NUFFIELD COUNCIL ON BIOETHICS

The culture of scientific research

Background paper

Published December 2014

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Introduction

1 This paper provides a review of recent research, evidence, media and policy activities related to the culture of scientific research in the UK in order to provide background information for the Nuffield Council on Bieothics' project on this topic.

2 The paper does not attempt to map exhaustively the issues or to reach any particular conclusions or recommendations. It instead seeks to set out the background as a basis for work by the Council and others in understanding whether and how concerns about the current culture of research might influence research behaviour and activity.

3 Scientific research is conducted by individuals in a variety of environments, for different purposes. Scientists work at universities, research institutions, research charities, trusts and foundations, Goernment departments, agencies and research councils, as well as in industry for profit-focused organisations such as pharmaceutical or technology companies. Some researchers work on collaborative projects combining expertise from the public, charitable and private sectors.

4 The research sector has grown significantly over the last 60 years. It is estimated that the numbers working in science research have increased from a few hundred thousand in the 1950s to 6 – 7 million today.[1]

5 A range of different factors work together to influence how researchers do science, including competition for funding, research assessment, publication of research and peer review, career paths and research governance. A short overview of the some key issues affecting science is set out in this paper, including:

- science **funding**, looking at where money for science comes from, and how it is allocated; the prevalence of short term grants in the sciences; and research assessment activities that determine the allocation of core funding to higher education research institutions in the UK.

- science **publishing**, in particular, claims that there are biases in how science journals select papers for publication; debates around open access publishing; issues relating to peer review including questions around its efficacy and fairness; proposals for different models of post publication peer review; and authorship and publication ethics.

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[1] The Economist (19 October 2013) *How science goes wrong*.

- how science is conducted, including growing trends towards **interdisciplinary** approaches, as well the impact of the progressively **international** nature of science, **training**, **commercialisation** and the influence of the **media**.

- science **careers**, including pressures affecting particular groups of UK scientists and how the field is viewed by researchers as a profession.

- the current **regulatory and governance frameworks** for scientific researchers and issues around **research integrity** and misconduct; the prevalence and nature of scientific misconduct, the procedures to which researchers are subject, and the effectiveness of initiatives developed to promote research ethics.

Research funding

6 In the UK, funding for publicly supported research has diminished over the last four years. Whilst science was considered to have fared less badly than other areas of public spending in the Coalition Government's 2010 spending review, scientific research nevertheless experienced a real-terms cut of around ten per cent.[2] Though recent Government announcements make commitments to maintain steady levels of funding for the UK science research councils, funding across the higher education sector as a whole is due to decrease by £125m for 2014-15.[3] This trend is not confined to public sector funding. In the private sector, spend on research and development increased by just one per cent between 2007 and 2013, compared with an increase of 34per cent between 1995 and 2011.[4] The discrepancy between demand for, and availability of, research funding means competition for money to support science is high.

7 Public funding for scientific research comes from a range of sources. These include Government departments, such as the Department of Health and the Ministry of Defence, through the UK research councils, including the Medical Research Council and the Science and Technology Facilities Council, and through the higher education funding bodies. There are three bodies that have this function in the UK: the Higher Education Funding Council for England (HEFCE), the Scottish Funding Council (SFC), and the Higher Education Funding Council for Wales (HEFCW). In Northern Ireland, this role is undertaken directly by the Department for Employment and Learning. The bodies deliver institutions' 'core funding', money allocated for teaching,

[2] The Guardian (19 October 2010) *Spending review spares science budget from deep cuts.*
[3] Research Fortnight (11 February 2014) *Another year of tight cash for the UK research councils*.
[4] National Audit Office (2013) *Research and Development funding for science and technology in the UK,* available at: *http://www.nao.org.uk/wp-content/uploads/2013/07/Research-and-development-funding-for-science-and-technology-in-the-UK1.pdf.*

research and related activities, over which each institution takes its own, local decisions about allocation.

8 Research council funding, on the other hand, is typically allocated through short-term (typically three year) awards for particular projects led by individual scientists or small teams. Funding administered through the UK's higher education funding bodies (core funding) to higher education institutions (HEIs) amounted to £2.547[5] billion in 2011, whereas money allocated through the individual research councils for projects run in HEIs, public research institutions, private non-profit orgnasations, UK businesses and overseas research, totalled £3.130 billion.[6] Area-specific bodies, such as the National Institute for Health Research (NIHR) which funds research aimed at improving national health services in the UK, also allocate Government money to particular projects.[7]

9 Other sources of funding are charities, trusts and foundations which typically make grants or awards for short-term or defined-length projects. The Wellcome Trust is the UK's largest non-Government funder of biomedical research, investing around £600m per year in science with the potential to improve human and animal health.[8] The Royal Society, one of the principal learned societies for science, is another funder of research in the UK. There are also a number of charitable trusts and foundations, such as The Leverhulme Trust and The Wolfson Foundation, providing grants and awards to individual research projects, usually for defined periods of time. Medical research charities, such as the Multiple Sclerosis Society and Cancer Research UK for example, provide support for basic and clinical research, on research into particular diseases.

10 European Union (EU) funding is now a significant source of support for science in European universities and businesses. UK science is typically successful in competing for EU research grant money, receiving a larger share than any other EU state, excluding Germany.[9] The European Commission's primary science funding scheme over the last seven years, the *7th Framework Programme for Research and Technological Development* or 'FP7' recently concluded and had a budget of 53.2 billion euros (£42.1 billion) for the seven years between 2007 and 2013. It was estimated that this resulted in 1 billion

[5] See Figure 2 of National Audit Office (2013) *Research and Development funding for science and technology in the UK*, available at: *http://www.nao.org.uk/wp-content/uploads/2013/07/Research-and-development-funding-for-science-and-technology-in-the-UK1.pdf.*

[6] The proportion of money distributed to scientific research through short-term project-specific funding is particularly high in the UK, as compared to some of the other European states, which do not all have state research councils, as in the UK.

[7] The NIHR model now makes use of a model 'Adding Value in Research', designed to optimise use of resources, which proactively commissions research it has previously identified as necessary or useful for improving health services. National Insitutue of Health Research (2014) *Research.*

[8] Wellcome Trust (2014) *Frequently asked questions*.

