinion formers are drawn to stories that minister to a growing cultural ambivalence about established authority and accepted knowledge.

These developments, which are discussed in Section 1, have resulted in a greater public need for clarity about the status of new research claims, as people are being compelled to ask, 'whose claims can we trust?' and 'which study is right?' A wider understanding of peer review's role, in assessing whether work is competent, significant and original, is central to achieving that clarity about the status of research. The opportunity to explain peer review needs to be seen within this

[3] Recommendations are indicated in **bold** text.
[4] A short version of Section 2, *A guide to peer review*, will be available for separate distribution in October 2004.

broader social interest in the reliability and quality of research, rather than identified with the preoccupations of particular scientific groups that their messages are not getting through.

The public, in its widest sense, should be encouraged to ask questions about peer review when listening to claims about scientific findings in an interview, press release, or news report. Has the work been evaluated by experts in the field, or is the report based on opinion or unsubstantiated extrapolation? Is it acknowledged by other scientists as a contribution to the field, or dismissed because it is flawed? Has it been replicated? (p.22)

While many concerns were raised with the Working Party about the serious effects on society of misleading and conflicting research claims — from creating unnecessary parental anxieties to wasting research funds — there is little empirical data about these effects. **This paper recommends further collaborative research between scientists and social scientists to extend existing accounts of how science stories are reported and the questions that are asked about new research by different social groups.** (p.36)

Balancing the criticisms

One of the reasons for establishing a Working Party was the predominance of criticism of peer review, relative to the paucity of explanations about what it is or why it has become the system for sharing scientific findings between scientists. These criticisms are often concerned with very different things.

Scientists tend to be concerned about the practical difficulties involved with managing the peer review of thousands of papers and maintaining standards. Some individuals are called upon very frequently to review papers and attentive reviewing takes time. Some of these challenges are discussed briefly in this paper, but there is an outstanding need for scientists to review the best ways for scientific publishing to deliver to their required standards, which falls beyond the remit agreed by this Working Party.

Some critics of scientific practice have accused peer review of being a barrier to new ideas. In some cases, particularly concerning claims about new threats to health or to the environment, critics have promoted 'going straight to the public' as preferable to the more disciplined approach of scientific publishing and peer review. Yet, if research findings are so significant that they might transform our understanding, for example about what is a cause of illness, or change the course of our actions, then it is all the more important that the research is on sound foundations tested by peers. The time taken to review research is frustrating, but must be considered against the potentially enormous costs — not least to public health — of regularly promoting research findings that turn out to contain serious errors.

Concerns about peer review being misused, for example to suppress worthwhile work for competitive ends, are discussed midway through Section 2. Such criticisms tend to exaggerate the problems of peer review relative to its fundamental contribution to knowledge and research discipline. They also demonstrate an unrealistic notion of the suppressive powers of scientific publishing. This discussion paper explains how, on the contrary, scientific peer review helps to ensure that plausible results *are* published, irrespective of the social or commercial aims. Once papers are written and submitted, if they are published in the peer-reviewed scientific literature we can at least be sure that they have been judged independently to have scientific merit — to be competent, significant and original — with no regard for who funded the research or what occupies the news or the political agenda of the day.

The peer review of scientific papers submitted to journals for publication has a widely proven record as a means to test the plausibility of new findings. However, scientists never regard peer-reviewed research as beyond criticism. Peer review of a paper is just the first stage: a hypothesis that survives this first test must go on to be re-tested, and judged for its coherence with work in related areas.

As with any system that is dependent on human judgement, such as jury trials and doctors' diagnoses, mistakes are sometimes made by referees. These can result in valuable papers being overlooked by the higher quality journals, and also in weak or flawed papers occasionally being published. But if the findings are very significant, any flaws are likely to be discovered quite quickly because the paper will be widely read and discussed and other scientists will attempt to repeat the work. (This rapid discovery of mistakes is often referred to as science being 'self-correcting'.)

In short, the most basic problem with peer review is that so few citizens are made aware of it, at a time when people have become very concerned about how to weigh scientific research claims meaningfully. **Scientific bodies should make systematic attempts to explain peer review and to communicate what it is to a wider public, especially when there is controversy about particular claims.** Section 2 describes the peer-review process and addresses some of the questions about how and why it is used.

Peer review and how science becomes public

The Working Party has looked for ways to promote a culture in which people who promote research claims in the public domain feel obliged to explain the standard of the evidence on which they are based. In doing this they can encourage the public to ask more effective questions about the scientific information put before them. This small but important cultural change in how we engage with scientific information in the public domain requires greater attention to whether work has been peer reviewed by all who shape public discussions about science, from government ministers to health writers.

Section 3 addresses the different ways in which scientific information enters the public domain and how these interact with the peer-review process. This is accompanied by recommendations on responding to the need for a clearer, more vigorous explanation of peer review, which are summarised below.

I. Popular science reporting takes on much of the responsibility for explaining scientific work and getting non-scientists interested in it. **Scientists' conferences, press releases and other promotional activities should help this process by stating clearly whether particular scientific claims have been peer reviewed wherever possible.** (p.26)

II. In recent years, universities and research institutions have considerably expanded their promotional activities, and the majority now employ a much large press and public relations staff. **Scientists should work with press officers to ensure that their peer-reviewed work is reflected accurately in all publicity. Universities and other organisations involved in scientific research should ensure that any press officers who do not have a background in science understand the peer-review process, for example as described in this discussion paper.** (p.26)

III. **It is further recommended that scientists follow reports of their research in the wider media, and try to correct claims that deviate substantially from peer-reviewed**

results; but that they distinguish between this and matters of taste and style in how others choose to discuss their work. (p.27)

IV. Scientific results are often discussed at conferences and there is growing media interest in these as a source of news. With talks covering a combination of new and old work, conference organisers would find it almost impossible to indicate systematically what has been peer reviewed. **However, it is recommended that conference organisers try to put information about the peer-review status of claims into their promotional literature, and encourage presenters to communicate with them about this when (i) a talk is clearly likely to cause wider controversy; or (ii) new findings are being widely promoted to draw attention to a conference.** (p.26) Scientists also need to be aware of the context of informal discussions about their work.

V. Regulatory obligations require many commercially generated scientific findings to be announced immediately (for unavoidable reasons such as preventing 'insider trading' in shares). Unlike peer-reviewed publications, Stock Exchange notifications (usually a press release) do not require sufficient information for other scientists to be able to evaluate the research, so at this point peer review of any sort can be impossible. **A best practice guide should therefore be developed by companies that are obliged immediately to report R&D results to the financial markets and to product licensing authorities. It is also recommended that the use of an 'open access' Web-based resource be explored, where organisations can provide supporting scientific data simultaneously with any press release.** (p.31)

VI. Peer review has too low a profile in science education in the context of rapidly escalating sources of scientific information and the need to equip students and pupils with an understanding of how scientific material is generated. With the increasing use of the World Wide Web, students encounter material on scientific topics with great diversity in its status. It has become more difficult to assess the information sources used or to predict the material that student research will generate. **It is recommended that bodies concerned with devising curricula, producing teaching materials and promoting science education, produce teaching resources on peer review for educators for all age groups.** (p.33) In further and higher education, all courses covering risk assessment and the philosophy of science should include some education about the process of peer review.

Many different groups of people comment on scientific issues and very few of them refer to whether work has been peer reviewed. There is little pressure for them to do so while scientists themselves rarely explain peer review to the public and sometimes fail to demonstrate regard for the distinction. If scientists regularly draw attention to whether work has been scrutinised by peers, and to whether results have been replicated, it will become easier for everyone to be more demanding about the quality of information that informs social discussions about science.

The social 'uncertainty' and scepticism of our times undoubtedly make the tasks of conveying scientific evidence and weighing scientific claims more challenging. In such circumstances, the fact that the development of science has at its centre a trust culture and deference to knowledge, codified in peer review, is potentially very significant. There is an opportunity to share its benefits with wider society within the debates about scientific evidence. This discussion paper encourages scientists, and others, to take that opportunity and to explore how an understanding of peer review can contribute to society's judgements about the results of scientific research.

Section 1
A cultural challenge for peer review?

Debates about scientific research

1.1 *"The dissident, so-called whistleblower, however dodgy the research on which his or her 'evidence' is based, is afforded massive attention; it is taken as axiomatic that the mainstream, evidence-based government-endorsed view will be self-serving and wrong. More than half of us believe the medical profession is divided over the health risks of MMR; in fact, it is more or less united that there is no risk."*[5]

This was how the current popular treatment of scientific evidence was summed up by the commentator Will Hutton in a British newspaper in 2003.

1.2 In recent years, public discussion has frequently been dominated by debates about the findings of scientific research, particularly when research has a policy implication. Claims that the Measles, Mumps, Rubella (MMR) vaccine could cause autism have generated several years of debate, during which scientists, clinicians and health officials have presented many studies indicating that there is no discernible risk of autism from the MMR vaccine. Over the same period, other scientists have been caught up in contesting claims about research into alleged risks posed by genetically modified (GM) crops and food. Physicists have found themselves trying to respond to claims that non-ionising radiation from mobile phones caused brain tumours and disturbed sleep. Endocrinologists and toxicologists have been engaged in responding to announcements that research has demonstrated a link between pesticides in food and damage to human health. These are just some of the more sustained debates that have circulated against a rapidly moving background of research claims about health and environmental risks, including plastic softeners, hormone replacement therapy, and silicone-gel-filled breast implants.

1.3 'Bad news' assertions have not been the only source of publicly contested claims about research findings. Announcements about the imminent production of pig organs for human transplantation were seen by many scientists as premature and unsupported by research. Scientists were also almost unanimously sceptical about claims that human reproductive cloning was about to succeed, which provoked concerned reactions from politicians despite the lack of evidence to support the claims.

1.4 As stories about environmental risks, health risks, and new research findings accumulate, scientists and medical practitioners have expressed frustration that unsubstantiated claims are treated with the same seriousness as more reliable studies, and that in some cases evidence is apparently ignored altogether. People who rely on the media and public bodies to interpret findings describe themselves as "confused" about what to believe. Some have become very sceptical of new claims, particularly those concerning health risks.[6] Doctors experience the opposite phenomenon: they complain of surgeries full of "the worried well"[7], resulting in part from "scare stories" and unfounded claims. Organisations charged with providing public health services and developing environmental and health policies are also frustrated about conflicting claims and the influence of unreliable research.

[5] Hutton, Will (2003) 'Facts are free, opinion is sacred.' *The Observer*, 17 August.
[6] See Philo, G. (ed.) (1999) *Message received: Glasgow Media Group research 1993-1998*. Cambridge: Longman.
[7] Le Fanu, J. (1999) *The rise and fall of modern medicine*. London: Little Brown & Co. p.xix.

1.5 What is often missed in public discussions of these kinds is the fact that scientists subject their work to a system called 'peer review', to determine which research papers qualify for publication in scientific journals.[8] Formalised peer review began with some journals in the 18th century and scientists have used it as a systematised method of quality control for the last 100 years.

1.6 To succeed in getting a paper published, scientists must present their findings clearly for review by experts in their field, chosen by a knowledgeable, neutral journal editor. This process is the accepted route for making findings public: only once a paper has been reviewed, revised and published does the wider scientific community take it seriously, examine it and evaluate its contribution. For new work to be incorporated into the body of scientific knowledge, researchers must first convince those knowledgeable in the same field about the plausibility of their claims and the appropriateness of the research methods and evaluation techniques they use.

1.7 The peer-review system means that statements made by scientists in published papers are unlike other kinds of statements or claims. For example, claims made by politicians, newspaper columnists, think tanks or campaign groups are not systematically subjected to independent quality review beforehand.

1.8 Consequently, scientists usually make a distinction between claims that have been peer reviewed (and published) and those that have not. Peer review ensures that the research has been evaluated by other scientists with appropriate knowledge. There has been an opportunity to spot mistakes and omissions for example, as well as to clarify what the findings show. It also means that the results are then available to the wider scientific community, so that others in the field can consider the work and try to replicate the findings, or use them, in conjunction with other work or results, to reach further conclusions.

1.9 Scientists never regard peer-reviewed research as beyond criticism. Over one million papers are published in peer-reviewed scientific journals worldwide each year. Peer review of a paper is just the first stage: a hypothesis that survives this first test must go on to be re-tested, and judged against other work in the same area, and for its coherence with work in related areas. Some of a paper's conclusions will be hotly disputed or further research will show that they need to be revised as more data are acquired. The quality of peer review can also vary, so scientists treat work in some publications as more significant than others. Scientists rarely draw firm conclusions from just one paper or set of results, but consider the contribution it makes in the context of other work and their own experience. However, because peer-reviewed results can be treated as plausible and scientifically accountable, peer review is an essential dividing line for scientists to judge what is scientific fact and what is speculation.

Science in a challenging environment

1.10 Traditionally, peer review has been important mainly for scientists, who need to put their trust in others' work in order to develop their own. Some policy-making bodies and science writers pay attention to the extent to which claims are backed up by peer-reviewed work. For the rest of society it is the authority accorded to leading scientists that has often tipped the balance of public discussions.

1.11 In British society today, however, science has become the subject of many wider political and public controversies. The authority of scientists is much more open to question[9], and critics increasingly emphasise how research was funded and who conducted it, with the thought that this will bolster or discredit particular claims, and with little consideration for its scientific merits. The personal histories and interests of researchers, their funding sources and their personal appeal are

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[8] Peer review is also used by many scientific funding bodies to assess proposals for future research. However, the focus of this report is solely on the use of peer review to determine which research papers should be published.

[9] See Reilly (1999) on public understanding of the BSE crisis. See also: MORI (2001) *The role of scientists in public debate,* research conducted by MORI for the Wellcome Trust.

often treated as more significant than whether their work has been peer reviewed and at what level. This is particularly the case when research is funded to any degree by corporations. Just under half of the UK's research and development work is funded by private enterprise.[10]

1.12 The confusion about what scientific evidence tells us and about what is credible in the light of available evidence may be exacerbated by non-reviewed claims that are presented as 'scientific', whether by scientists going beyond their reviewed findings, or by others who advance claims that *appear* to be scientific in the thought that these may have more public impact.

1.13 For example, one of the first claims that mobile phone emissions are unsafe was made in 1998 by Mr Roger Coghill, a self-employed researcher, who had previously argued that mobile phones cause headaches and memory loss. In 1998, he said that the waves that phones produce could damage the activity of lymphocytes in the body's immune system. Coghill published these claims himself and released them to the media, rather than submitting them first for peer review. Many other studies have failed to point to damage specifically of the body's immune system as a result of mobile phone usage, before or since. Despite the lack of corroboration, Coghill's claims were widely reported, and fuelled discussion about mobile phone safety. Between 1998 and 2003, he was cited in 119 printed news publications in the UK, most of which made no reference to the lack of peer review of the research or to the fact that other, peer-reviewed research did not corroborate the hypothesis.

1.14 A similar attitude to scientific expertise was displayed in claims about the MMR vaccine and autism by Mr Paul Shattock, a pharmacist who set up the Autism Research Unit at the University of Sunderland, which advocates the view that autism is a metabolic disorder. In June 2002, he claimed to have identified a group of children whose autism resulted from the MMR vaccine. The research, based on the claim that children with bowel disease have abnormal levels of indolyl acryloyl glycine in their urine, was not published in a scientific journal but made headlines and Shattock was cited 41 times in 2002 in newspaper articles about the safety of the MMR vaccine.