[9] BBC news (31 January 2014) *Horizon 2010: UK launch for EU's £67bn research budget.*

euros (£0.8 billion) per year, on average, being directed to UK science during this period.[10] The successor to FP7 is Horizon 2020[11] which was launched in 2014 and whose budget totals almost 80 billion euros (£63.3 billion). It is estimated that the UK may receive up to 2.5 billion euros (£2 billion) of these funds in the programme's first two years. [12]

11 Private sector research funding forms a substantial proportion of the total funding of science in the UK. National audit office figures show that the total amount spent by UK business on research and development in 2011 was £12.555 billion.[13] A large part of this was composed of very large research and development budgets of individual companies. GlaxoSmithKline, for instance, spends around 3.6 billion euros (£2.35 billion) every year on its own research and development activities.[14]

Short-term project grants from research councils, charities and foundations

12 Powerful competition for short-term, project-specific funding has the potential to impact on the sector in a number of ways.[15] Decisions about how such money is assigned by research councils and other bodies may have the capacity to impact on decisions scientists take about what particular projects to pursue, where to take up positions or even in what field to work. The time-limited nature of this kind of support also has the potential to impact on the appeal science has to prospective or current researchers as a career and may thereby affect the numbers of those choosing to pursue careers in science. It is possible that funding trends may therefore shape the field over time, by influencing what is studied and who studies it.

13 Statistics on funding decisions are made available by research councils, for example on grant size, recipients' institution, age or gender.[16] Whilst individual research councils are transparent about outcomes of particular funding decisions, it does not seem to be common to provide analysis of trends across a number of years in which particular fields, or sub fields, of science are being supported by funders. Nor does any other formal analysis of over-arching patterns or trends in how public money is assigned to individual research

[10] Parliamentary Office of Science and Technology (June 2010) *EU Science and Technology Funding*, *June 2010,* available at: http://www.parliament.uk/business/publications/research/briefing-papers/POST-PN-359/eu-science-and-technology-funding-june-2010.
[11] European Commission (2014) *Horizon 2020: The EU Framework Programme for Research and Innovation.*
[12] BBC news (31 January 2014) *Horizon 2010: UK launch for EU's £67bn research budget*.
[13] See Figure 2 of National Audit Office (2013) *Research and Development funding for science and technology in the UK*, available at: *http://www.nao.org.uk/wp-content/uploads/2013/07/Research-and-development-funding-for-science-and-technology-in-the-UK1.pdf.*
[14] Fierce Biotech (2014) *GlaxoSmithKline – the world's biggest R&D sepnders*.
[15] Funding is normally considered short–term in the sciences if it supports a project for three years or less.
[16] The Science and Technology Facilities Council, for instance, publishes funding statistics on grants awarded: Science and Technology Facilities Council (2014) *STFC Funding Statistics: Grants*.

projects seem to have been conducted. The situation is similar with third sector funding; whilst many trusts and foundations publish outcomes of decisions or describe examples of funded work on their websites[17], it is not straightforward to identify work exploring in depth more general trends in which fields, or sub-fields, of science are being funded by charities or trusts (or both) over time.

14 Information about how funding bodies make decisions about which projects to fund can be garnered by looking at assessment criteria for applications. Research Councils UK (RCUK), for instance, which sets out assessment criteria for use by all seven of the individual research councils, include a *Pathways to Impact* component of the application process. This encourages prospective researchers to plan how they will engage with the potential beneficiaries of their research to increase the chances of delivering ‘economic and societal impacts’.[18]

15 Individual research councils also publish their own criteria, including organisational or strategic priorities, to which decisions about grant giving are sensitive. The Biotechnology and Biological Sciences Research Council (BBSRC), for instance, list agriculture and food security; industrial biotechnology and bio-energy; and basic bioscience for health as their three strategic research priorities[19] (‘responsive mode priorities’[20] are topics listed within these priority areas, and include nimal health, reducing waste in the food chain, synthetic biology, welfare of managed animals, amongst others) and explain that competitive applications addressing a strategic priority will have an advantage in competition. A number also provide statistics on how allocated funding correlates with their priority research areas, publishing information on what proportion of their funding was assigned to each area in a given period. [21] Nevertheless, conclusions about the ways that such criteria may, over time, be shaping the broader direction of scientific research as a whole are less easy to draw from this information.

16 It is possible to make some conservative inferences about this from information that is in the public domain. To take one example, information from the ‘Funding rates’ section of the Engineering and Physical Sciences Research Council (EPSRC) website can be used to determine how levels of support for projects categorised within their ‘Energy’ theme has changed, both in absolute

[17] See for instance Wellcome Trust (2014) *Grants awarded* and The Leverhulme Trust (2014) *Previous Awards*.

[18] Research Councils UK (2014) *Research Council guidance for completing the Pathways to Impact*.

[19] Biotechnology and Biological Sciences Research Council (2014) *The Age of Bioscience: Strategic Plan: Biotechnology and Biological Sciences Research Council: Updated 2013/14*,available at: http://www.bbsrc.ac.uk/web/FILES/Publications/strategic-plan.pdf.

[20] Biotechnology and Biological Sciences Research Council (2014) *Responsive mode priorities*.

[21] See for instance the Engineering and Physical Sciences Research Council information on how money is to allocated to projects by ‘theme’. Engineering and Physical Sciences Research Council (2014) *Research Proposal Funding Rates 2013-2014*, available at: http://www.epsrc.ac.uk/newsevents/pubs/201314/.

terms and as a proportion of the Council's overall expenditure between 2006/7 and 2010/11.[22] Figures suggest that absolute funding for work classed as 'Energy' research, increased markedly in 2008, more than doubling from 27 million (or 4.7per cent of the Council's total expenditure that year) in 2007 to 59.1 million (11.5 per cent). The figures then fluctuated between 37.2 and 59.1 million (8.1 per cent and 11.5 per cent) over the subsequent four years, dropping noticeably in 2010 (absolute figures were 59.1, 57.8, 37.2 and 56.0 million in respective years, or 11.5 per cent, 10.5 per cent, 8.1 per cent and 11.4 per cent).