1.15 In April 2002, the world media reported research results from Stockholm University and the Swedish National Food Administration that suggested that people were at risk of cancer from ingesting acrylamide from heated fatty foods. The reports provoked "serious concern" from the World Health Organisation, the UK Food Standards Agency and cancer charities, and reports of this concern in turn added to speculation about dangers, for example to children from eating crisps. According to a BBC report, *"the research was deemed so important that scientists took the unusual step of going public with their findings before the details had been officially published in an academic journal."*[11] Later studies found no relationship between acrylamide-rich food consumed and incidence of kidney or bladder cancer, and possible beneficial effects on bowel cancer rates.[12] It is likely that there will be further scientific contributions to understanding of acrylamide. However, playing out such debates about early findings in the form of public announcements and health warnings has promoted confusion that reduces the effectiveness of public health information.

1.16 The demand for pre-scientific news seems to encourage a culture that erodes the distinction between expertise and subjective experience. As a public and a news readership, we seem to be attracted to what has *not* been endorsed by experts, perhaps wanting to believe that authentic information is that which does not conform to accepted ideas. At a popular level, this cultural move might be captured by the refrain of many campaigners and advocates of 'alternative' therapies and theories: "I don't care what the experts think, I know that my child has been affected…". The publication of claims without reference to whether they have been reviewed suggests that there is little recognition of the significance of peer review, and that some believe that "going straight to the public" underlines the importance of claims.

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[10] Office for National Statistics (2003).

[11] 'Bread and crisps in cancer risk scare'. *BBC News Online*, 25 April 2002.

[12] Mucci *et al.*. (2003) 'Dietary acrylamide and cancer of the large bowel, kidney and bladder: absence of an association in a population-based study in Sweden'. *British Journal of Cancer,* 88, 84-89.

Can peer review help society navigate the constant stream of science news?

1.17 Since many of the claims about the findings of scientific research have serious implications for matters ranging from global policy to family health, it is regrettable that scant attention is paid to the widespread use of peer review by scientists, with all the invested hours of expert scrutiny that it represents. That so little is known about it suggests that there has been a missed opportunity on the part of scientists, both to explain how scientific findings are shared and advanced, and to equip a wider public with a more reliable tool for assessing the claims put before them.

1.18 In November 2002, a Working Party on Peer Review of Scientific Papers was convened by Sense About Science[13], a charitable trust promoting public use and awareness of scientific evidence. The Working Party's aim was to explore ways of equipping a wider public with an understanding of peer review and the relative merits of research claims in the public domain.

1.19 From the outset, the Working Party recognised that scientific peer review has, traditionally, not been a subject of general public interest. It has been seen as a technical topic or a set of procedural issues for organisations concerned with science publishing.

1.20 There are concerns within the scientific world about the challenges of managing peer review. However, peer review is not only a technical issue. It is central to establishing which scientific claims should be trusted. Some contributors to these debates are directly critical of the peer-review system in scientific publishing, arguing that it is used by the scientific establishment to screen out unorthodox work or troublesome findings. Some campaigners on issues as diverse as microwave emissions from mobile phones, genetically engineered crops, homeopathic treatments, chemical testing and the use of illicit narcotics see peer review as a cover for, rather than a corrective of, poor science.

1.21 More widely, the appeal of questioning conventional wisdom often encourages commentators to overlook the distinction between research that has been peer reviewed and that which has not. For example, amid controversy about the alleged links referred to previously between the MMR vaccine and autism and between mobile phone emissions and cancer, many contributors to public debate ignored the very different levels of scientific peer review and credibility of competing claims. Yet the significance of the issues clearly warranted a comment. Without it, the public at large was denied important means for evaluating what was being said. At least two social surveys have indicated that there is a public demand for greater discrimination in the quality of scientific information that is reported.[14]

1.22 However, the Working Party acknowledged that very little effort has been made to draw out the social implications of peer review. Specifically, these were identified as:

- how peer review influences the quality of scientific claims reaching the public domain;
- what the social effects are of publicising unscrutinised scientific claims, for example about risks to health or the environment;
- the insights that peer review provides into the way that scientific knowledge advances, a subject for which there is a growing audience given the popular interest in scientific controversies;
- peer review's potential value for a wider public as an indicator of the plausibility of research claims;
- an explanation of how and why peer review is conducted.

[13] See Appendix 6.
[14] Hargreaves *et al.*. (2003); MORI (2004).

Why should the public be interested in peer review?

1.23 This was a question that the Working Party revisited frequently. It is clear that, while the extent of public interest in 'how science works' is hard to gauge, there are already many groups of non-scientists who are required to, or desire to, make judgements about science, for professional, political or personal reasons.

1.24 In this respect, peer review is germane to the wider questions people ask when making judgements of science issues, such as 'whose claims can we trust?' and 'which study is right?' The many non-scientists who read material from the Internet, or other sources, about health risks or new treatments for illness, might appreciate some indications about how to weigh up the enormous quantity of material available.

1.25 The Working Party noted at the outset that the 'public' reaction to particular research claims, and what can be trusted, are often shaped by debates between particular commentators rather than among the public at large. A growing number of groups and organisations have made questioning the validity of scientific claims, particularly about the safety and risk of certain technologies, a part of their own agenda.

1.26 It is to this public, ranging from those who declare antagonism towards the process of science to those who promote understanding of how science advances, that this Working Party report addresses the discussion about peer review in Section 2. In addition to scientists themselves, the following groups were identified as having a significant role:

- scientific bodies, research organisations and science communicators;
- MPs, Government and others with an interest in scientific development and policy making;
- science educators, from primary to higher education;
- commercial organisations, and their regulators and advisers;
- organisations concerned with public health and risk, nutrition, environment, research into specific diseases, and other such groups that use or respond to scientific evidence in the pursuit of their work, including those interested in the 'politics of science'.
- all public sources of information about scientific results and evidence (general media, *Internet* sites, family health literature, lifestyle advice, and advertising).

1.27 Discussions about the need for scientists to recover public trust often emphasise more detailed regulation of scientific work. However, while it is true to say that science now develops in a climate of public scepticism about established sources of information, there is not a spontaneous and focused public demand for specific reforms to which scientists can respond. The Working Party judged that attempts to address suspicion by seeking changes in the practice of peer review might be misplaced or premature. Such action would neglect the opportunity to explain the process, and could overgeneralise accusations about peer review raised in the heat of particular controversies.

1.28 The challenge for the Working Party was to consider peer review from a social perspective and to engage the groups identified above in explanations of how peer review 'works' for science and society. In this sense, it took as its starting point the idea that wider public interests might be served by the scientific interest in peer review, rather than the more prevalent assumption that they necessarily conflict.

1.29 Members agreed that the best aim for a discussion about peer review would be a *cultural shift* in the treatment of scientific claims. The Working Party has looked for ways to promote a culture where people bringing research claims to the public domain feel obliged to pay greater heed to expertise and evidence. In doing this they can encourage the public to ask more effective questions about the scientific information put before them.

Specifically, the Working Party has sought measures that:

- help to explain the practice of peer review to a wider public;
- explain how scientific findings of sufficient quality, validated by peer review, are essential for the policy and decision-making process;
- popularise the benefits of ensuring that work is judged by other scientists before it is made public;
- contribute to clearer understanding of the status of research claims made in the media, on the *Internet* and in other public domains;
- build awareness among scientists and commentators about the social consequences and costs of disregarding peer review.

1.30 Deliberations were therefore focused around these social aims, rather than around refining scientific or technical processes[15]. Themes discussed by the Working Party over the past 18 months are listed below.

- What critics of peer review have said and written.
- Transparency and democracy.
- Attitudes to expertise.
- Editorial 'pre-screening', or 'triage', at wide-spectrum journals.
- How scientists might communicate peer review via the media (from proceedings of a session held by the Science Media Centre as part of its 'How Science Works' series).
- The requirements of the financial markets that publicly listed companies make some research results public immediately, and good practice in doing so.
- The social consequences and costs of publicising misleading scientific claims.
- Increased social and political interest and contestation about scientific claims.
- How to explain the 'science publishing scene' to a non-scientific audience.
- Evidence of grantsmanship, institutional promotion and other motives in research reporting.
- Claims that peer review is inherently anti-orthodox or suppressive.
- Recognition of peer review in the formal education system.
- Interplay between peer review and editorial judgement.

1.31 Finally, while the experience and specialisation of the Working Party have been diverse, its members have shared a common view: peer review is a valuable thing and there is a considerable gap between the principles and energetic commitment it represents, and the way it is treated or understood in wider controversies about science. As explained in the following pages, peer review is not simply the best quality checking system. It is more accurately understood as the process of science itself and has by far the longest track record. As one useful account describes it, science is cumulative, often collective, and comprises "a body of knowledge that is logically consistent, testable, and self-corrective." Peer review is fundamental to this as the "process through which scientists test one another's theories and evaluate and criticise one another's research".[16] The following report draws attention to the need to establish how an understanding of peer review can contribute to society's judgements on which scientific research to trust.

[15] The Working Party confined itself to the issue of peer review *of scientific papers in the public domain*. This is distinct from peer review of grant applications, which, while the subject of similar discussions, is bound up with funding policy, so more usefully addressed elsewhere. It is also distinct from the scientific analysis of confidential material, such as commercial or military-related papers. Other projects addressing peer review are listed in Appendix 4.

[16] Murray *et al.*. (2002) p.149.

Section 2
A guide to peer review and scientific publishing

What is scientific peer review?

2.1 **Scientific peer review is the evaluation of scientific research findings or proposals for competence, significance and originality, by qualified experts who research and submit work for publication in the same field (peers).**

2.2 Most commonly, peer review is used by the editors of scientific[17] journals, who ask well-qualified experts to provide written opinions about research papers that have been submitted for publication. On completing a project or stage of work, researchers write up their results into a paper presenting their experiments, findings and conclusions, and send the paper to a journal to be published. Scientific papers are sometimes written by individual scientists, but frequently the authors are groups of scientists who have worked as a team on the research.

2.3 The journal's editorial staff selects experts in the same field of work who are qualified to judge the scientific merits of the paper – its competence, significance and originality – and who are themselves involved in research and publication and subjected to the same discipline (peers). For some journals the editorial staff is employed by the journal and for others the work is done by professional scientists who act as editors as an additional activity. The selected experts, known as referees (or reviewers) review the paper and judge such things as whether the design and methodology of the research were appropriate, the data are plausible and the paper is written clearly. The referees are asked whether the paper acknowledges prior work, whether it is suitable for the journal's scientific readership and whether it should be published in its current form or with revisions. (See Boxes 1 and 2.) Sometimes peer review is used to decide which papers should be delivered at scientific conferences.

2.4 Many funding bodies ask scientific peers to assess whether proposed research is likely to contribute something new and significant, and whether it uses suitable expertise and methods. Peer review helps to keep funding decisions objective.[18] However, our focus here is on the use of peer review to provide corrective feedback on papers describing research results submitted for publication. This is the process through which research findings become formally public.

Why is peer review used?

2.5 Peer review is an expert advice system to help editors of scientific journals in judging the scientific value and plausibility of research papers they receive, and deciding which should be published. This helps to make journals a reliable source of new information and discoveries for other scientists to investigate or build on.

2.6 We can think of peer review as "a form of scientific quality control" or "an error detection system".[19] But it is a much more critical and dynamic process than many other forms of quality regulation. It is based on using the scientific judgement of other experts who are also trying to advance knowledge in the area as to whether work is competent, significant and original. Scientific

[17] Peer review is also used by many other academic journals, for example in the social sciences and humanities, to determine whether work is sufficiently competent, significant and original to merit publication.
[18] See the peer review guidelines of the Association of Medical Research Charities (1993).
[19] Science Media Centre (2003) *Communicating peer review in a soundbite*, p.1.

publishing requires very specific and substantive feedback about each paper, not just a 'yes' or 'no' decision. Referees might notice mistakes in calculations, or the absence of sufficient safeguards for checking results, for example, or inappropriate statistical tests. Whether research has been conducted by distinguished scientists in an eminent laboratory or by less established teams, it is subject to this scientific scrutiny. A useful summary of peer review has been provided by a group of social scientists:

> "*Researchers can make mistakes that render their conclusions worthless; and even when they conduct their research properly, they are also all too likely to exaggerate its importance. A review by scientists familiar with the subject matter is likely to detect mistakes and to qualify exaggerated claims. Thus peer review is important because it helps determine whether a study's substantive conclusion follows logically from the procedures used to arrive at it and whether the conclusion makes a significant contribution to our knowledge.*"[20]

2.7 Papers are sent to scientists to review because of their abilities to make a scientific assessment. Without the peer-review system, which research findings come to prominence would be arbitrary. Personal attributes and social influence or power would be more likely to play a role. Papers would be published regardless of whether experiments are poorly constructed, control groups inaccurately devised or the data insufficient. Every scientist would have to navigate so much unfiltered material that they would have time for little else. Scientists would have no choice but to resolve this arbitrariness because they depend on published results they can trust, in the same way that people on the sixtieth floor depend on the lift working – scientists would reinvent peer review.

BOX 1 Referees usually comment and make recommendations on some of the following:

1. Significance:	Are the findings original? Is the paper suitable for the subject focus of this journal? Is it sufficiently significant? (Is it a 'me too' paper; is it 'salami slicing?[21])
2. Presentation:	Is the paper clear, logical and understandable?
3. Scholarship:	Does it take into account relevant current and past research on the topic?
4. Evidence:	Are the methodology, data and analyses sound? Is the statistical design and analysis appropriate? Are there sufficient data to support the conclusions?
5. Reasoning:	Are the logic, arguments, inferences and interpretations sound? Are there counter-arguments or contrary evidence to be taken into account?
6. Theory:	Is the theory sufficiently sound, and supported by the evidence? Is it testable? Is it preferable to competing theories?
7. Length:	Does the article justify its length?
8. Ethics:	In papers describing work on animals or humans, is the work covered by appropriate licensing or ethical approval? (Many biological and medical journals have their own published guidelines for such research.)

[20] Murray *et al.* (2002) pp.148-149.
[21] 'Me too' papers are those that are predominantly repetitious of previous work, albeit reporting different experiments. 'Salami slicing' refers to dividing a corpus of research work between several minimal papers at the threshold of acceptability, rather than presenting it in one.

2.8 In wider society, we also depend on peer-reviewed work but in a way that is not so obvious. If a close relative is seriously ill, we assume that they will be treated according to expert knowledge. We would consider it unacceptable if it transpired that they were treated on the basis of an arbitrary free-for-all, where the distinction between reliable expertise and ignorance, incompetence or charlatanism had been left to individual clinicians to assess, on a paper-by-paper basis.[22]

The relationship between the referees and the journals

2.9 Editors select referees who have verifiable expertise, usually scientists who have recently published papers on related subjects. One of the roles of editors is to keep abreast of scientific publications so that they have a constantly developing pool of scientists who can be asked to review papers that are submitted to the journal. The editor assigned to deal with a paper asks appropriate experts – usually two but often more – to review it. Sometimes an editor, on receiving the referees' assessments, will seek further opinions, for example if there is strong disagreement between the referees. Editors build up knowledge and select people who deliver – in good time – to the required standard for the journal.

2.10 Scientific referees generally do not get paid. A few journals use small incentives to reward referees who return comments quickly. Reviewing can involve a lot of work, especially if scientists are referees for several journals, and this work is often done in their spare time. Scientists accept this as part of their scientific activities. They often have a sense of commitment to the journal's output quality or to the learned society that publishes the journal.

2.11 Confidentiality is an essential part of the undertaking in reviewing scientific papers. Referees should not keep copies of the papers they are sent for review, nor reveal them to anyone, nor use any part of their content, without prior permission.

What happens to a paper once it has been reviewed?

2.12 On receiving the reviews, the editor decides whether the paper is suitable for publication. If it is judged to be potentially suitable for publication, this will usually be dependent on whether the author responds satisfactorily to the referees' comments. The editor's response is sent to the author with details of what the referees have said. There are five kinds of basic response:

i. The paper is accepted as it is. (This is relatively unusual nowadays.)
ii. The paper is accepted with minor amendments. (The editor can check that these are made and it does not need to go through peer review again.)
iii. Major revisions are proposed and acceptance is dependent on whether the author can deal with those satisfactorily. (The paper may be sent out again for peer review.)
iv. The paper is rejected but the author is advised to publish it elsewhere.
v. The paper is rejected and further submission of it to any journal is not advised because the work is seriously flawed.

2.13 Some journals send referees each other's comments together with details of their decision about publishing the paper. This is a relatively recent development, facilitated by email. It provides useful feedback and extends accountability among peers; all journals should adopt the practice.

[22] Harnad (2000).

BOX 2 Typical examples of referees' comments

"The experiment has not been repeated sufficiently to allow this statistical test to be used."

"In general the experiments to address these hypotheses are carefully done, but I believe the data are greatly over-interpreted and the authors neglect alternative explanations for their results as well as precedents in the literature that would provide a different model."

"The explanation of the null hypothesis is not clear and this is a very important point: what is the baseline?"

"Since the audience are biologists rather than chemists I think the author should supply the chemical structures and if possible describe the chemical reaction which gives rise to them."

"How do the authors exclude the possibility that most of the two proteins are sorted to protein storage vacuoles in endosperm by another mechanism?"

"The statistical analysis, which underpins the major conclusions, is flawed. The authors state that the difference in plasma insulin levels between the experimental and control groups reached statistical significance (i.e. $p<0.05$). However, the small print in Table 2 shows that the t-test that they applied was one-tailed, which would be appropriate only if there were clear reasons to expect a deviation from equality in one particular direction. Since there was no such hypothesis, a two-tail test should have been used. By my calculation, this raises the probability of the observation to $p=0.07$ and the result can rightly be described as no more than a trend. Since this finding is pivotal to the paper, I strongly advise that the authors should extend the study, presumably with a new, much larger sample, in order to test properly whether this result is secure, before publishing it."

"This reagent will give poor resolution and there and therefore the claims are not justified."

"This experimental design will not detect false positives"

"A delicate subject is the data presented in Figure 4. It seems to me that I have seen these exact data before, albeit in the form of tables. If this is true (I do hope it isn't), such a work philosophy is highly unethical."

"It is unacceptable that the authors do not refer to the extensive work in this field from --- laboratory. Since those papers describe very similar results, they are not only relevant, but they also render the present study much less original than the authors claim. With no special reason to justify the publication of a replication, I think that the paper should not be published, certainly not in a journal for which there is much competing material."

"The authors cite the earlier paper of *A* (2001), as the basis of their experimental design and interpretation, but do not refer to the widely accepted failures of *B* (2002) and *C et al.* (2002) to replicate those findings. This contradictory evidence should be cited, and, unless the authors can adduce a convincing argument for rejecting these contradictory results, I cannot see how their own paper can be accepted, since it rests so fundamentally on the results of *A*."

"… the paper is extremely dense and data-rich, and is much longer than is usual for this journal. In my opinion the latter part of the Results should be removed, together with Figs 11-13. These data are rather preliminary, perhaps not as conclusive as the authors imply, and in several respects unsatisfactory."

"This study is topical, highly original and technically impressive. Although the results are unexpected, and not entirely easy to interpret, I think that the paper should be published with high priority. It will have considerable impact in the field."

Rejection

2.14 Some journals reject a proportion of papers before sending them out to referees because they do not fit the emphasis of the journal. This is called editorial ‘pre-screening’. Journals that cover a range of subject areas receive many papers and use pre-screening more than others. Rejection at this stage does not imply that papers are of poor quality; many go on to be published in other, high-quality journals.

2.15 If a paper is rejected *following* peer review, it may be submitted to a different journal, perhaps one with a more specialised readership or a stronger interest in the paper’s topic. If the paper has been rejected because of the low importance or quality of the work, the author might publish it in a journal with lower quality standards, and hence also less influence in the field.

2.16 In the vast majority of cases, when a paper is rejected, authors do submit and publish the work in some form. Particularly with the rapid growth of online publishing, the range of journals in some fields of research is very wide and most papers find an outlet at some level. In order to understand this process, it helps to have a map of the ‘scientific publishing scene’. (See Box 3.)

The problem of time delay

2.17 If a paper is revised and resubmitted it can take a very long time to publish. Even straightforward papers may not be published in much under a year from first being written. This sounds like an incredibly long time — you can change jobs, get married and start a family in the time it takes to get a 6-page article published! There are several improvements that could be made to avoid wasting referees’ time and speed up reviews[23], and these are currently being considered by science publishing bodies[24]. Some journals are improving the time between a paper being accepted and appearing in the journal by making the refereed draft available online beforehand (this is the final version of the paper that has been amended by the author following referees’ comments and accepted for publication); and also by introducing a fast-track approach for very high-quality, original work. However, whatever improvements are made, peer review and publication times will probably still seem long to our fast-turnaround, 24-hour-news society!

2.18 Editors do try to avoid delays and normally ask for referees’ reports to be returned within two to four weeks. However, harnessing appropriate expert judgement, evaluating and developing a paper on new scientific findings, takes time on all sides – editors, referees and authors. It is as well to acknowledge this, because, as a society, we do need to take a view on the value of the peer-review process.

2.19 Science and health scares are sometimes caused by research results that have been put before the public prior to being peer reviewed. The justification given — that findings were ground-breaking or of too great a public interest to wait for peer review — might seem reasonable to the scientists concerned, to their sponsors, or to the reporters or campaigners revealing the claims. However, it could be looked at another way: if a research claim is so significant that it might transform our understanding, for example about what is a cause of illness, or influence regulation or behaviour, then it is all the more important that the research is on sound foundations tested by peers. The time taken to review research is frustrating, but must be considered against the potentially enormous costs to science and to society of promoting research findings that turn out to be scientifically weak or to contain serious errors.

[23] For example, to charge authors a small submission fee, refundable if the paper is accepted, to discourage sloppy papers and multiple submissions.

[24] See Appendix 4.

BOX 3 The scientific publishing scene

Types of journals

Internationally, there are 11,370 active-status refereed journals in scientific subjects.[25] Around 8,500 of these are listed on the Web of Science citation index and these are referred to as 'the peer-reviewed literature'.

There is a hierarchy of journals, from the highest quality, with rigorous peer review and usually the highest rejection rates for their respective fields, to a virtual vanity-press[26] at the bottom. When scientists refer to the 'peer-reviewed literature' they are not usually including low quality journals, even though these may have some semblance of peer review. A journal's size does not indicate reflect its quality: the highest standards of peer review are also found among small, specialised journals.

Journals are evaluated using 'impact factors', which are based on how often their papers are cited in other journals (citations).[27] Use of citations is sometimes criticised because they may not always indicate scientific value.[28,29] In general, what matters to scientists is a combination of the journal name, its track record and speed of publication.

There are **journals with a wide readership**, which represent very few of the total number of journals but they are the most well-known. Some cover several fields of scientific research, such as *Nature* and *Science*, and there are also wide-spectrum clinical journals, such as *The Lancet* and the *New England Journal of Medicine*. Peer-reviewed papers are only part of their content: up to between one-third and two-thirds of each issue is made up of comments, news and features, which are not usually subject to peer review.

By far the largest number of scientific publications are **basic research journals** (mostly biomedical). The content of these is almost entirely peer-reviewed papers, with little in the way of editorials or other types of articles.

The publishing business

There are, in the main, four types of journal ownership:

- commercial publishers, such as Reed Elsevier, some of whom own many scientific titles;
- scientific publishing groups, which run as commercial brands, such as *Nature*;
- academic publishers, either with their own publishing companies (for example, Portland Press is owned by the Biochemical Society), or who subcontract their publishing to commercial companies, such as Blackwell;
- Other scientific groups and associations, some of whom run low-cost online journals.

Journals are mainly funded by subscriptions. Wide-circulation journals also receive significant advertising revenue.[30] The scientific journal market is estimated to be worth several billion pounds (sterling) per annum[31]. At the other end of the financial scale, some journals don't make enough money from subscriptions to cover costs, so are subsidised, for example by the use of staff at learned societies or by the income that is generated by more popular titles.

Staff

At high-circulation weekly journals, editors and editorial staff are usually paid, whereas many basic research journals that publish less frequently are run by academic scientists who receive little or no payment.

A note on non-primary sources

There are magazines about science, such as the *New Scientist* in Britain, which regularly do a very good job of making specialised scientific information accessible to a wider public. They report research claims from work that is peer reviewed and also from some that is not. They are not themselves peer-reviewed journals.

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[25] Figures compiled by Yvette Diven for Ulrich's Periodicals Directory 29 August 2003.

[26] Vanity-press refers to low-cost publishers with low standards of editorial control. They serve the needs of authors wanting to get their work into print rather than the needs of any readers.

[27] Produced by the Institute of Scientific Information in the US and available on the Journal Citation Reports database.

[28] Citation counts can reflect the size of a research field and bad papers may be cited while being criticised. For a range of views, see Seglen (1997); Lachmann and Rowlinson (1997); Lee *et al.* (2002); and Ray *et al.* (2000).

[29] There is a concern among some scientists that publishing poor but controversial papers could be used by competitive wide-spectrum journals to increase their citations ratings.

[30] A typical science and technology journal's revenue breakdown is: 5% advertising, 85% subscriptions, 6% back copies, 1% offprints/reprints, 1% permissions and 2% from other sources. Pira International (2002) p.37.

[31] Pira International (2002).

2.20 There is a different issue of time delay in relation to papers that have been reviewed and accepted for publication, but that have to be held back by the journal until there is a suitable space for them. Authors often discuss the findings in these papers publicly before the paper appears because the final version has been agreed at that point.

Referees' motivation

2.21 To people who do not work in scientific research, it may seem strange that scientists are willing to spend hours reading through papers in great detail, without payment! But while there may not be a financial reward, referees feel strongly inclined to 'do their bit' and this seems to be for a number of reasons.

2.22 It is a marker of a scientist's own scientific contribution, as a researcher and author, to be considered suitably expert and the peer of others publishing research in the field. For the majority of people involved in research and discovery, sharing knowledge and expertise is important. Scientific journals are, by and large, a dialogue between scientists, to share ideas and debate new findings. Considering the findings written up in a paper, and pondering the questions it raises, can be as interesting and challenging as any other aspect of scientific endeavour. Reviews are one way that scientists contribute to this exchange and ensure that it is kept at a high enough quality to be genuinely useful. Journals would quickly become of little use to any scientist if the material in them was full of mistakes or hard to follow. More specifically, this is what is meant by scientific publication being public and self-correcting: if a journal's standards drop, it loses both its authors and its readers to competing journals with higher standards.

2.23 Referees depend on others being willing to review their own papers attentively and objectively, and understand how valuable that critical scrutiny can be in making sense of their own results and improving their presentation for others.

Do scientists use peer review to pursue their own personal agenda?

2.24 In recent years, it has become more common for some commentators on science to draw attention to the possible misuse of peer review by referees. These accusations highlight three areas of concern: competition over publication, grants and commercial interests; abuse of privileged information; and personal prejudices. Problems may arise in each of these areas, although there is little evidence that they are frequent. Where unacceptable behaviour occurs, it must be challenged.

Competition over publication, grants and commercial interests

2.24.1 There is competition to be the first to publish and competition for grants. This is why peer-reviewed publications ask referees to declare possible conflicts of interest. A referee might wish to publish a similar paper and might seek to improve its chances by holding up or advising against the publication of results from competitors. A referee might be applying for a grant to do similar work and not wish to see publicity given to competing institutions.

2.24.2 Although these are *possible* conflicts, the fact that referees are in competition for a grant, for example, may not mean that they cannot offer valuable insights about another scientist's work. In such cases, many scientists report that they tend to be more scrupulous than usual to ensure that they are not being ungenerous or subjective in their review.

2.24.3 Commercial interests also need to be considered. A referee might, for example, have a significant share-holding in a company whose product is called into question by a piece of research. It is important that anything of this nature is declared by referees immediately on receiving the paper.

2.24.4 Authors and referees should be expected to complete statements about their interests and possible conflicts by all journals.[32] Where conflicts of interest are declared, an editor may decide either to

[32] For examples of these, see Appendix 2.

use a referee and to weigh their comments accordingly or to seek another or an additional referee. Editors of specialised journals often know a lot about the referees that they use, having used them over time and formed opinions about their reliability and standards.

2.24.5 Authors are often given the opportunity to name anyone to whom they feel their papers should not be sent for review because of conflicts of various sorts. They are told what referees have said. They can challenge an editor if they feel a publication decision is biased. It is worth noting the comment of more than one experienced editor that, in such cases, authors often guess the identity of referees incorrectly!

Abuse of privileged information

2.24.6 Papers are sent to referees in confidence. They may not use any part of the paper, retain copies or show it to anyone else, without permission. In some research areas, such as microbiology, the speed at which new insights can be adopted by other scientists is very fast and research papers may contain information that puts the reader immediately at a potential commercial or research advantage.

2.24.7 If a paper has *commercial* implications, these are for the author and associates to assess when deciding on a suitable time to publish in relation to protecting new discoveries by a patent or licence. Research publication is, after all, about publicly reporting findings for the use of fellow researchers.

2.24.8 Papers may provide a *research* advantage to the referee. (Referees have to seek permission for any use of the content, and failure to do so is considered serious misconduct by journals and by many employers.) In the main, authors publish because they *want* other experts to read and comment on their work, so long as they are acknowledged as the author of the paper.

Personal prejudices

2.24.9 Referees might recommend rejection of a paper because they do not agree with it or because of personal prejudices, rather than because the work is weak or clearly flawed. Alternatively, they might recommend acceptance of a paper because it backs up their own approach, even if there are questions about its quality or originality. Competent editors minimise the chance of this affecting publication decisions by selecting referees carefully and using more than one. Editorial correspondence with referees is a matter of record and can be challenged.

2.25 It is worth remembering that the mere observation that 'scientists could misuse peer review' does not establish the factual claims that 'scientists do misuse peer review'. Authors are committed to publishing their work and are liable to complain if they feel that criticisms are unreasonable, or to go elsewhere if there are unjustified delays in reviewing their papers. These realities are a further discipline on the behaviour of referees.