17 It is also possible to use research council information to see how absolute funding levels, across all themes, have changed over the last several years. The ESPRC total expenditures for years between 2007 and 2012 were 573, 513, 548, 459, 488 and 377 million [23]respectively, showing that noticeably less money has been available in the last three years, as compared with the three preceding years .

18 Figures from charitable funding organisations similarly suggest a slump took place around the time of the global economic crisis in 2008. The Wellcome Trust accounting figures show that their science funding expenditure has increased for the last two years (growing markedly between years 2012 and 2013, from 435.7 to 515.4 million). This period followed a steady decrease in science funding, beginning in 2008 and running up to 2011 (464.0, 461.7, 436.5, 377.8 million for each respective year).[24]

19 There are obvious limitations to the conclusions that can be drawn from analysis of this kind in isolation, however. More detailed data, from a wider range of sources, about the success rates of different kinds of science in winning funding, over longer periods of time, may be able to paint a fuller picture of how funding decisions may exercise influence over the direction science takes in the long term.

20 Whilst cuts to public spending of recent years have been less pronounced in science than in other areas of research, there is a perception that resources for science research have become significantly more scarce since the 2010 spending review. There is evidence, for instance, that scientists across the board are finding it harder to secure funding for research projects. In a survey

[22] The absolute figures for the year 2012 and 2013 are not presented and the Council's theme 'Energy' did not exist before that.
[23] This information can be extracted from the Enigneering and Physical Sciences Research Council research proposal funding rates information from the years between 2007 and 2012 published on the Council's websit: Engineering and Physical Sciences Research Council (2014) *Funding rates for previous years*.
[24] Wellcome Trust (2012) *Summarised Annual Report and Financial* Statements, available at: http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_publishing_group/documents/web_document/wtp041264.pdf.

of research scientists conducted in 2013, respondents reported a decrease in numbers of grants funded, and smaller amounts of money being awarded per grant, leading to reduced recruitment of researchers, PhD students and other staff and difficulties in purchasing equipment.[25]

Peer review in funding allocation

21 A separate issue concerning short-term grants is the process by which funding applications are assessed. Decisions about how to allocate research council funding are typically made by peer review (95 per cent of the money allocated to medical research in the UK is assigned in this way).[26] This involves academic researchers evaluating their peers' research proposals and making recommendations for whether or not the work should receive financial support. However, questions have been raised about the effectiveness and efficiency of the peer review process in this context. A recent report looking at this area identified issues relating to this system and the burden it places on reviewers, as well as less favourable outcomes for interdisciplinary research, innovative research and research by early career scientists.[27] The report suggests that making either a single individual, such as an expert programme director or an executive, or an interdisciplinary committee incorporating research 'end-users', decision-makers and community members responsible for decision making, may improve the current system.

22 The same report outlines a range of options for altering the funding process more broadly. The current model tends to involve a funder issuing a call for proposals and research teams responding by submitting (and often refining and re-submitting) applications independently, to a deadline. Alternatives to this model include holding joint workshops and brainstorming sessions with research teams to identify and develop ideas for proposals, for funders to more proactively source applications by working alongside research teams on proposals, or using 'pre-selection' support or mentoring. This, it is suggested, may produce a 'mixed system' more suited to meeting a range of research aims, where such aims can be clearly identified.[28] Some of the UK research

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[25] Science is Vital (2013) *Legacy of the 2010 Science Budget Cash Freeze*, available at: http://scienceisvital.org.uk/wp-content/uploads/2013/06/SIV_170613a_Legacy.pdf.

[26] Ismail S, Farrands A, and Wooding (2012) Evaluating grant peer review: Key findings of a literature review of grant peer review in the health sciences, *RAND*, available at: http://www.rand.org/content/dam/rand/pubs/research_briefs/2012/RAND_RB9682.pdf.

[27] Ismail S, Farrands A, and Wooding (2012) Evaluating grant peer review: Key findings of a literature review of grant peer review in the health sciences, *RAND,* available at: http://www.rand.org/content/dam/rand/pubs/research_briefs/2012/RAND_RB9682.pdf.

[28] Guthrie S, Guerin B, Wu H, Ismail S, and Wooding S (2013) Alternatives to Peer review in Research Project Funding: 2013 update *RAND*, available at: http://www.rand.org/content/dam/rand/pubs/research_reports/RR100/RR139/RAND_RR139.pdf.

councils have more recently explored the use of these kinds of approach, such as the ESPRC's 'sandpit' residential workshops.[29]

23 A recent article examining the system underpinning biomedical research in the US advocated a number of changes to grant-making review panels. These included proposals to broaden the range of scientific problems appraised by groups and diversifying panels so that scientists from different fields are represented.[30]

24 Another issue with the role of peer review in the assessment of short term grant proposals concerns the conflicts of interest that may arise when members of competing teams of scientists are asked to assess each others' work. It has been suggested by some that this system invites 'game playing' and may tempt scientists appraising proposals in their own field, with which their own work may be in competition for funding, to make less favourable recommendations than they otherwise would. Issues relating to the use of peer review and publications are discussed at paragraphs 89-98.

25 The impact on researchers' job satisfaction of the prevalence of short-term funding has been explored in a range of work and is discussed in more depth below (paragraphs 129 –134).

Core funding and the Research Assessment Framework (REF)

26 The core funding for research departments in UK HEIs is currently administrated by the higher education funding bodies. For the year 2014-5 £1.558 billion is ring-fenced for research, across all areas, in England.[31] Decisions about how to divide core funding up between the different HEIs are made based on an assessment of the quality and impact of research they produced over a defined period of time.

27 The UK began using research assessment to guide decision-making around allocating core funding to HEIs in the 1980s. The first incarnation of this activity was the Research Assessment Exercise (RAE) which ran between 1986 and 2008.[32] The RAE was considered to suffer from a number of flaws and was criticised, for instance, for permitting system 'gaming' such as the manipulation

[29] Sandpits are "residential interactive workshops over five days involving 20-30 participants; the director, a team of expert mentors and a number of independent stakeholders" intended to generate "lateral thinking and radical approaches to address research challenges": Engineering and Physical Sciences Research Council (2014) *Sandpits*.
[30] Alberts B, Kirschner M, Tilghman S and Varmus H (2014) Rescuing US biomedical research from its systemic flaws *PNAS* **111(16)**: 5773–5777.
[31] The total amount, counting 'non-recurrent elements' which include "capital grants and funding for national facilities and initiatives" is £1.838 billion for 2014/15. Higher Education Funding Council for England (2014) *Recurrent grants and student number controls for 2014-15*, available at: http://www.hefce.ac.uk/media/hefce/content/pubs/2014/201405/HEFCE2014_05.pdf.
[32] Research Assessment Exercise (2005) *Guidance on submissions: RAE 2008*.

of departmental boundaries to optimise returns and for the imposition of considerable costs and bureaucracy on HEIs.[33] The Research Assessment Framework (REF) was developed as the RAE's successor, following the Review of Research Assessment undertaken in 2003 by Sir Gareth Roberts.[34]

28 HEFCE announced in 2007 that the REF would be introduced following the final RAE in 2008, and would inform the subsequent set of decisions around HEI core funding. The REF requires HEIs to make submissions about their research, including up to four research publications for selected staff members, for review by expert panels. HEIs will subsequently be assigned a quality profile on the basis of agreement with a number of criteria. These criteria include research quality, cashed out as originality, significance and rigour; vitality and sustainability of the research environment; and the 'impact', or reach and significance the research has outside the academic community.[35] The outcomes of the next cycle of the process will be published in December 2014 and will determine the levels of core funding that universities and other higher education organisations receive from the academic year 2015-16 onwards.

29 Whilst research assessment initiatives used in the UK have been unpopular in parts of the academic community, most accept that some form of research evaluation is necessary to inform and provide a foundation for fair decision-making around core funding. A Select Committee on Science and Technology 2002 inquiry, for instance, found that that the RAE had had a broadly beneficial effect on research, improving HEIs management of research, prompting more sophisticated institutional research strategies and stimulating the development of research facility in HEIs formerly less engaged in research activities.[36]

30 Controversy continues, however, over the particular nature of research assessment activities in the UK and the ways they might be intensifying already high levels of competition within academic science. Concerns about the REF relate to its fairness as an indicator of quality, with some claiming that the REF mechanisms are not able to effectively identify quality research in all cases, with the consequence that decisions about funding allocation may not be fair. Other issues relate to the wider influence of the REF on the research sector as a whole.

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[33] Science and Technology Committee (2002) *Second Report:The Research Assessment Exercise,* available at: http://www.publications.parliament.uk/pa/cm200102/cmselect/cmsctech/507/50702.htm.

[34] RA Review (2003) *Review of research assessment: Report by Sir Gareth Roberts to the UK funding bodies*, available at: http://www.ra-review.ac.uk/reports/roberts/roberts_summary.pdf.

[35] REF (2011) *Assessment framework and guidance on submissions (updated to include addendum published in January 2012)*, available at: http://www.ref.ac.uk/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf.

[36] Science and Technology Committee (2002) *Second Report:The Research Assessment Exercise,* available at: http://www.publications.parliament.uk/pa/cm200102/cmselect/cmsctech/507/50702.htm.

REF and Impact

31 A key area of the REF about which complaints have been made is the appropriateness of 'impact' as a measure of research. One line of argument concerns the challenges of reliably measuring impact. This has been discussed repeatedly in the media[37] and in academic work looking at gauging impact in specific sectors. For example, a recent report on measuring impact in academic clinical medicine concluded that there were significant difficulties in comparing evidence of impact across different individual cases in a standardised manner.[38] Some have argued that dedicated research is required to help devise adequate measures that can fully assess societal impact and thereby provide a reliable basis on which to take decisions about funding.[39] The worry here is that impact cannot be a fair measure of quality if it is not commensurable across different fields. It has been pointed out, though, that the same may be true of other features of the REF. The assessment that is made of different research outputs in terms of their 'originality, significance and rigour' may also be difficult to compare, in which case the problem would not be distinctive to the use of impact criteria.

32 Another charge levelled at the use of impact criteria relates to the time that a piece of science may take to exert a tangible influence on society. The length of time over which the REF allows the impact of admissible work to take effect is quite long – research published as long ago as 1993 may be included.[40] However, for some fields of science, certain areas of physics for example, this time period may not be long enough to allow work with important social benefits to be recognised. The laser is sometimes cited as an illustrative example of a technology which turned out to have a high degree of social impact, used widely, as it is, in a wide range of industrial and commercial contexts. These applications, however, did not materialise until long after the technology was developed. [41]

33 A distinct issue, connected to some of the concerns above, relates to the incentives that the impact agenda may create for scientists to exaggerate the

[37] See for example, Times Higher Education (23 February 2012) *REF's effort to make knowledge visible may have cloudy results* and Times Higher Education (11 October 2012) *Bracing for impact may cost sector millions*.

[38] Ovseiko P, Oancea A and Buchan A (2012) Assessing research impact in academic clinical medicine: a study using Research Excellence Framework pilot impact indicators *BMC Health Services Research* **12 (478)**.

[39] Bornmann L (2012) Measuring the societal impact of research *European Molecular Biology Organization* **13(8)**: 673-6.

[40] REF (2011) *Assessment framework and guidance on submissions (updated to include addendum published in January 2012)*, available at: http://www.ref.ac.uk/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf.

[41] Times Higher Education Leader (12 February 2009) *Short term outlook, no blue skies*.

economic or societal significance of research findings. It is possible that, given the highly competitive nature of academic science, pressure on researchers to demonstrate impact may encourage them to overestimate or inflate the societal potential of their work. It has been argued that this factor may have played a role in growing levels of 'hype' around new research which, some worry, has the potential to undermine public trust in science.[42]

34 Impact nevertheless constitutes only 20 per cent of the assessment, meaning the greater emphasis continues to be on appraisal of other features of academic work. There are also defenders of the impact component of the REF. Advocates have argued that impact, under the guidance on submissions to the REF, is construed quite broadly, so as to include a range of possible sources of impact. Impact is defined in the guidance as "an effect on change or benefit to the economy, society, culture, public policy or services, health, the environment, quality of life, beyond academia"[43], which may make it flexible enough to accommodate academic works' wider significance along a number of dimensions – public engagement activities, for instance, might count for some researchers.[44] Some have argued, too, that it is quite proper for academic work supported by the state to benefit the wider public in some way. Others have argued that the requirement to show evidence of impact has provided univiersites with an opportunity to gather useful information about, and take deserved credit for, the wider influence of parts of their research portfolios.[45]

35 Whether or not the impact component of the REF is sensitive enough to capture the value of work whose wider societal and economic effects are hard to measure, or which may take longer to materialise, there is nevertheless a perception in some areas that this aspect of research assessment creates difficulties for academic scientists. This fact alone may have the potential to influence the sector insofar as these perceptions may affect the decisions scientists take about what areas of science to work on (see paragraphs 40-41).