2.26 In general, the system of peer review does not facilitate, but rather discourages or exposes, abuses of trust. The fact that referees are obliged to provide a review that will be scrutinised by an editor, usually shown to a second referee, and relayed to the author is a considerable discipline. Editors have an interest in ensuring that their referees use agreed criteria (see Box 1) for assessment, both to decide what is worthy of publication and to avoid future embarrassment.

Do journal *editors* give priority to particular kinds of results or newsworthy 'stories'?

2.27 While editors have to balance the interests of readers, authors, staff, owners, editorial board, advertisers and the media, "editors' decisions to accept or reject a paper for publication should be based only on the paper's importance, originality, and clarity, and the study's relevance to the remit of the journal".[33] Furthermore, journals are public. Their quality is in turn assessed by readers and authors, who can then vote accordingly (by defecting to better journals).

[33] Committee on Publication Ethics (1999) 'Guidelines on good publication practice', *The COPE Report*, Section 8.

'Negative' results

2.27.1 It is often said that journals turn down research if the results are negative. There is some confusion here about what makes a result 'negative' in scientific terms. Critics have taken it to mean those results showing *adverse* effects of particular technologies, for example that a chemical is harmful to health. By contrast, when *scientists* say that negative results are rarely published, they mean that many studies that have no clear result, that fail to confirm previously demonstrated effects, or that find no effect, are less likely to be published (which does present some problems, for example for developing overviews of clinical trial data). They do not mean that papers are rejected because their findings have negative social or business implications, such as indicating that some process or product is harmful. In fact, these kinds of findings are regularly published and there are whole fields, like toxicology, that are devoted to reporting such effects. Scientific peer review helps to ensure that plausible results are published and that editorial decisions are not prejudiced by social or commercial aims.

Seeking to make news

2.27.2 Some journals promote the studies that they publish to the general media. Science commentators have raised concerns that, in a competitive publishing world, news journalism considerations may trump the criteria – competence, significance, originality – on which peer review is based.[34] It is to be expected that when journals publish articles about new discoveries these are reported more widely. For a handful of wide-spectrum journals, though, competition for news attention does appear to be influential. They sometimes tell authors not to promote their work in other ways before the paper is published and they use embargoes to encourage the timing of media discussions to suit the date of the journal's publication. Some scientists suspect that papers are 'pre-screened' for newsworthiness but this is more difficult to determine, because originality and newsworthiness may often coincide.

2.27.3 However, at the reviewing stage, newsworthiness considerations are marginalised. There is no evidence, or even anecdote, to suggest that anticipation that a paper might be of wider news interest influences *referees'* judgements. Referees are usually anonymous: they have no public association with, or credit for, the work they review and they are not involved with journals' promotional strategies. It is important to remember that these concerns are only directed at a small part of the work of a handful of journals. The editors of these journals insist that any desire they have to publish exciting new developments is kept in check by the recommendations of referees who are concerned only with the science.[35] They cannot disregard those recommendations in any but a tiny minority of special cases without damaging the reputation of the journal with authors, referees and readers.

Should referees be anonymous?

2.28 The identity of referees is not usually revealed to the author of a paper. It is sometimes said that allowing referees to be anonymous creates suspicion about the motives behind decisions about whether a paper should be published.

2.29 However, anonymity has a purpose. It helps referees to focus on making a scientific evaluation, rather than being distracted or influenced by the ways in which their comments might affect relationships with others in their field, some of whom may be colleagues. Without anonymity, for example, a young researcher with a career to make might not feel comfortable criticising the work of more senior people. It should be noted that referees are not anonymous to editors. Journals hold referees' reports on file, so there is a record of their identity in the event of a dispute about a paper. Some journals also publish a list of the referees consulted each year, without attributing names to particular papers.

[34] See, for example, Stewart (2003).
[35] Adam and Knight (2002) p.774.

2.30 Some scientists prefer to disclose their names when they referee papers. Editors usually give referees the option of waiving anonymity. Some journals also offer the option of waiving anonymity among referees. There does not appear to be any clear evidence available to show how anonymity, or waiving anonymity, affects the standard or range of scientific papers published.

2.31 Some commentators on scientific practices have suggested that the names of referees should always be published with the paper unless they provide a compelling reason not to, and that unsigned reviews should be given less influence.[36] However, weighting reviews according to the referees' preferences for anonymity would treat the identity of the referees as more significant than the content of the paper and could lead to very uneven criteria in editorial decisions.

2.32 The anonymity issue really comes down to a *practical* matter of establishing what works. What encourages scientists to give time to being referees? What encourages them to write frank, attentive and fair reviews that help editors to make accurate and objective assessments? This is the shared goal in scientific publishing. Although editors vary in their attitudes to the significance of anonymity, they generally think that it elicits candid reviews and it is common practice.

Are some scientists' results suppressed through rejection of their papers?

2.33 Authors occasionally suspect that referees recommend to an editor that a paper should be rejected only because they don't agree with the theory behind the work, or even because they are antagonised by the conclusions. Some campaigners argue that findings which dispute the views of powerful organisations or of the 'scientific establishment' are not published.

2.34 Journals would lose their scientific credibility and readership if they became 'cause-led' or systematically tendentious, instead of using scientific criteria. The principle of peer review applies expert judgement of the competence, significance and originality of scientific work. These standards would be betrayed by adopting an establishment – or an anti-establishment – agenda.

2.35 Claims about suppression rest on a conception of the power to suppress new ideas that has become obsolete with the proliferation of many different types of journals. Failing to get a paper published in the journal of first choice is very common and has nothing to do with suppression. There might be many reasons. The work might not have met the standards required; it might have been too long; it might have been inappropriate for that journal; the editor might decide that a given area had had sufficient coverage for a time; or a better paper on the same subject might have been received. As in other spheres of life, scientists' own status and passion is bound up with their work and rejection from a chosen journal can be demoralising. Most scientific researchers, including Nobel Laureates and those with long and respected research and publishing careers, have experienced rejection of papers. Yet, the number of scientific authors who have built a campaign out of their publishing disappointments is very low.

Is 'maverick' science rejected through peer review?

2.36 In one sense, yes. If 'maverick' science refers to claims that are not based on careful scientific research, this will usually be obvious to referees and they will not recommend publication.

2.37 Recently, the word 'maverick' has sometimes been used in a more flattering way, to suggest that some unconventional work should be exempted from the discipline of peer review. There is a common refrain among critics of scientific practices that Galileo would never have managed to publish his work if peer review had existed. Some would-be scientific authors have likened themselves to the historical figures who made scientific leaps forward against the wisdom of their times, such as Thomas Edison, William Harvey and Charles Darwin. This outlook can be a form of self-reassurance for authors who have not met success when they've submitted work for publication. However, there is a more serious version of the thought: perhaps genuinely ground-

[36] See, for example, Collins (1996).

breaking scientific work is beyond conventional judgement? If so, peer review would be incapable of offering proper assessment of such work. Yet it is hard to imagine what other practices might be used in place of drawing on the expertise of others.

2.38 Sensitivity about misunderstood genius draws upon a very individualistic notion of genius. Moreover, since great leaps forward in science often arise from thorough and brilliant appropriation and transformation of existing knowledge, original science cannot dispense with the background of 'normal' peer-reviewed work.[37] Many developments in scientific understanding are the result of an interactive and cumulative process, as occurred in the *series* of results that led to the sequencing of the human genome.[38]

2.39 In some cases, referees or editors have been slow to spot the significance of a paper submitted, and a journal has missed the opportunity to publish ground-breaking work. This is arguably more damaging for individual journals than for the advance of science since the paper will almost certainly be published elsewhere. While the full implications of such work may be beyond the comprehension of referees — and even beyond that of the discoverers themselves — this does not suggest that peer review is dispensable or damaging. Subjecting work to the scrutiny of scientific peers can help to bring discoveries forward in a number of ways. The peer-review system imposes discipline on researchers to check results and to cross-reference their material with others. This itself can push scientists to think more about their findings and can be a source of discovery.

Does peer review reinforce scientific resistance to change?

2.40 Are scientists inherently resistant to new ideas? Is there a danger that they will use peer review to stick with old methods or theories, screening out and rejecting novel research findings? Certainly it is possible that those who are personally conservative about change may be less open to new ideas. But two observations might be made about this claim. Firstly, there does not seem to be any evidence to show that peer review has been or even can be used to exclude new ideas systematically across all science publishing. (It may preclude views based on little evidence; the onus is on authors to provide some evidence for their claims.)

2.41 Secondly, it is sometimes good to have diversity in how scientists respond to new information in the short term. It means that there is a mix of fashionable and unfashionable approaches, and that knowledge advances carefully as old ideas prove inadequate and new data accumulate, rather than lurching from one finding to another. Consider a comparison with introducing new equipment into medical practice: no matter how spectacular a study's findings, we would want to introduce change slowly, in some hospitals rather than in all, and to observe the effects at each. In many such cases, very different data come to light following an initial study. The efficacy of therapies for patients, for example, can be significant with small sample groups, but may diminish in trials involving a larger number of people.

2.42 When good evidence is published, and discoveries can be replicated, there is little incentive to resist them. A scientist's own work is unlikely to progress if it is based on flawed understanding; a doctor wants to treat patients effectively, not ineffectively. A good example of the speed with which substantial findings can change prevailing ideas and practices is the discovery of the bacterium *Helicobacter pylori*. In 1983, Barry Marshall, a young doctor, contended that the presence of helicobacter in the stomach might be linked to gastritis and peptic ulcers. His findings were

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[37] Kuhn (1970) p.23.

[38] "Did we realise the significance of our discovery? Yes we did ... . Did we foresee the sequencing of the human genome? No we didn't. We saw as far as the genetic code … but we did not foresee either introns or RNA editing. We thought then that sequencing DNA would be very difficult and time consuming. Nor did we foresee recombinant DNA. But I think that this is a rather general rule, that one can seldom predict correctly more than about 10 or 15 years ahead. Unexpected discoveries can often change the picture completely." Francis Crick, The Biology of DNA, Cold Spring Harbor Laboratory, NY. 26 February 2003. http://meetings.cshl.org/2003helix_online.htm.

published in *The Lancet.*[39] The hypothesis ran counter to established medical science, which maintained that high levels of hydrochloric acid in the stomach killed *all* bacteria. Within a year, Marshall had produced clear evidence and convinced his peers of the connection, leading to treatments of peptic ulcer and gastritis and lower rates of stomach cancer.[40]

2.43 Far from limiting recognition of new ideas, the peer-review system ensures that scientists, as referees, read many new papers in their field and evaluate them for competence, significance and originality.

Why can't there just be a technical checking system, rather than peer review, to make sure the researchers have abided by good practice?

2.44 Referees are sometimes given guidance about what to look for in a paper (see Box 1) but ultimately they are being asked to make an informed judgement. A technical checking system may work for marking arithmetic tests, but any original piece of research has its own unique features, requiring the application of expert judgement in ways that no one yet has been able to codify in a check-list. It would be no easier to devise a checklist to replace referees' judgements than it would be to prepare one to replace medical diagnoses or juries' judgements of guilt.

Should research be judged on the basis of who funds it?

2.45 A commonly cited concern by single-issue campaigners and journalists about the credibility of some types of scientific findings is the source of the research funding. It is occasionally alleged that a funding body has interfered in a specific way with a piece of research, but more usually, critical commentators simply emphasise the source of research funding in order to imply that the researcher's findings may be unreliable in some unspecified way.

2.46 These allegations particularly relate to research funded by sections of industry that excite active opposition and sometimes to governments' claims about the scientific basis for their policy choices,[41] but similar concerns about influence over publication decisions have also been raised in relation to research funded by campaign groups and others.

2.47 Clearly, people with money shape priorities, which is why research dedicated to improving European cosmetic products outstrips research into the improvement of African staple crops. Organisations that fund scientific research, which include governments, universities, scientific institutes, private companies, charities and individuals, set priorities which determine what is funded. Many organisations abide by codes of practice on being explicit about any non-scientific criteria they use and some use scientific peer review to make decisions between suitable bids.[42]

2.48 At the research publication stage, however, the results have already been generated and the question is whether and what to publish. The writing up of research can be covered by contracts between the funding and researching organisations. These contracts are typically concerned with the protection of intellectual property, the right to publish and appropriate acknowledgements. They are not concerned with the nature of the research findings. Any attempt by funders or anyone else to interfere directly with research results is considered to be serious scientific misconduct or fraud.

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[39] Marshall *et al.* (1984).
[40] Marshall and Warren (1985).
[41] A US campaign, Center for Science in the Public Interest, refers to "well known cases of industry seeking to prevent the publication of research results that are critical of its products". It aims to "raise awareness about the role that … corporate interests play in scientific research, oversight, and publication". www.cspinet.org/integrity/index.html. Media broadcasts have raised the same question: "Some scientists question if commercial and political interests tied to biotechnology can tolerate scientific dissent." *The Today programme*, BBC Radio 4, 19 September 2003. Nicholas Regush, ABC news medical producer, has similarly complained that heavily funded scientific claims, such as the HIV-AIDS model, are rarely questioned. Regush (2000).
[42] See, for example, Association of Medical Research Charities (1993).

2.49 Once papers are written and submitted, if they are published in the peer-reviewed scientific literature we can at least be sure that they have been judged independently to have scientific merit – to be competent, significant and original – no matter who funded the research.[43] The findings are also then available to be replicated and debated. For society, scientific peer review is something of a safeguard against special interests, be they policy, commercial or campaign group led, that might distort the reporting of scientific findings. The problem with using funding as a guide to plausibility is that it generally relies on guesswork and rumours. The peer-reviewed literature offers a more accountable, reliable guide to what is scientifically plausible.

The limits: when is peer review not really peer review?

2.50 The peer-reviewed scientific literature broadly refers to the over 8,500 journals listed on the Web of Science citation index. These all have recognised standards of peer review and a degree of authority with a scientific readership.

2.51 There are, inevitably, variations in standards. Peer-reviewed journals are predicated on the existence of an area of expertise with some standing in a research community. Authors, referees and editors are more likely to want to contribute to a respected journal that is widely read, so such journals can reject the majority of papers. In some highly specialised subjects by contrast, journals struggle to retain a range of experienced referees and a regular supply of good-quality papers. Most fields of study, though, are large enough for editors to achieve good standards of objective reviewing. (In the cases of non-reviewed claims that have fuelled public controversies in recent years, editors would have been able to locate suitable expert referees had research papers been submitted.)

2.52 There are also ‘peer-reviewed’ journals that are in reality just vanity presses. Most scientists know this, or discover it quickly. Sometimes organisations or individuals claim to have put their studies through peer review when, on inspection, they have only shown it to some colleagues. Such claims are usually made in the context of a campaign directed at the public or policy makers, as a way of trying to give scientific credibility to certain claims in the hope that a non-scientific audience will not know the difference. Nothing can prevent any group from writing a study or forming its own journal and calling its vetting policy "peer review”, just as nothing can prevent an institution from dubbing itself educational and issuing what it calls degrees. Unfortunately, individuals may sometimes be fooled by such things, but the scientific research community is not, even though it has no formal accreditation system as educational institutions do.