REF and publications

36 A distinct potential problem with the REF is the link with scientists' published research. Whilst many accept that a researcher's publications may be a reasonable measure of quality, practical features of how the publishing system

[42] Nerlich B (2013) Moderation impossible? On hype, honesty and trust in the context of modern academic life *The Sociological Review* **61(S2)** 43-57.
[43] REF (2011) *Assessment framework and guidance on submissions (updated to include addendum published in January 2012)*, available at: http://www.ref.ac.uk/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf.
[44] The Guardian (22 November 2013) *Six good things about the REF*.
[45] The Guardian (22 November 2013) *Six good things about the REF*.

works may cast doubt on how facts about researchers' publication records should be viewed.

37 For instance, the length of time that many journals take to accept or reject articles may unfairly disadvantage a researcher whose work may be waiting in a bottleneck for review. Given the sometimes unpredictable nature of publication timescales, the format of REF submissions can create added difficulties for researchers, which raise other questions about the fairness of using publication as a strong indicator of research quality. Each researcher involved in the REF is asked to submit up to four pieces of their published work, which must fall within a particular period, and this may make it difficult for them to make decisions about whether to submit work which has been accepted, but not printed, by a journal whose precise date of publication is unknown. Work accepted by journals may take some time to appear, and the gap between acceptance and publication dates presents a dilemma for academics who want their best work to be represented, but who also do not want to risk making an incomplete submission to the REF. Some have suggested it is unfair for researchers to be in a position where significant parts of their work may be 'wasted', in never being acknowledged in research assessment activities at all. [46]

38 A range of issues relating specifically to the systems underlying publication and peer review themselves also raise questions about basing judgements of quality on publications; these are discussed in more depth below (paragraphs 44-98).

Effects of the REF on research priorities

39 A further issue concerns the potential influence that the REF may have on the direction of the research sector as a whole in the long term. Some worry, for instance, that the REF and the emphasis it places on impact may create incentives for researchers to avoid work in areas which are deemed to have less impact, leading to concerns that certain areas of research may in the future be neglected.[47]

40 It has been argued that 'blue skies' research, or research in highly theoretical fields, which may have less societal influence in the short term, or whose impact may take longer to manifest itself, may be disincentivised by research assessment activities which focus on impact. Similarly, the issues around assessing impact, may induce researchers to focus efforts in areas of work in

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[46]The Guardian (28 October 2013) *Nobody wants their research impact to be graded 'considerable' in the REF*.

[47] Society for Research into Higher Education (2012), *Final report: assessing the impact of developments in research policy for research on higher education: an exploratory study*, available at: http://www.srhe.ac.uk/downloads/Leathwood_Read_Final_Report_16_July_2012.pdf

which impact is perceived to be more easily measured.[48] Responses to HEFCE's 2009 public consultation on proposals for the REF revealed concerns of this kind, relating to the stifling of innovation and the undermining of academic autonomy.[49]

Cost effectiveness of the REF

41 Whilst it is largely accepted that some method is needed to allocate limited core research funds, questions have been asked about the proportionality of running the REF. Doubts have been raised in recent work over whether costs involved in administrating a large complicated system may ultimately outweigh the benefits.[50]

42 The models of research assessment used in the REF, and previously in the RAE are not unique in attracting criticism. Finding ways of reliably and fairly assessing research continues to present a challenge for policy makers and funders, and it is unlikely that a fully accurate, objective system, capable of satisfying all parties, is possible to devise. Nevertheless, continued concerns about research assessment have led some to call for reforms to the way that research is evaluated and to advocate the exploration of alternative models for research assessment (see paragraph 54).[51]

Publication of scientific research

43 In the contemporary science environment there is an expectation that scientists will publish their work in peer-reviewed journals. Publication of this kind is a fundamental constituent of science and one of the cornerstones of research culture. Published work represents the current body of scientific knowledge at any given time and shapes both the nature and content of future research.

44 Quality-checked published science is considered by many to be an important feature of how science works. It offers a means of communicating robust

[48] Bornmann L (2012) Measuring the societal impact of research *European Molecular Biology Organization* **13(8)**: 673-6.
[49] Higher Education Funding Council for England (2010) *Research Excellence Framework: Second consultation on the assessment and funding of research: Summary of responses*, available at: http://www.hefce.ac.uk/media/hefce/content/pubs/consultationoutcomes/2009/200938outcomes-secondconsultationontheref/REF2_0310.pdf.
[50] Martin BR (2011)The Research Excellent Framework and the 'impact agenda': are we creating a Frankenstein's monster? *Research Evaluation* **20(3)**: 247-54.
[51] An alternative model of research assessment involves assessing different academic disciplines in series, rather than in parallel, once every few years, which it has been suggested allows the process to avoid some of the difficulties presented by cross disciplinary comparison encountered by the REF. Research assessment in the Netherlands has this feature. See for instance Association of Universities in the Netherlands (VSNU), the Netherlands Organisation for Scientific Research (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW) (2014) *Standard Evaluation Protocol 2015-2012: Protocol for Research Assessments in the Netherlands*.

research findings to other scientists to inform future work, as well as making important new scientific knowledge available to practitioners, such as doctors, in relevant fields. The material limitations of printing articles in journal hard copies meant that, historically, editorial decision-making necessarily involved taking judgements on comparative quality to guide choices about which articles to publish. This selective component of academic publishing continues today, in spite of the considerable increases in capacity supplied to journals by developments in digital publishing.

45 Publication not only plays an important role in research assessment by funders, but is a key determinant in making appointments to academic departments and in a researcher's career development, resulting in many researchers feeling 'pressure to publish'. A recent piece of work modelling factors involved in the development of scientists' future success found that first-author credits in published science are the most potent predictors of whether a scientist will become a Principal Investigator (PI).[52] The way in which publications are often assessed in these contexts has engendered another important way in which competition manifests itself in research culture.

46 The idea that researchers must 'publish or perish' is commonly expressed in the media, but commentators do not agree on whether very intense competition to have work published is ultimately good or bad for science. Some argue that high expectations, especially on early career researchers, create a healthy competition that raises standards and drives forward scientific endeavour. But it has also been claimed that these pressures undermine the objectivity and integrity of science.[53] Some point out that the strong expectation on young researchers to publish material may encourage them to engage in ethically dubious practices, such as submitting identical material to different journals simultaneously, contrary to the submissions policies of many journals, resulting in 'double publications' or 'self plagiarism'.[54] Alternatively it may tempt them to publish work too quickly which may be of less high quality, and which may remain largely unread.[55] There is also a worry that pressure on researchers to have their work accepted by journals threatens to influence the direction of scientific research itself, and the kinds of work that scientists choose to pursue.

[52]The study also found that the impact factors of journals in which scientists' work is published, alongside their institution and their gender, were also key predictors: Van Dijk D, Manor I and Carey L (2014)) Publication metrics and success on the academic job market *Current Biology* **24(11)**: pR516-7.
[53] Science and Policy Exchange blog (23 January 2014) *Publish or perish: is the pressure to publish in 'brand name journals' hurting science?*
[54] Neill U S (2008) Publish or perish: but at what cost? *Journal of Clinical Investigation* **118(7)** 2368.
[55] Gad-el-Hak M (2004) Publish or perish: an ailing enterprise *Physics Today* **57(3)** 61-2.

47 This pressure may be exacerbated by expectations that researchers have their work accepted for publication in certain kinds of 'high impact' journals, of which Nature and Science are seen as exemplars. As the number of people working in science increases over time, the levels of competition for publishing work in such journals has become much more intense. Acceptance rates for Nature, already low in 1997, have fallen steadily over the last 15 years, dropping from 10.7 per cent to 7.8 percent in 2013.[56]

48 The issues around high impact journals received mainstream media attention at the end of 2013 when Nobel prize winning biologist, and editor of the recently established open access science journal eLife, Randy Schekman denounced of the the ongoing veneration of 'luxury journals', arguing that such trends encouraged scientists to work in fashionable fields and to cut corners when doing science. He announced publicly that he would no longer be submitting work to Nature, Science and Cell.[57]

Publication metrics

49 The use of journal 'impact factors' – metrics that reflect the average number of citations to articles published in given journal in a defined period of time after their publication – as a mark of the importance or quality of a journal has also aroused considerable controversy in recent years. Impact factors were first used to rank journals in the early seventies and have been viewed as a means of rating the quality of research published within specific journals. However, they have been criticised for a range of reasons. It has been pointed out, for instance, that the frequency and immediacy with which articles tend to be cited varies across different fields of science, meaning that they cannot be viewed as a fair mark of quality across disciplines.[58] It has also been argued that such metrics are vulnerable to manipulation – any editor wanting to increase the impact factor of their journal may commission reviews in fields where their journal frequently publishes, may publish work more likely to be cited earlier in the year (which would allow more time for it to influence the journal's impact factor) or even regard more favourably submitted work that cites their own journal's papers.[59] In spite of the ongoing debates around their use, and recent trends away from their application in formal research assessment[60] they are still perceived by scientists to play a significant role in the way that science and

[56] Nature (2014) *Getting published in Nature: The editorial process.*
[57] The Guardian (9 December 2013) *Nobel winner declares boycott of top science journals*.
[58] E V Nierop (2009) Why do statistics journals have low impact factors? *Statistica Neerlandica* **63(1)**: 52-62.
[59] Ogden T and Varley D (2007) The Ups and Downs of Journal Impact Factors *The Annals of Occupational Hygiene* **52(2)**: 73-82.
[60] Commitments were made, for instance, that REF sub-panels would not make use of impact factors in assessing the quality of research outputs:REF 2014: Research Excellence Framework (2013) *Research outputs (REF2) Latest FAQs*.

scientists are appraised[61], and may play a role in more informal decision making involved in hiring and promotion. In some parts of the world, such as China, impact factors are still used directly to support decisions about funding allocation, attracting ongoing criticism from parts of the scientific community.[62]

50 The h-index is another metric used in the appraisal of scientific work, and is assigned to the published work of individual scientists, or groups of scientists, rather than to journals. Like the impact factor, the h-index has been criticised for being subject to manipulation, since authors are able to increase their own h-index by citing their own work . Nor is the h-index sensitive to different conventions around authorship credits in distinct fields (see paragraph 87) relating to numbers of authors typically credited or positioning on an author list. Some think this undermines the reliability of the metric as a guide to science quality, across different areas of science.

51 There is a growing interest in 'altmetrics', which are based on factors including download and bookmark numbers, blog and social media mentions, and expert recommendations. Altmetrics are increasingly being used by publishers, funders and institutions, which are looking for new ways to measure the reach of research in the digital age. A number of companies, such as Altmetric.com and Plum Analytics, now provide research evaluation services to researchers based on a variety of altmetrics. [63] Correspondingly, tools for sharing and promoting research online such as Mendeley are increasingly being used by researchers.

52 In April 2014 the Government requested that HEFCE conduct an independent review of the role of metrics in research assessment and management.[64] The review is due to report in Spring 2015.

53 The San Francisco Declaration on Research Assessment (DORA) is a worldwide initiative aiming to improve the ways in which scientific research is evaluated, by publishers, research institutions, funding agencies and others.[65] DORA was set up in 2012 by the American Society for Cell Biology (ASCB) but applies to all areas of academic research. The declaration makes a range of recommendations for publishers, research institutions, funders, and researchers themselves, relating primarily to issues around the use of metrics and in particular the use of journal impact factors in the appraisal of

[61] Nature (16 June 2010) *Do Metrics matter?*
[62] Nature (17 August 2011) *China's chemists should avoid the Vanity Fair*.
[63] Altmetric (2014) *What does Altmetric do?*
[64] Higher Education Funding Council for England (2014) *Independent review of the role of metrics in research assessment*.
[65] American Society for Cell Biology (2014) *San Francisco Declaration on Research Assessment: putting science into the assessment of research*, available at: http://www.ascb.org/dora-old/files/SFDeclarationFINAL.pdf.

researchers' and their work. It also requests greater transparency and openness in criteria used in decision-making and calls for the scientific content of research to be the primary focus. The initiative encourages individual researchers and organisations to sign the declaration and support the implementation of the DORA recommendations. At the time of writing, 11,214 individuals and 492 organisations had signed the declaration.