2.53 With increased awareness about scientific peer review, such pretence would be less likely to succeed. Reporters or advocates citing these sources as peer reviewed would show themselves to be biased or uninformed. Simple checks with journals and with other scientists can clarify the status of a publication.[44]

But is it true? Error and correction

2.54 When research findings have been peer reviewed and published, this indicates that they are sufficiently competent, significant and original to merit the attention of other scientists, but publishing research findings in a peer-reviewed journal is only a part of the ongoing process of science progressing. When the wider scientific community is able to read these findings, other scientists notice things that were not picked up in peer review. They can consider the paper in the context of their own work, which can lead to new insights or modifications. Some journals provide a forum for other scientists to comment on technical aspects of published papers. Referees will have tried to ensure that there was enough factual information in a paper to enable replication of the work

[43] Authors generally state their funding in a declaration form; on receiving the reviews, editors assess whether the referees have detected any weaknesses that may be explained by a funding bias. Failure to disclose anything that would influence the editor’s assessment is treated very seriously by scientific journals and can damage a scientist’s career.

[44] The Committee on Publication Ethics (COPE) states that journals should publish accurate information about their peer review and appeals process. COPE (1999) Section 5.

and further critical assessment. Other scientists try to repeat the experiments, checking the results and considering alternative explanations.

2.55 All of this careful deliberation, repetition and commentary are an essential part of scientific enquiry. Scientific research is written to be used in further research, so tends to be self-correcting. Errors are caught because it is not possible to build further research on a foundation that will not bear the weight.

> *"Error is a normal part of science, and uncovering flaws in scientific observations or reasoning is the everyday work of scientists."*[45]

Peer review helps to avoid a lot of error and unnecessary wasting of time by asking authors to rectify defects in their papers before they are published, and by indicating to the wider scientific community which papers are most worthy of their attention.

2.56 Very occasionally, there are serious flaws in a paper that should have been apparent to the referees but which they missed in recommending the paper for publication. The cases where this has happened in recent years are quite varied and too few to suggest that there is a pattern to mistakes. It is a feature of any system of judgement, however expert, that mistakes are occasionally made, and scientists are aware of this possibility. If the findings are very significant, any flaws are likely to be discovered quite quickly because the paper will be widely read and discussed and other scientists will attempt to repeat the work.

2.57 Dealing with those *major* flaws that come to light when a paper is already published is a challenge for scientific publishing. Editors are expected to take responsibility for correcting the record prominently and promptly,[46] but there is no single, accepted route for doing this. Authors often adjust their own findings, sometimes by writing to the journal that published their paper to retract some or all of their results, but often by submitting a further paper. Sometimes editors correct the record by printing a paper from another scientist. Editors rarely take the step of distancing themselves from the papers they publish, unless a mistake is very serious or there has been a breach of trust.[47]

Fraud and misconduct

2.58 Peer review is not a fraud detection system. Referees are reasonably likely to detect wrongdoing such as plagiarism and falsification because, as experts with knowledge of the research field, they can spot such things. However, if someone deliberately sets out to falsify data, there is sometimes no way of knowing this until the paper is published or even until the experiments repeated and scrutinised by the scientific community.[48]

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[45] Park (2000) p.9.
[46] COPE (1999).
[47] In November 2001, *Nature* published a paper by David Quist and Ignacio Chapela, of the University of California, stating that genetically engineered DNA had found its way into wild Mexican corn. The paper drew complaints from scientists about apparent flaws in the methodology. In April 2002, the editor of *Nature* published a statement, saying, "*Nature* has concluded that the evidence available is not sufficient to justify the publication of the original paper". *Nature* 416, p.601.
[48] In October 2002, Jan Hendrik Schon, of Bell Laboratories in New Jersey, was exposed by other scientists as constructing fraudulent data to claim ground-breaking discoveries in nanotechnology. He had written (and had published) 25 papers by this time, most in the high-impact journals *Nature* and *Science*. Sixteen of these were deemed entirely false and the journals retracted many of the papers. With so few laboratories as well equipped as Bell Laboratories, other scientists had been unable to test the claims. The fraud was discovered as a result of other scientists comparing the published papers, which indicated a pattern between each set of data where there should have been random events.

2.59 Scientific bodies typically classify scientific misconduct under the following headings:

- Piracy – deliberate exploitation of ideas from others without proper acknowledgement.
- Plagiarism – copying ideas, text, or data without permission and due acknowledgement.
- Misrepresentation – deliberate attempts to represent falsely the ideas or work of others.
- Fraud – deliberate deception, which may include the fabrication of data.[49]

2.60 Serious scientific fraud appears to be very rare.[50] Cases that come to light receive considerable attention and condemnation,[51] as one would expect when trust and integrity are so fundamental to the scientific system of sharing ideas.

Some challenges for scientific publishing

2.61 The principle of peer review is unchanging but the way in which the process is managed by scientific journals is likely to develop, particularly in the face of two current challenges: the sheer volume of research papers seeking an outlet and the pressure for open access to journal content in place of subscription-only models.

The volume of research papers

2.61.1 The number of research papers has risen steadily. In research areas that generate regular advances (and so papers), this places an increased reviewing burden on the available pool of qualified scientists. This leads to delays in obtaining sufficient reviews, and some scientists worry that it also affects the quality of the reviewing. There are likely to be a number of different responses from publishers and scientists to this problem over the coming years. Ultimately, because there is an elementary need for good peer review, the volume problem may strengthen the most respected journals, as referees focus their available time.

Electronic publishing and 'Open Access'

2.61.2 The rise of electronic publishing and the World Wide Web has facilitated both publishing and access to published papers, and has presented new opportunities to reconsider the current subscription-based model, where the costs of scientific publishing are borne by subscribers. The subscription rates for journals have increased, partly because of the growing number of papers that are submitted.[52] The cost of subscribing to a range of scientific journals limits access to published papers among the worldwide scientific community and in particular in less-developed countries. There is now a move towards 'Open Access' models of publishing, where the costs of scientific publishing are borne by authors, who would pay a fee when their articles are accepted for publication.[53] This model would enable the entire scientific community to have online access to published papers free of charge.

2.61.3 Some of the concerns raised about the new model include problems for authors (particularly those in developing countries) in finding the required fees, the end of cross-subsidising for other publications and activities carried out by the learned societies, and the need to maintain current quality standards. Negotiation of these matters between different publishers is far from complete. In the meantime, a rapidly growing form of Open Access is developing from authors self-archiving

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[49] Edited text from King's College London's 'Guidelines on good practice in academic research' www.kcl.ac.uk/depsta/kcle/research/resdocs/Ethics.pdf.

[50] Goodstein (2002).

[51] For example, the Lawrence Berkeley National Laboratory in California admitted in 2002 that its scientist, Victor Ninov, had fabricated the discovery of two new chemical elements. This admission was reported in many scientific journals and consequently in major newspapers across the world.

[52] Royal Society response to the House of Commons Science and Technology Committee Inquiry into scientific publications, February 2004, policy document 04/04, p.1. http://www.royalsoc.ac.uk/files/statfiles/document-252.pdf.

[53] Some models of Open Access envisage charging authors a fee for processing the articles they *submit*, whether or not they are published.

their published, peer-reviewed journal articles on their own institutional websites to make them available to everyone.[54]

2.61.4 The scientists involved in all sides of the debate about the way forward are committed to good peer review. Open Access may even increase the extent to which science is self-corrective because all qualified experts will be able to access all published papers. Whatever model is eventually adopted, it will be organised around the needs of the scientific community and the publishing houses to maintain a peer-reviewed literature.

Asking questions about research claims

2.62 Most scientists make a careful distinction between their published research findings and more speculative ideas. They also usually avoid discussing research from other scientists that has not yet been published. It is a kind of code among scientists, which recognises the distinction between evidence and speculation.

2.63 When controversies and claims are in the news, insistence on peer review may seem a frustrating, quaint scientific practice. When scientists refuse to be drawn into discussions about unpublished work they may appear to be stubborn.[55] But scientists do this because they know that the distinction is a meaningful one. In their own work they will have seen early hypotheses being overturned in the face of results, and they will have clarified and developed their ideas considerably in the process of writing up and submitting their results for publication. This does not mean that scientists should not share their more general thoughts about new findings and what they might one day mean for society. What research findings show and what scientists wonder about are two different things and it is important to distinguish them. Many different groups of people comment on scientific issues and very few of them refer to whether work has been peer reviewed. There is very little pressure for them to do so while scientists themselves rarely explain peer review to the public and sometimes fail to demonstrate regard for the distinction.

2.64 Everyone should be encouraged to ask questions about peer review when listening to claims made about a scientific advance in an interview, press release, or news report. Has the work been evaluated by experts in the field, or is the report based on opinion or unsubstantiated extrapolation? If published, what is the standing of the journal? Has the work been acknowledged by other scientists as a contribution to the field, or dismissed because it is flawed? Has it been replicated? Is it being reported by science correspondents, who know the importance of peer review, or by those who do not distinguish science from opinion? If scientists regularly draw attention to whether work has been scrutinised by peers, and to whether results have been replicated, it will become easier for everyone to be more demanding about the quality of information that informs social discussions about science.

[54] See http://www.eprints.org/self-faq/.

[55] “The scientific establishment’s obsession with the ‘peer review’ means important science that raises risks of GM technology is side-lined.” Rowell, A. (2003) ‘Safe science is not always good science’. *The Guardian* 19 August.

Section 3
Raising the public profile of peer review

Introduction

3.1 The discussions of the Working Party brought forth a distinction between the practical problems that are faced by scientific publishing, which concern practitioners, and the task of explaining the peer-review process in response to the lack of wider awareness that scientific claims have been scrutinised in this way.

3.2 Most criticisms of peer review are overstated. It is regrettable that they have not been diminished by a more accurate account of the peer-review process and what it offers both to science and to society. That this opportunity has not yet been seized perhaps reflects the general mood of defensiveness about scientific authority that has arisen in recent years, particularly in Britain.

3.3 Peer review is very rarely contested as a matter of sustained principle. The promotion of alternative sources of authority and information to peer-reviewed research seems to come about because some journalists and opinion formers are drawn to stories that minister to a growing cultural ambivalence about established expertise. The specific attributes of 'shocking' research claims about genetic modification, stem cell research, cloning, the MMR vaccine, new variant CJD and mobile phone radiation, for example, are presented to an increasingly common formula: when public stories begin to take shape, there is an almost instinctive search for a wronged scientist, suppressed research, apparently unco-ordinated official denials of risk, and so on. Under such conditions, peer review is treated as irrelevant and so the scientific merits of the claims become particularly hard to judge for everyone looking on.

3.4 That scientists need to act with greater emphasis to challenge indifference to expert judgement is also underlined by the political reaction to some recent science 'scare stories'. It is increasingly recognised that we now live in a climate where political actors and state bodies are very anxious and reactive on issues of science and risk. They seem less inclined to take responsibility for judgements based on scientific expertise. One consequence of this seems to be the potentially irresponsible practice by policy officials of putting scientific material into the public domain for conclusions to be drawn, without any indication as to its purpose or judgement on how it should be viewed.[56]

3.5 While the greater ambivalence about expert opinion means that less social emphasis is placed on expert review, it does not amount to a general critique. Likewise, people objecting to the conclusions of peer review complain predominantly about their *own* exclusion from the traditional vehicles of expert authority, scientific journals. This was apparent in the examples of 'dissenting scientists' on subjects such as mobile phones and alternative health therapies that were considered by the Working Party.

3.6 Some science commentators have tended to present complaints about peer review without first explaining why it is used. In 1999, Richard Horton, editor of *The Lancet*, described peer review as

[56] The publication of specific energy absorption rates (SAR) for mobile phones, for example, quite predictably was met with indifference in the absence of any meaningful interpretation or judgement. Department of Health (2000) *Mobile phones and health,* leaflet, 8th December, London: HMSO.

"usually ignorant" and "frequently wrong"[57] after the journal was criticised for publishing research on the effects of feeding GM potatoes to rats, which had been turned down by another leading journal. He did not, though, explain why *The Lancet* would continue to base its publication decisions on reviews that are "usually ignorant". Horton also argued that BSE had made the public deeply sceptical about science and that *The Lancet* was encouraging a more open debate by publishing the GM paper. Being vague as to whether decisions about scientific publication should be based on peer review or on editorial ideas about the needs of public discussion is unlikely to diminish public scepticism, or to promote well-informed debate, and indeed it does not appear to have done either.

3.7 Even if some people are minded to criticise peer review more systematically, the limitations are immediately obvious. It is only possible to question the use of scientific expertise up to a certain point without eroding one's own grounds for reporting and commenting, or without sounding unconvincing to a society that, while more open to 'alternative' views, does still expect healthcare rather than quackery, and science not witchcraft.

3.8 The arguments and material reviewed and the discussions pursued by the Working Party have failed to indicate that there is anything *systematically* wrong with the conduct of peer review. What did become clear is the absence of wider recognition that scientific papers are peer-reviewed papers. There is a very confused picture of what peer review is and a lack of sensitivity on the part of scientists about explaining that. In short, the most basic problem with peer review is that so few citizens are made aware of it, at a time when people have become very concerned about how to weigh different claims meaningfully.

3.9 In the context of the need for a more vigorous and clearer explanation of peer review, the Working Party considered four matters which were thought to be significant to promoting knowledge about peer review and eliminating causes for reservation among the scientific community. These were:

- The 'supply chain' for promotion of research findings.
- Commercial publishing of research outside of the peer-reviewed literature.
- Peer review as part of science education.
- The need to find out more about the impact of different research claims on wider society.

These are discussed in the following pages. **Recommendations are highlighted in bold.**

[57] Horton (2000) 'Genetically modified food: consternation, confusion and crack-up'. *The Medical Journal of Australia,* 172: 148-149.

Public promotion of research findings and the peer-review process

Science information 'supply side'

3.10 On 27th December 2002, Clonaid, a company in the United States owned by the Raelian cult, which believes human beings are descended from aliens, announced the birth of the first cloned human being, a baby girl. Despite the provenance of the story (a Clonaid statement), and the absence of a baby or any independent corroboration, the international media devoted headlines and front pages to discussing it over three weeks. While most reports drew attention to the absence of evidence and the unfulfilled promise by the cult to produce it imminently, there was no shortage of commentary about the implications for society.

3.11 The story prompted discussions from "Do human clones have souls?" to whether there should be a "crackdown" on the activities of scientists in related fields. On 28th December, BBC Online ran a reader survey, "Have your say. Should human cloning be banned?" Most reputable scientists and clinicians were unwilling to comment on such unfounded claims, but this made little difference. Dr Patrick Dixon, a futurist and business consultant, was quoted as giving the scientists' response with his statement: "There's a global race by maverick scientists to produce clones, motivated by fame, money and warped and twisted beliefs. The baby has been born into a living nightmare with a high risk of malformations, ill-health, early death and unimaginably severe emotional pressures".[58]

3.12 Officialdom was no less circumspect. The Chairman of the US President's Bioethics Council, Leon Kass, declared to the BBC, "If this is the wave of the future then I don't want it."[59] President George Bush's White House spokesman called for congressional legislation against cloning. On 3rd January 2003, French President Jacques Chirac accused scientists of reviving the eugenicist fantasies of the Nazis and pressed for states to sign an international convention against human cloning as a matter of urgency. In mid-January 2003, a court in Florida issued a summons to the Vice-President of Clonaid, Thomas Kaenzig, to appear before a hearing to decide whether the State should appoint a guardian for the cloned child. Despite the wider scepticism with which the human cloning story was treated, anyone reading these official reactions would be forgiven for thinking that the clone birth had really occurred. The reaction to a story that clearly had no factual let alone scientifically validated basis became a dress rehearsal for the real thing. It is a useful indication of the kind of chain of events that can be put in motion by a science story.