54 The fairness of judging the standard of a researcher's work by their peer reviewed publications relies partly on the processes involved in publishing and in peer review being as impartial and reliable as possible. Quality is usually thought of as a function of both rigour and significance, but the latter in particular may be very difficult for different reviewers to appraise in an entirely uniform manner. Whilst it is plausible that judgements about the standard or overall quality of a piece of science may inevitably involve an element of subjective judgement, there is nevertheless an expectation that journals, will on the whole, accept for publication the best science.

Publication bias towards positive findings

55 A number of studies have addressed the existence, and effects, of publication bias in science journals, particularly towards positive results and novel findings. Publication biases are problematic not only because of the strong connection between publications and funding, appointment and career progression, but also because they have the capacity to create a distorted picture of scientific findings as a whole. They may also create incentives for particular kinds of work to be conducted over others.

56 One purported bias is the tendency of reviewers and editors to favour studies that report positive results which allow definitive rejection of a null hypothesis. Recent work has argued that in many fields of science, research is more likely to be published, and more likely to be accepted by high-profile journals, if it reports positive results.[66] This raises the possibility that rigorous work of equal scientific merit is not being accepted for publication.

57 Such a bias would evidently have the capacity to distort the picture presented by the body of published science. A theoretical example demonstrates this; if multiple tests of a single hypothesis are conducted by different researchers, with the majority reporting negative findings, when these are presented individually to different journals it may nevertheless be that the single study purporting to have identified a positive relationship is the only work published.[67] In an environment in which editors may have incentives to favour more

[66] Fanelli D (2010) Do Pressures to Publish Increase Scientists' Bias? An Empirical Support from US States Data *PLoS ONE* **5(4)**: e10271.
[67] National Bureau of Economic Research (2006) *Researcher incentives and empirical methods*, available at: http://www.nber.org/papers/t0329.pdf?new_window=1.

significant or 'exciting' work, this has the potential to impact on the integrity and quality of science as a whole.[68]

58 The tendency towards publishing positive results may have the effect, analysed in one recent study, of favouring research findings that have a higher likelihood of being false.[69] This analysis suggested that when considered alongside the prior unlikeliness of a tested hypothesis and a study's typical statistical power, the bias in favour of publishing positive results implied that less than 50 per cent of published findings are likely to be true. Because of this, the study claims, publications reporting positive results are statistically more likely to be false than those reporting negative findings, with obvious consequences for the credibility of the scientific literature.

Duplication

59 A publishing model that favours certain types of research over others may obscure the existence of quality science that has already been conducted, increasing the likelihood of unnecessary repetition of existing, unpublished work. A trend for publication of positive over negative results would make it more likely that science reporting negative results will be needlessly repeated, as researchers considering new work and writing proposals are unlikely to know it has already been done.[70] Ideas for addressing this issue include a proposal recently made in the BMJ that abandoned or 'invisible' work, which may have been misreported, should be restored by researchers publicly registering the possession of publishable data. [71]

60 A related but separate issue relates to researchers' access to information about ongoing, incomplete work, which is not yet ready to be submitted for publication. Similar issues around duplication may arise in cases where a particular piece of work is underway, unbeknownst to other scientists, who may begin identical research independently. One suggested solution to this challenge is the construction of a publicly-accessible database registering ongoing, unpublished work, such as, for instance, the US Health Services Research Projects in Progress database (HSRProj). [72]

[68] A natural reply to this argument may be that false positive findings are likely to be exposed when other groups of scientists find they are unable to reproduce the result – however, various issues concerning replication work mean that this mechanism may not always function effectively (see p.20).
[69] Ioannidis J (2005) Why Most Published Research Findings are False *PLOS Medicine* **2(8)** 124.
[70] Ioannidis J *et al.* (2014) Increasing value and reducing waste in research, design, conduct and analysis *The Lancet* **383(9912)**: 166-75.
[71] British Medical Journal (2013) *Restoring invisible and abandoned trials: a call for people to publish the findings.*
[72]The database can be accessed throught the USNational Library of Medicine website:US National Library of Medicine (2014) *NIH US National Library of Medicine*.

61 Minimising the unnecessary repetition of research is also one of the arguments made in favour or promoting wider access to research data (see paragraphs 74-82). It has been claimed that opening access to existing published scientific studies would make it easier for researchers to survey what work has already been both carried out and published.[73]

62 Duplication and waste in research are problems which transcend issues around publication bias. A series of five Lancet articles published at the start of 2014 looked in detail at various ways in which the the current system can give rise to waste in the biomedical sciences, including in how research priorities are set, how research is designed, conducted and analysed, and how it is regulated and managed.[74] The series raises questions around how biomedical science as an enterprise should change in order to become more reliable, accessible and able to engage with real challenges faced by society.

Verification and reproducibility of published research

63 Whist the duplication of unpublished science may involve waste there is nevertheless a legitimate, and very important, role for the repetition of experiments in order to verify published results. The convention in science is for separate research teams to attempt the reproduction of published results and if other groups are not able to make the same findings as those published, this undermines those findings. The reproduction of previous results – replication or verification – therefore plays a key role in the scientific process, and replication has historically acted as a self-correcting mechanism through which results are robustly assessed over time.