3.13 One of the hurdles for the Working Party was trying to make sense of the many anecdotes and accusations about where the problem lies when scientific 'stories' become separated from published peer-reviewed science. Consideration has been given to a number of developments in the science information 'supply chain', including press officers, the role of pressure to publish and the regulatory demands on companies undertaking research to report it. However, the extent to which action is required, and what type of action, is not entirely clear because of the lack of systematic information about the origin and destination of science stories.

3.14 Popular science reporting is often very effective at explaining scientific work and getting non-scientists interested in it. The Working Party also noted that, on investigation, some claims about distortion were misplaced. For example, scientists sometimes assume that journalists have introduced unfounded claims about the significance of new findings, when in fact the press release issued by the research organisation or even the journal's publishing house has been responsible for making the suggestions.

3.15 There has been significant growth in press and external relations work by university and institute administrations, as competition for funds, status and students has increased, and we see no reason to expect any change in this development. The Working Party felt that there was insufficient recognition of how this change has affected the promotion of scientific research results. It was noted

[58] http://news.bbc.co.uk/1/hi/health/2608655.stm.
[59] *op. cit.*

that in some instances scientists may be overruled by an institution that wants publicity and in other instances the scientists' publicity needs may not match the research data. **It is recommended that scientists work with press officers to ensure that publicity is correct and sign it off.** At the same time, press officers (including those working in other areas of science promotion such as conference organisers) should be aware of the potential impact of editing press releases and other communications about research and should seek to clarify what has been peer reviewed. **It is recommended that universities and other scientific bodies endeavour to make press officers without a scientific background more aware of the peer-review process, for example as outlined in this report.**

Talks at conferences

3.16 Many contributors to the Working Party's discussions have pointed out that confusion about research findings and their scientific status often arises from the reporting of conference proceedings. Conference organisers now regularly promote the talks to be given at their events to the media, and the greater demand for news stories about science makes these events attractive to journalists and commentators. There are different kinds of scientific conferences. Some are held to showcase areas of work to a wider audience, sometimes to non-scientists. These are usually concerned with published work. Others have traditionally been quite closed events where peers — people working on similar problems at an advanced level — can discuss and criticise one another's work, usually at a more preliminary, pre-publication stage.

3.17 It is not feasible, nor desirable, to discourage interest in scientific conferences. After all, it is far more likely that there will be accurate, evidence-based discussions about subjects like the SARS virus if reporters and policy advisers attend a microbiology conference on the issue.

3.18 With talks covering a combination of new and old work, and information about what is peer reviewed changing in the run-up to an event, conference organisers would find it almost impossible to indicate systematically what has been peer reviewed. **However, it is recommended that conference organisers try to put information about the peer-review status of claims into their promotional literature, and encourage presenters to communicate with them about this when (i) a talk is clearly likely to cause wider controversy; or (ii) new findings are being widely promoted to draw attention to a conference.**

3.19 Reporters do not have time, nor the specialised knowledge, to read and interpret even a small selection of research findings, and so the contents of a press release or promotional material could well be taken to represent the findings. These materials are usually prepared by conference organising committees or by staff at a professional or learned society. While many of the people involved understand peer review, **it is recommended that non-scientists employed in conference promotion are informed about the peer-review process.**

3.20 **It is also recommended that scientists pay greater attention to the context of informal discussions about their work, such as conferences that may now have a media orientation.** This does not mean that scientists should retreat from discussions of their work, either with peers at conferences or with others attracted to those events. Rather, it is sometimes appropriate to provide *more* information, for example to state clearly which findings have been peer reviewed. One can assume that others in the field know the distinction from reading the same journals, but this is not so for a wider audience.

Following media reports

3.21 Once scientific information has been released, it becomes subject to many other considerations in how it is presented. Scientists are not alone in being frustrated about the very obvious lack of substance in 'scientific' claims based on personal stories, such as 'mobile phones caused my cancer'. Although these kinds of reports seem like the worst kind of scaremongering, when considered from the perspective of how, as a society we make judgements about the quality of what we are told, they do not seem to be such a problem. With stories that are clearly personal accounts we are given enough information about the source to deploy our scepticism and see clearly that it is an individual's perception. It is when we are told wrongly that 'scientists are divided', or 'x study proves a link', that deception is really a problem.

3.22 When reporters choose wilfully to withhold information that would clearly influence the conclusions that readers or listeners will draw about the authority of a study, that is deceptive.[60] This is not the same thing as journalists' more subtle choices of presentation to make a subject more dramatic or interesting. That may be frustrating to scientists, but it seems a rather necessary 'spoonful of sugar' for non-specialists reading such reports.

3.23 **It is recommended that scientists follow the presentation of their work in wider media, and endeavour to correct unfounded claims that deviate substantially from their peer-reviewed work; but that they distinguish between this and matters of taste and style in how others choose to discuss their work.** While it is reasonable to expect accuracy in reports, it is unfair to charge journalists with the same responsibilities as public health officials. News and public information are not the same thing and the latter is the responsibility of public bodies rather than the news and entertainment industry, for good reason.

3.24 Journals are the main source of science stories for the wider media, but journalists have sufficient contacts with scientists to know when new developments are expected, rather than simply relying on the journals. Increasingly, scientific journals make some papers available electronically to prevent delays and speculation.[61] However, there continue to be tensions between journals (particularly the widely read ones), authors and journalists about the appropriate time for a paper to be discussed. Journals that attempt to hold back discussion of new work until the paper appears run the risk that it will happen anyway, without reference to the paper at all. On the other hand, they are free to try to maximise their own publicity in this way. There is no unifying process to deal with the problems that these tensions create for each party. From the perspective of clarifying the use of peer review, though, it makes little difference whether peer-reviewed findings are discussed before or after the publication date, so long as the fact that they have been peer reviewed and accepted is made clear.

3.25 The relatively few scientists who choose to publicise their findings *before peer review*, on the other hand, sometimes add to the confusion and potential for misleading claims that have been described in this report. Those whose 'expertise' depends on promoting stories rather than convincing peers also put themselves at the mercy of other non-scientific priorities. This was clearly illustrated in February 2004, when many of the British news agencies that had courted Dr Andrew Wakefield for stories about the risks of the MMR vaccine beyond the findings reported in his papers, were able, very quickly, to destroy his position of 'expert comment'. **It is strongly recommended that scientists make it very clear whether their findings are peer reviewed and avoid speculation if it is liable to be treated more seriously than their actual findings.**

[60] O'Neill (2002).
[61] Authors sometimes make pre-print copies available for other scientists.

Commercial publishing of research outside of the peer-reviewed literature

3.26 Many announcements about new research findings come from companies and their research contractors. Commercially funded research accounts for almost half of all scientific research and development activity in the UK.[62] The Working Party looked at two particularly high-profile cases of British companies releasing unreviewed research results directly into the public domain: the announcement by the small biotechnology company PPL Therapeutics in January 2002 of the birth of five cloned, genetically modified piglets; and the promotion by British Biotech of anti-cancer and anti-pancreatitis drugs. In both cases, unreviewed claims of successful research and application prospects were made to the financial markets and wider news media. These cases have become a touchstone for wider concerns about the lack of peer review of claims made by companies. (See Box 4 for details.)

BOX 4

PPL Therapeutics' cloned pigs
On 2 January 2002, PPL Therapeutics plc issued a statement to the London Stock Exchange that five cloned genetically modified pigs had been born in December 2001, with a single copy of a gene 'knocked-out' so that their organs and tissue would not trigger an immune reaction in humans and would therefore be suitable for transplants.[63] No corroboration of the claims was available; the work was not peer reviewed at that time. The announcement naturally made news headlines.

Two days later, the peer-reviewed results of work by Immerge BioTherapeutics in the United States, also resulting in 'knock-out' pigs born three months previously, were published in *Science*, but this was barely reported. Reporters commented that PPL's announcement might have been intended to overshadow its competitor's imminent publication, under pressure to maintain a competitive edge in the financial markets. The company argued that Stock Exchange Rules had obliged it to publish the information.[64]

British Biotech
In 1997, British Biotech's former head of clinical research trials publicly accused the company of misleading investors about the effectiveness and prospects of its anti-pancreatitis drug Zacutex and exaggerating slender results from research into the anti-cancer drug Marimistat. The company's share price fell dramatically, and it was investigated by the Stock Exchange and the House of Commons.[65]

3.27 Press announcements about results put scientists in a difficult position because they are unable to comment on claims about 'breakthroughs' and implications of the work due to an absence of accessible data. There is some concern among scientists outside of the commercial sector, and science commentators, about the practice of announcing commercial scientific results through press releases.

3.28 The Working Party looked at the prospects for encouraging greater use of peer review or peer scrutiny for commercial findings. However, it became clear that there is indeed a tension between the demands of financial reporting and the time involved in having results peer reviewed. For pharmaceutical companies, the situation is further complicated by regulations governing the supply of product information in different countries and the duty to inform licensing bodies.

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[62] Office for National Statistics (2003). *N.B.* Some of this work is conducted in public institutions.
[63] 'World's first announcement of cloned 'knock-out' pigs: Christmas-born pigs are a major step towards successful production of animal organs and cells for human transplant use', PPL Therapeutics plc, Press Release, 2 January 2002. http://www.revivicor.com/KOrelease.htm.
[64] Firn, David (2002) 'Cloned pigs raise hackles of scientists.' *Financial Times*, 6 January.
[65] BBC News 15 June 1998 and 17 August 1998. http://news.bbc.co.uk/1/hi/business/the_company_file/133740.stm.

The legal situation

3.29 Companies are subject to the Stock Exchange Rules, which demand that they notify the Stock Exchange without delay of any business development that is likely to result in a material change, defined as a shift in share price of 10% or more. Such developments include research findings that are likely to have a beneficial or detrimental effect on commercial prospects. The notification is in the form of a news release. A company is required by law to publish this information; failure to do so can result in fines and even jail. The Stock Exchange investigates all claims of withheld information.

3.30 The regulation has a differential impact on companies conducting research and development. Scientific results are more likely to lead to material changes in the share prices of smaller companies', particularly because they are more likely to be based around one type of product or process, or have a future dependent on the outcome of research. In practice it is a difficult figure to assess, so companies err on the side of caution and make announcements.

3.31 The share prices of larger companies are less likely to be influenced by one set of research results because they are a small part of overall valuing activity. (The pressures on larger companies to announce research results quickly stem more from their regulatory obligations to the licensing authorities.)

3.32 There is no scope for amending the regulations governing the release of research information to allow for results to be peer reviewed. It is impossible for companies to hold back information without the risk of it being leaked. Releasing information differentially is a criminal offence because of the commercial advantage in share trading to those who receive the information first.

3.33 Even if information about research results was not leaked beyond the company and research referees, the privileged access creates the possibility of share dealing on the basis of the information ('insider dealing'). Furthermore, it would be privileged access over considerable time, and is likely to involve larger shareholders within the company.

3.34 Leaks can occur quite unwittingly. For example, a visiting broker being told that a paper was shortly to be published in a prestigious journal could be interpreted as 'insider dealing'. If a broker looks favourably on a company and encourages buyers to increase their holdings (so driving up the share price), the Stock Exchange computers identify the increased trade and cross-check it with announcements from that company; when there are none, an explanation is requested. If it transpires that the company was holding back information, then it is treated as a potential criminal conspiracy.

3.35 Peer review for printed publications is not flexible enough to deal with the demands of stock market notification. Even if it is relatively efficient, several weeks would be too long to hold onto new information. A paper could not be written up in the time, let alone submitted, reviewed and published.

3.36 Companies notifying the stock market of research results, good or bad, generally give a summary and do not publish the detail of the study. It is difficult for other scientists to assess claims and judge their plausibility from such announcements.

3.37 It may be that companies sometimes use the regulatory demands as promotional opportunities. Such advantages are, however, balanced by the disadvantage of the requirement equally to announce 'bad news' from research, when the same companies suffer negative media headlines. These headlines can be damaging to small companies even if findings are preliminary or are later revised.

Other commercial issues

3.38 Issues of intellectual property rights do not usually have a bearing on companies' release of research results. By the time that a company reaches the point of generating results, the intellectual property issues will have long been dealt with.

3.39 Any initiative to promote peer scrutiny must consider the relatively short-term character of many small companies in the science and technology sector. Many function on the margins of financial viability. Under such conditions, admonitions to submit results to peer-reviewed journals are unlikely to make any progress.

3.40 The conditions described above concern *publicly listed companies* in the UK only. The Financial Services Authority (FSA) is responsible for ensuring that companies listed on the London Stock Exchange announce price-sensitive information promptly. It provides guidance on disclosure (see Appendix 3) and a guidance manual. The FSA does not publish guidance specific to particular sectors, but it encourages trade bodies, professional bodies and other such organisations to develop relevant guidance and good practice, so long as these are consistent with the generic advice on reporting. It should be noted that the FSA's remit not extend to other listings such as AIM (the Alternative Investment Market). These include a greater proportion of small and medium-sized enterprises (SMEs) involved in science-related industries and the development of new technologies.

3.41 Taking into account the constraints outlined above, the Working Party looked at whether scope exists for improving the level of data provided to support research claims made by companies.

Comment

3.42 It is in the interests of science and society, and of course companies themselves, if those involved in research in the science and technology sectors conduct themselves in a way that scientists find defensible. The range of approaches adopted by companies making announcements is quite broad. Some provide much greater supporting detail than others, particularly when announcing 'good news'. Some companies make a simple announcement to the Stock Exchange, while others combine it with a press release to the general media, news agencies and medical and scientific press. Improvements should be focused on the information that is made available, and the potential for scientific scrutiny, rather than on trying to curtail the use of announcements as promotional opportunities.

3.43 Many larger companies already have policies or good practice guides in place for the publication of their research. These deal with peer review, the style of announcement and the stakeholder groups that should be informed, such as patient groups in human trials, as well as the financial and legal obligations. Some aspects of best practice might be applicable to smaller companies.

3.44 All companies are able to submit their work for peer review at the same time as an announcement; and any guideline, cultural pressure or good practice model that encourages this is to be welcomed. However, some improvement in the availability of data for expert comment and scrutiny at the point of announcement is desirable. This might overcome the fact that some small companies, due to their time constraints and short-term outlook, are unlikely to write up papers for peer review.

3.45 Scientific journals have become more flexible about authors making aspects of their findings public before a paper appears in the journal.[66] However, it is still widely believed that any kind of publicity about results will discourage journals from considering a paper for publication. It urgently needs to

[66] In the 1970s, because of a surplus of manuscripts, journals were able to be very selective. Dr Franz Ingelfinger, editor of the New England Journal of Medicine, demanded exclusivity and refused to publish any paper that had been reported in detail elsewhere. This became known as the "Ingelfinger Rule" and was imposed by many other journals.

be clarified with the editors of journals: (a) whether they would refuse to consider a paper if the research had been the subject of an announcement; and (b) if so, whether there are some kinds of announcement that would avoid this problem, for example whether a distinction would be drawn between an announcement made to the financial markets and a press release to the national news media. (The latter is still forbidden, in advance of a paper's publication, by many journals).

3.46 In respect of guidance about the publication of scientific results, the Financial Services Authority has drawn attention to its current review of the listing regime. It is anticipated that new rules and guidance will be issued in 2004. The new rules will ask listed companies to review their own practices and this suggests a timely opportunity to launch guidance on the publication of scientific results.

3.47 **It is recommended that guidance on good practice in announcing the results of scientific research by companies should be produced to coincide with the general guidance issued by the Financial Services Authority.** This should include a template to accompany announcements against which companies can provide information about their data and research that is relevant for wider scientific expert scrutiny, for example details of trial sizes and stage of work. This should be drawn up in collaboration with scientific and learned bodies, large and small companies, scientific research publishers and the relevant financial, trade and corporate regulatory bodies. Organisations that should be involved in the development and adoption of guidance on the publication of scientific results to the Stock Exchange, in order to ensure that they are taken up, include: the 100 Group; the Investor Relations Society; the Association of the British Pharmaceutical Industry; the BioIndustry Association; and scientific institutes with corporate members. A range of companies need to be canvassed about their own in-house standards and practices concerning making announcements about scientific research. **It is recommended that a collaborative network be established, with the potential to see through the proposed guidance.**

3.48 **It is recommended that the guidance should also provide information about the requirements of publishers concerning how announcements might affect the opportunity to submit research results for peer review.** The Royal Society, as a learned society and publisher and in view of its recent consultation about peer review, the Academy of Medical Sciences, and the Royal Academy of Engineering, among others, are well placed to contribute to, or adopt, a project of this nature. In particular, to consult journal editors and to clarify how the type and scope of a recommended announcement protocol might be shaped to avoid disqualifying the research from publication. Also to assist in establishing good-practice guidance concerning commercial announcements of research results and clinical trials.

3.49 **It is recommended that the viability of a Web-based resource for submitting announcements of corporate scientific research against a recommended template be investigated.** This would need to be maintained by a suitable trade or regulatory body and would be accessible to scientists, journalists and other interested parties.

Peer review as part of science education

3.50 The increased use of the World Wide Web has resulted in a wide-ranging retrieval of documents related to scientific and medical issues. Specifically in the context of education, use of the Web has meant that pupils encounter material on scientific topics with great diversity in its status. It has become more difficult for teachers to assess the information sources that pupils use or to predict the material that student research will generate. The Working Party felt that it therefore seems appropriate to provide education-based guidance about how to make judgements on scientific literature, and specifically on the significance and evidence of peer review.

3.51 A recent Curriculum and Staffing Survey[67] found that one third of secondary school lessons are taught by teachers who do not have a degree in the subject they are teaching; science is one of the subjects where this problem is prevalent.[68] Teachers of science who have not experienced degree-level science are less likely to be familiar with scientific processes, including peer review.

3.52 The statutory national curriculum in England and the specification for qualifications, such as GCSE, AS levels and A levels, are controlled by the Qualifications and Curriculum Authority (QCA).[69] The QCA's programme of study for science in education includes:

- experience of critical reflection, evaluation, improvements, etc;
- how evidence is gathered.

3.53 Currently, education about the process of peer review is not formally reflected in the curriculum. However, one initiative is developing packs for teachers, offering guidance and teaching materials, about the scientific process. This includes a new set of materials called 'Ideas, evidence and argument in science', which is aimed at putting science's commitment to evidence to the fore of teaching:

> "*Essentially, we believe (and we have evidence to support this belief) that knowing why the wrong idea is wrong is as important to your learning of science as knowing why the scientific idea is correct… [Teachers should]* "*lead pupils through historic evidence, so they understand how each idea was rigorously tested*." [70]

3.54 The purpose of these materials is to help students understand that scientific knowledge that we regard as facts, such as the earth revolving around the sun, are actually the result of many years of academic argument and of evidence gathering. In this way, students are encouraged to consider new research critically and to consider its evidence base, not just to believe new theories because they appear to 'make sense'.

3.55 A new science curriculum, 21st Century Science,[71] is currently being piloted in schools in Britain and also aims to encourage students to understand the processes of science. The curriculum's objective is to increase 'scientific literacy' (as defined in Box 5) and to teach "the kind of science that everyone needs to understand – as citizens".[72]

3.56 The Environmental Inquiry, a website and curriculum series developed at Cornell University in the United States, has developed teaching resources that aim to help high-school students conduct science research and to participate as a 'community' with other student scientists.[73] One of the

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[67] Department for Education and Skills (2002) *Secondary schools curriculum and staffing survey: provisional.* November. http://www.dfes.gov.uk/.

[68] 'Lessons taught by non-specialists'. *BBC News Online,* 25 September 2003.

[69] Similar bodies fulfil this function for Wales, Northern Ireland and Scotland.

[70] Osborne (2004) 'Behind the Big Bang'. *Times Education Supplement*, 2 January.

[71] Co-ordinated by the Nuffield Foundation and the University of York: http://www.21stcenturyscience.org/home/

[72] http://www.21stcenturyscience.org/home/.

[73] http://ei.cornell.edu/toxicology/peerreview/prtutorial/scientists.asp.

modules focuses on the peer-review process and suggests ideas and activities for school classes to engender an understanding of its importance.

BOX 5 Scientific literacy

A scientifically literate person should be able to:

- appreciate and understand the impact of science and technology on everyday life;
- take informed personal decisions about things that involve science, such as health, diet, use of energy resources;
- read and understand the essential points of media reports about matters that involve science;
- reflect critically on the information included in, and (often more important) omitted from, such reports; and
- take part confidently in discussions with others about issues involving science.

Consumers not producers of science

Most people are unlikely ever to be producers of new scientific knowledge. But all of us, as citizens, need to be informed users and consumers of scientific knowledge. For this, we need to have some understanding of two quite distinct kinds of thing:

- ideas about science;
- science explanations.

(Source: 21st Century Science.[74])

3.57 Each of these educational resources aims to improve secondary school students' understanding of the scientific process, and with it the peer-review process, but currently the use of these resources is not widespread and it will take time for these measures to be used in the classroom. In addition, these tools are aimed only at secondary school students: how to educate primary and degree-level students in these issues has not been addressed.

3.58 Tools and classroom materials for teachers are a valuable resource for building an understanding of peer review. Important steps have already been made toward providing this support in the UK by the Nuffield Foundation, the University of York and King's College, London. **It is recommended that the available resources are collated as a resource list, together with some discussion about the significance of educating students and pupils about peer review.** This would need to be repeated for the teaching of different age groups. It might best be done by the Association for Science Education. **It is also recommended that a similar summary is developed for students of other subjects that are concerned with evidence, risk assessment or the sociology and philosophy of science.**

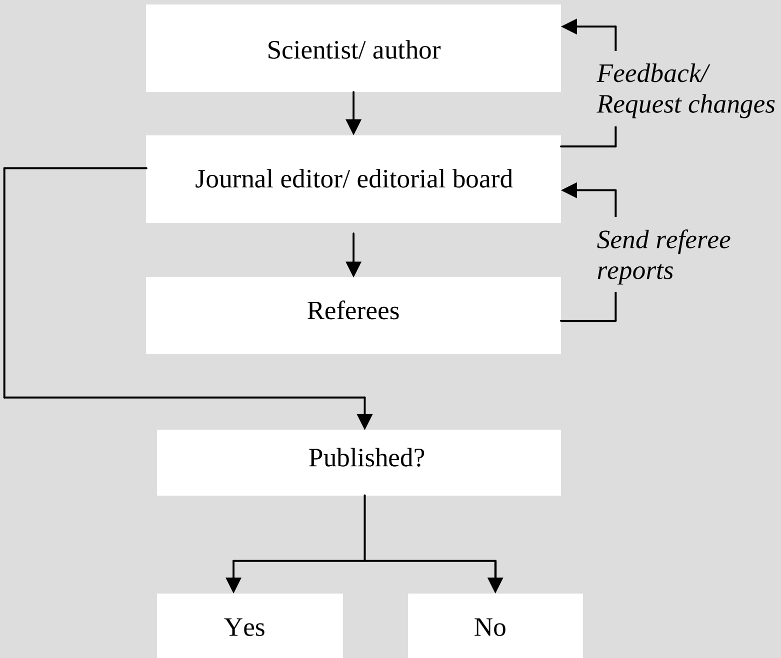
3.59 **It is recommended that the following materials are produced:**

- **first-hand descriptions of roles played by scientists in peer review: author, referee and editor;**
- **explicit description of the way in which students' and pupils' reviews of one another's experimental outcomes develops an understanding of the role of peer review;**

[74] http://www.21stcenturyscience.org/newmodel/literacy.asp.

- **a programme of familiarisation with scientific publishing, including typical visual aids (see Box 6).**

BOX 6 Flow chart indicating the typical process of peer review



Equipping a wider public with an understanding of peer review

The social implications of research claims

3.60 In December 2003, a MORI poll for the Science Media Centre, funded by *Nature,* asked a nationally representative sample of the British population about their understanding of peer review. Respondents were asked what, if anything, they understood by the phrase "scientific peer review in scientific publications". A correct answer was recorded if respondents indicated that it involved scientists' scrutiny of others' work in academic journals, or simply scientists' scrutiny of other scientists' work. Seventy one percent of people were unable to provide an answer; and five percent guessed incorrectly.[75]

3.61 Contrary to the kinds of claims that are sometimes made about peer review leading to the suppression of information, the response of the public, insofar as it has been examined, suggests that non-scientists themselves see some form of expert review as adding to the *quality* of information that is available. The MORI poll described above asked people what scientists should do when their research raises concerns about the possible risks to human health and safety. Thirty percent opted for something along the lines of peer review; 41% wanted an even more rigorous system where results are replicated by other scientists and confirmed before going public. Fewer than one in ten people believed that scientists whose findings had raised concerns about possible risks to human health and safety should issue these straight to the media.

3.62 Research published by an ESRC-funded group at Cardiff University into the British public's reaction to media coverage of the alleged MMR vaccine and autism connection claim showed that 48% of people interviewed felt that the news media should have waited for more information before reporting a 'possible link'. This calls into question the 'public interest' justification that is often given for making early announcements about new research claims.

3.63 Publicity for 'hyped' or unfounded claims that are not exposed to peer review may be frustrating for many working in scientific organisations and science communication, but the more significant damage is often in the consequences for society, beyond issues of public knowledge. As indicated by patient groups, it can lead to unnecessary anxiety, withdrawal of beneficial procedures, self-blame, self-(mis)diagnosis, use of inappropriate therapies or remedies, refusal of appropriate therapies, unwarranted medical consultations, confusion about relative levels of risk, and damage to industry or research. The MMR vaccine fears, for example, prompted parental scrutiny of children for autism indicators, anxiety about vaccination and self-blame. The scare about mobile phone mast emissions and brain tumours caused some people to take their children out of school, and also added to confusion about the relative safety of sources of *ionising* radiation such as X-rays and radon, where public caution is important.

3.64 The significance of peer review for wider society is both the discipline it establishes across scientific publishing and the guide it provides for sifting many research claims. There is a period, often long or indeterminate, between obtaining research results and being able to reflect on their historic usefulness and accuracy. During this period, peer review, as part of broader peer commentary, plays an important role in establishing the plausibility of claims and in assigning social weight to them.

3.65 The Working Party agreed that the opportunity to explain peer review needs to be situated within this *broader social interest* in reliable and good-quality research, rather than identified with the

[75] In relation to the proportion who answered correctly, Michele Corrado, Head of Medicine and Science Research at MORI, noted, "Because the question actually describes the process, some respondents may have demonstrated an understanding of the words, and/or logically deduced an answer, rather than having a prior familiarity or an understanding of what is involved in peer review in any detail. One could therefore conclude that the proportion to communicate the meaning of this phrase with is *at least* seven in ten British adults." MORI correspondence, March 2004.

preoccupations of particular scientific groups that their messages are not getting through. The aim is to strengthen and support the public's ability to assess warnings and research claims. While it has been possible to identify significant opportunities to extend knowledge of peer review, there is a need for social research into the way that perceptions about research results are developed. **It is recommended that more extensive research is undertaken, collaboratively between scientists and social scientists, to develop accounts of how science stories are reported, the questions that are asked about research by different groups, and the resulting perception about the relative merits of different claims.**

Clarifying the contribution of peer review to scientific publishing

3.66 As has been noted, scientists do not seem to have grasped the opportunity to speak about peer review as a significant part of public communication about science. From the perspective of individual scientists, peer review of research papers can appear largely as a practical matter, and even as an unavoidable nuisance as writing up research papers takes them away from work at the laboratory bench. The implicit respect among scientists for peer review is not always consciously perceived or reflected on in a broader way. The lack of reflection about what peer review does for science overall might help to explain why there is so little research into how peer review affects the quality of papers from a scientific perspective:

> *"[W]e have never tried to define the relative gravity of the various faults detected by peer review, and no one has come to grips with how they should be weighed in the evaluation of manuscripts."*[76]

3.67 The Cochrane Collaboration reviewed biomedical research into the effectiveness of peer review early in 2003. It looked at 135 studies designed to assess the evidence that peer review is an effective method of deciding what should be published. The group excluded 114 of the studies because they did not meet its inclusion criteria. The review drew attention to the lack of empirical evidence to support the use of editorial peer review as a mechanism to ensure the quality of published biomedical research.

3.68 To underpin a more vigorous promotion of knowledge about peer review, **it is recommended that further work be undertaken to understand and explain the contribution of peer review to the quality of papers published, for example to look at how anticipation of peer review influences the standard of papers that authors submit.**

[76] Kassirer and Campion (1994) p.97.

Concluding comments

3.69 This report argues that the current cultural challenges to science, and particularly the frustrations experienced by scientists and the public about how to weigh different claims, make it imperative to see past the narrow experiences of science publishing to the essence of peer review as the culture of science. **It is recommended that systematic attempts are made to develop effective explanations of peer review and to communicate these to a wider public.**

3.70 Peer review is systematised accountability to expert judgement. The issue for scientists has traditionally been how best to organise this and ensure a reasonable degree of fairness from the review process. It has rarely been noted that other organisations do not have this kind of quality control. Charities, for example, are accountable through whether people continue to donate money to their causes, journalists through whether people read their articles and opinion formers through popularity and cultural recognition. It seems ironic that in a culture that emphasises the need for continual audit and rules of governance, the arguably more engaged system of accountability that is central to the practice of science, namely peer review, receives little attention or celebration.

3.71 The social ‘uncertainty’ and free-floating scepticism of our times undoubtedly make the tasks of conveying scientific evidence and weighing scientific claims more challenging. In such circumstances, the fact that the development of science has at its centre a trust culture and deference to knowledge, codified in peer review, is potentially very significant. There is an opportunity to share its benefits with wider society within the debates about scientific evidence. This report encourages scientists, and others, to take that opportunity.

Appendices

Appendix 1: References and sources

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Appendix 2: Conflict of interest form

The form below is used by the journal *Science*.

Statement on Real or Perceived Conflicts of Interest for Authors

Science has a primary responsibility to its readers and to the public to provide in its pages clear and unbiased scientific results and analyses. Although we rely on the expertise of our Board of Reviewing Editors and our peer reviewers to help us accomplish this, we think that our readers should be informed of additional relationships of our authors that could pose a conflict of interest. Thus, for readers to evaluate the data and opinions presented in *Science*, they must be informed of financial and other interests of our authors that may be at odds with unbiased presentation of data or analysis.

Therefore, *Science* believes that manuscripts (Brevia, Essays, Perspectives, Policy Forums, Reports, Research Articles, Reviews, Viewpoints) should be accompanied by clear disclosures from all authors of their affiliations, funding sources or financial holdings that might raise questions about possible sources of bias. Disclosure is accomplished in three ways:

First, by a complete listing of the current institutional affiliations of the authors. This list must include academic as well as corporate and other industrial affiliations. As the editors deem appropriate, items in this list will be included in the author affiliations printed in the manuscript**.** Please indicate below:

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Second, through the acknowledgment of all financial contributions to the work being reported, including contributions "in kind." All funding sources will be listed in the published manuscript. Please indicate below:

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We declare that we have read Science's full Conflict of Interest Policy and have disclosed all declarable relationships as defined therein, if any.

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Appendix 3: Guidance on price sensitive information

Financial Services Authority
July 1996

[extracts of relevant sections, including appendix of London Stock Exchange Listing Rules]

1 The regulatory framework seeks to secure as fair a distribution of information as is practicable. The Listing Rules place a general obligation on companies to disclose certain information which is not public knowledge and which may lead to a substantial movement in the price of its securities. Such information will include major new developments, changes in the company's financial condition or business performance or changes in the company's expectation of its performance. Information must always be given to the market as a whole, by an announcement to the Company Announcements Office. Companies are free to use additional media, but selective disclosure of price sensitive information, without an announcement, is never acceptable.

…4 It is not feasible to define any theoretical percentage movement in a share price which will make a piece of information price sensitive. Attempts at a precise definition of 'price sensitive' are not possible, since it is generally necessary to take into account a number of factors specific to the particular case, in addition to the information itself, which cannot be captured in a mechanistic formula. These include the price and volatility of the share and prevailing market conditions. No such definition is included in the relevant legislation.

5 However, price sensitive information will potentially have a significant effect on a company's share price. In particular, a company should be able to assess whether an event or information known to the company would have a significant effect on future reported earnings per share, pre-tax profits, borrowings or other potential determinants of the company's share price. The Listing Rules indicate many events which have to be announced to the market because they may be price sensitive. These include dividend announcements, board appointments or departures, profit warnings, share dealings by directors or substantial shareholders, acquisitions and disposals above a certain size, annual and interim results, preliminary results, rights issues and other offers of securities. In other areas judgement will necessarily be required. This guidance seeks to assist in these judgements by conveying the spirit within which investor communications are to be conducted.

…Handling of confidential information

16 Companies are sometimes confronted with the problem of how long to keep an issue confidential and what constitutes the proper time for its release. There are many processes which are inherently price sensitive where it is essential to maintain confidentiality until the major elements have been finalised and where premature release of information would be more misleading than informative. Such processes include, for example, the development of a new product, the planning of a major redundancy programme, the negotiation of significant financing arrangements, or the preparation of a take-over or partial disposal. Once these issues have been finalised an announcement should be made, unless a dispensation has been granted by the Exchange to avoid prejudicing a company's legitimate interests. However, if, during negotiations, the circle of parties involved becomes too large to ensure the confidentiality of the information, or there is a danger that information has leaked to parties not directly involved, an announcement should be made.

…Extracts from chapter 9 'Continuing Obligations' of The Listing Rules

…4 A company need not notify to the Company Announcements Office information about impending developments or matters in the course of negotiation, and may give such information in confidence to recipients within the categories described in paragraph five. If the company has reason to believe that a breach of such confidence has occurred or is likely to occur, and, in either case, the development or matter in question is such that knowledge of it would be likely to lead to substantial movement in the price of its listed securities, the company must without delay notify to the Company Announcements Office at least a warning announcement to the effect that the company expects shortly to release information which may lead to such a movement.

Appendix 4: Other projects and sources of information on peer review

Institute of Physics Working Party

This was established following high profile cases of fraud and bad practice, has given recommendations to the Institute of Physics Council for guidelines on ethical issues for members. When finalised Peter Main will circulate them to Sense About Science Working Party members. The likely scope of recommendations will be: ethical conduct; the question of personal conscience; ethical instruction in accredited degree courses; mistakes; internal review procedures; declarations of interest; authorship of research; grant applications and environmental implications; and 'whistle blowing'.

Dr Irene Hames, The Association of Learned and Professional Society Publishers

Irene Hames, Blackwell Publishing and Managing Editor of *The Plant Journal*, is working in association with ALPSP on developing guidelines for good practice in peer review. It followed an online survey and seminar to explore the current status of peer review, which confirmed that peer review is clearly a very important element in the publishing process. However, no guidelines for good practice exist. A working party was established, which concluded that there was a need for a 'how to' book on conducting peer review. This is being written by Irene Hames and will cover all practical aspects of peer review, with the aim of improving the general level of peer review. It will include information on how to set up and run a peer-review system, problems that might be encountered, the obligations, responsibilities and ethical standards expected of the parties involved, and the move to online peer review.

Parliamentary Science and Technology Committee
Inquiry into Scientific Publications

The Committee is looking at access to journals within the scientific community, with particular reference to price and availability. It is asking what measures are being taken in government, the publishing industry and academic institutions to ensure that researchers, teachers and students have access to the publications they need in order to carry out their work effectively. The inquiry is also examining the impact that the current trend towards electronic publishing may have on the integrity of journals and the scientific process. It is expected to report in June 2004.

Committee on Publication Ethics (COPE)

COPE was formed in 1997 to provide a sounding board for editors who were struggling with how best to deal with possible breaches in research and publication ethics. As a voluntary body providing a discussion forum and advice for scientific editors, it aims to find practical ways of dealing with the issues and to develop good practice. COPE's Guidelines on Good Publication Practice were published in 1999 and are available online at: http://www.publicationethics.org.uk/cope1999/gpp/gpp.phtml#gpp.

Appendix 5: Working Party members

Professor Sir Brian Heap CBE FRS (Chair)
Brian Heap is Master of St Edmund's College, University of Cambridge. He has been Foreign Secretary of the Royal Society, Senior Visiting Scientist in the School of Clinical Medicine, University of Cambridge, Director of the Institute of Animal Physiology and Genetics Research (Cambridge and Edinburgh) and Director of Science, Biotechnology and Biological Sciences Research Council, Swindon. He was a member of the Nuffield Council on Bioethics, served on the Expert Group on Cloning at the Department of Health, and has worked on developing-country issues, particularly in China, with the World Health Organisation. He has published extensively in the life sciences and been involved in publishing science papers either as a contributor or in helping to publish the contributions of others over the last 40 years.

Dr Derek Bell
Dr Derek Bell is currently Chief Executive of The Association for Science Education, having been involved in science education as teacher, lecturer and researcher for over 25 years. Throughout his career, Derek has maintained a strong and active interest in the enhancement of teaching and learning, and approaches to helping children develop their understanding of the world around them. He was a member of the SPACE (Science Processes and Concept Exploration) Project team and went on to co-ordinate the Nuffield Primary Science Project. Derek has published widely and is currently Chair of the Wellcome Trust's Society Awards Panel and its advisory group for public engagement in science.

Professor Colin Blakemore FIBiol FMedSci FRS
Colin Blakemore is Chief Executive of the Medical Research Council, which depends on high-quality peer review for its work in awarding support for research. Colin is on leave from the Waynflete Professorship of Physiology at the University of Oxford, which he has held since 1979. He was also Director of the Oxford Centre for Cognitive Neuroscience. Colin's research has been concerned with vision and the early development of the brain. He has been President of the British Neuroscience Association, the Physiological Society and the Biosciences Federation. Colin is passionately committed to the public communication of science. He has been President and Chairman of the British Association for the Advancement of Science. He is a frequent broadcaster on radio and television, and he has also written widely for the general public: his most recent book is *The Oxford Companion to the Body*.

Ms Tracey Brown
Tracey Brown has been the Director of Sense About Science, a charitable trust for the advancement of public knowledge about scientific evidence, since it was established in April 2002. She has a background in social research, particularly on the social dynamics of risk, together with experience of organising research projects in the social sciences. She previously worked on the establishment of an EC-funded regional research and academic teaching centre in Kazan, Russia, while based at the University of Kent; she spent a year in a more commercial research environment as an analyst, setting up a research unit for crisis management specialists. She is a regular contributor to public and media debates about science and progress.

Dr Peter Cotgreave
Peter Cotgreave is the Director of Save British Science, an independent campaign for effective science policies. He previously worked as a research ecologist at the Université Claude Bernard in France, as Lecturer in Ornithology and Human Sciences at the University of Oxford, and as a conservation biologist at the Zoological Society of London. He is the author of many scientific papers and popular science articles, and of two books, including *Science for Survival,* an exploration of the links between science and society. He has peer reviewed many papers for international journals.

Lord Drayson
As co-founder and Chief Executive of PowderJect Pharmaceuticals plc, Lord Drayson built the company from a technology start-up into the world's leading independent vaccines company. Following PowderJect's acquisition by Chiron, he has explored new projects in biotechnology and pharmaceuticals. His additional roles are as Science Entrepreneur in Residence at the Said Business School and as Chairman of the fund-raising campaign for Oxford's Children's Hospital. He took a seat in the House of Lords in June 2004.

Ms Fiona Fox
Fiona Fox is the Head of the Science Media Centre, an independent venture working to promote the voices, stories and views of the scientific community to the news media when science is in the headlines. She has a degree in journalism and 20 years experience in media relations. She was previously Head of Media at CAFOD, one of the UK's leading aid agencies. The Science Media Centre has produced a media training guide for 'Communicating Peer Review in a Soundbite', which was launched with a MORI poll on public attitudes to peer review.

Mr Tony Gilland
Tony Gilland is the Science and Society Director at the Institute of Ideas. He has organised and directed several major public engagement activities related to the controversies surrounding science today. These have included the Institute's "Genes and Society Festival" in London (2003), the Institute of Ideas' and New School University's "Science, Knowledge and Humanity" conference in New York (2001) and the Institute of Ideas' and Royal Institution's "Interrogating the Precautionary Principle" conference in London (2000). Tony is the editor of a number of publications, including *Science: can we trust the experts?* and a frequent contributor to journals, radio programmes, and public events on issues related to risk, the environment and scientific expertise. He holds a degree in Philosophy, Politics and Economics from the University of Oxford.

Professor Stevan Harnad
Steven Harnad was born in Hungary, did his undergraduate work at McGill University and his graduate work at Princeton University and is currently Canada Research Chair in Cognitive Science at University of Quebec/Montreal. His research is on categorisation, communication and cognition and he is the founder and editor of Behavioral and Brain Sciences (CUP), a journal of open peer commentary, and of Psycoloquy, an electronic peer commentary journal, as well as of CogPrints, an open access archive of peer-reviewed journal articles. He edited "Peer commentary on peer review: A case study in scientific quality control" (1982) and is the author of the articles "Rational Disagreement in Peer Review" (1985), "Implementing Peer Review on the Net: Scientific Quality Control in Scholarly Electronic Journals" (1996), "Learned Inquiry and the Net: The Role of Peer Review, Peer Commentary and Copyright" (1997), and "The invisible hand of peer review" (2000). http://www.ecs.soton.ac.uk/~harnad/.

Professor Sir Peter Lachmann FRS FMedSci
Peter Lachmann is Emeritus Sheila Joan Smith Professor of Immunology at the University of Cambridge. He has been President of the Royal College of Pathologists (1990-1993); Biological Secretary of the Royal Society (1993-1998) and founder President of the Academy of Medical Sciences (1998-2002). He has extensive experience of peer review both of grants and of journal papers. He is currently chairman of the research committee of the Digestive Diseases Foundation and has in the past held the same post for the Muscular Dystrophy Group and he has been chairman of the scientific advisory committee of the Association of Medical Research Charities. He was for many years the associate editor of *Clinical and Experimental Immunology*

Sir John Maddox FRS
John Maddox is a physicist and science writer. He is Editor Emeritus of *Nature*, and the author of *What Remains to be Discovered* (Macmillan, 1998). He is currently Editor of the *Foundation for Science and Technology Journal*.

Professor Peter Main
(Deputised by **Dr Philip Diamond,** Manager Higher Education and Research, Institute of Physics.)
Peter Main is the Director of Education and Science at the Institute of Physics, a learned society which supports physics at all levels. Previously, he was Head of Department and Professor of Physics at Nottingham University. He has been instrumental in developing an ethical code of conduct at the Institute of Physics.

Professor Alan Malcolm FIFST FIBiol
Alan Malcolm is Chief Executive of the Institute of Biology. His background has been in academic biochemistry with particular reference to medical applications, followed by seven years in food research. He was Director of the Institute of Food Research and Director General of the Flour, Milling and Baking Research Association. He is currently a member of the Government's Advisory Committee for Novel Foods and Processes. He was Vice-Chairman of the Food and Drink Technology Foresight Panel for six years. He has been an expert adviser to Select Committees in both the House of Commons and the House of Lords. He is a non-executive Director of Assured Food Standards (Little Red Tractor). He is a member of the European Commission Standing Group on Fresh Fruit and Vegetables, and a Visiting Professor at the Imperial College of Science, Technology and Medicine.

The Working Party would also like to acknowledge the contributions of the following people, who attended one or more meetings:

Professor David Cope and Dr Peter Border, Parliamentary Office of Science and Technology

Dr Ron Fraser, Society for General Microbiology

Dr Irene Hames, Blackwell Publishing and Managing Editor of *The Plant Journal*

Dr Robert Moor FRS, formerly at the Babraham Institute, Cambridge

Mr Bob Ward, Senior Manager Policy Communication, The Royal Society.

Appendix 6: Sense About Science

Sense About Science is a charitable trust, founded in 2002 to promote an evidence-based approach to scientific issues in the public domain. The trust works with organisations, scientific experts and opinion formers, to encourage this approach, particularly in areas of controversy, of which the debates surrounding genetics, hormones, and vaccines are current examples.

Sense About Science is governed by a Board of Trustees, which meets quarterly. Sense About Science currently employs a Director, Tracey Brown and a Programme Manager, Ellen Raphael. The Board and staff are supported by the Advisory Council, which is a voluntary network providing time and advice. The trust is also supported by some of the learned and professional societies, and scientific and medical organisations, which contribute in many ways to its objectives.

Objectives
The objectives of Sense About Science are:
To advance the education of the public in any branch of scientific research (including social science) and to disseminate useful information about such research.
To promote (for the benefit of the community) the understanding of, and to stimulate interest in, the creation, presentation and use of scientific research.

Board of Trustees

Members of the Board of Trustees sit as individuals, not as representatives of any other organisation. Sense About Science raises funds through inviting donations, to fund projects and cover the cost of a small staff.

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