64 It is widely thought, however, that research aiming to verify previous results is not proportionately represented in scientific journals and that work reporting novel results has a higher likelihood of being published. [75] If this were so, it would suggest that scientific results are not being scrutinised in the way the system requires. A number of papers have argued that this problem exists in different areas of science.[76] [77] [78]

65 This trend may be responsible for the feeling amongst many scientists that work aiming to reproduce previous results is less likely to further one's career. Replication of others' work may be seen, by younger researchers in particular,

[73] Velterop J (2003) Should scholarly societies embrace open access or is it the kiss of death? **16(3)** 167-9.
[74] The series included five articles and two comment pieces examining different aspects of waste in biomedical research (The Lancet (January 8 2014) *Research: increasing value, reducing waste*).
[75] The Economist (19 October 2013) *Trouble at the lab.*
[76] Porte, G *(*2013) Who needs replication? *CALICO Journal* **30(1)**: 10-5.
[77]Moonesinghe R (2007) Most published research findings are false – but a little replication goes a long way *PLoS Medicine* **4(2)**: e28.
[78] Redden DT and Allidos DB (2003) Nonreplication in genetic association studies of obesity and diabetes research *Journal of Nutrition* **133(11)**: 3323-6.

as provocative or as a challenge to authority and therefore less appealing. [79] Alternatively, it may be that replication work is simply seen as less exciting than work that produces novel results, and so may appeal less to researchers for that reason.

66 Recent work has demonstrated that significant proportions of research findings cannot be reproduced when scientists conduct work aiming to verify others' results.[80] It has been suggested that the extreme levels of competition now present in science, and careerism which may encourage scientists to exaggerate or 'cherry pick' their results, may be contributing to the amount of 'unreproducible' data currently being published.[81] There are also concerns that verification work is itself being neglected and that the current culture of science neither encourages nor rewards research which aims to reproduce others scientists' findings.

67 This feature of science has the potential to have a broad impact. Whilst very high-profile science, or work which is perceived to be important, may be more likely to be tested by replication[82], where results are seen as less important, scientific research may go unchecked. In addition if it is the case that journals are less likely to publish replication work, researchers under pressure to develop their publication record may be less likely to undertake it. In a system that overlooks replication work, the published scientific findings, which in former years would have been tested for robustness may remain unchallenged.

68 The Reproducibility Initiative,[83] launched in 2012 by PLOS ONE alongside Science Exchange, an organisation providing equipment and services to scientists, offers a service through which scientists can arrange for their work to be verified. Last year the initiative was awarded $1.3 million from the Laura and John Arnold Foundation to reproduce 50 high-profile pieces of cancer research.[84] The journal Nature has also recently introduced a checklist for submitting authors to use, requiring that raw data be published alongside research findings, in order to facilitate replication.

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[79]The Economist (19 October 2013) *Trouble at the lab.*
[80] Vasilevsky N, Brush MH, Paddock H, Ponting L, Tripathy SJ, LaRocca G and Haendel M (2013) On the reproducibility of science: unique identification of research resources in the biomedical literature *PeerJ* **1**: e148.
[81]The Economist (19 October 2013) *How science goes wrong*.
[82] A notable recent case concerned the eventual retraction of what was initially seen as groundbreaking work in stem-cell research, following a number of unsuccessful attempts to reproduce the study's results. (Nature (17 February 2014) *Acid bath stem-cel study under investigation*).
[83] Science Exchange Network (2014) *Reproducibility Initiative.*
[84] Nature blog (16 October 2013) *Initiative gets $1.3 million to veryify findings of 50 high-profile cancer papers*.

69 There are parallels between this issue and with funding trends: work that is aiming to produce novel findings may also be perceived to be more attractive to funding bodies.[85]

Clinical trial data

70 A subset of the issue of positive results bias relates to concerns about pharmaceutical companies concealing negative results of clinical trials that are perceived to go against their commercial interests.[86] This, it has been claimed, results in insufficient or misleading information on the effectiveness or availability of specific drugs or treatments, and gaps in the body of scientific literature. More on commercial influences on science can be found below (paragraphs 114-118).

71 This issue has received a high degree of interest in the press over recent years. A handful of high profile cases and initiatives such as the AllTrials campaign and other work of AllTrials co-founder doctor and journalist Ben Goldacre have prompted calls for the UK Government to require drug companies to make public complete information on clinical trials of new drugs.[87] AllTrials advocate the registration of all clinical trials, and the full reporting of methodology and results.[88]

72 The issue is currently being considered within the European Union, where members of the European Parliament recently voted to adopt the Clinical Trials Regulation. The regulation will require, amongst other things, that all future drug trials in Europe be registered and that a summary of the results from these trials and full Clinical Study Reports, containing detailed information on a trial, be made public.[89]

Open access

73 Open access in science publication is a widely discussed issue. The majority of scientific research is currently published in journals which charge subscriptions for readers, such as those published by Elsevier, Springer and Wiley, meaning that much science is behind a pay wall and therefore inaccessible to those without access rights. Advocates of open access claim that online peer-reviewed published research should be available for free, often arguing that this would result in a more efficient, productive research environment.

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[85] The Economist (19 October 2013) *Trouble at the lab*.
[86] An NIHR review conducted in 2010 found that clinical trials with positive results are around twice as likely to be published as those reporting negative results.
[87] The Guardian (5 January 2014) *It's scandal drug trial results are still being withheld.*
[88] AllTrials (2014) *What does all trials registered and reported mean?*
[89] European Commission (2 April 2014) *Q&A: New rules for clinical trials conducted in the EU*.

74 Different models of open access publishing have been proposed, the two primary varieties being gold and green open access. Gold open access involves publishing in a journal that makes all its published work freely available.[90] This sometimes requires that the publication costs are met by the authors themselves, though more usually these costs are funded by research grants or institutions. Green open access requires that research, which may be published in a subscription journal, be made freely available by researchers themselves in an online repository, often administered by a university.[91] A further variation involves hybrid gold open access journals, which charge a subscription for access, but authors can opt to make their papers freely available if they pay a fee. There is debate over which kind of open access is most appropriate, or feasible, for widening access to published research.[92]

75 There are growing numbers of gold open access journals. The Public Library of Science (PLOS) runs several such journals, including PLOS ONE, which publishes peer-reviewed research in all fields of science. PLOS journals impose an author fee and do not charge for subscriptions, making freely available all the work they publish. BioMed Central publishes 266 peer-reviewed open access journals in the fields of medicine and biomedical sciences. The Directory of Open Access Journals now lists 1870 open access science journals.[93]

76 The key arguments made in favour of opening access to research concern efficiency, the potential impacts on research and the wider benefits to science of greater knowledge-sharing. Ensuring that scientific data and findings are freely available means that researchers have more information at their disposal to inform and guide new work. The Finch report, conducted in the UK in 2012, argued that widening access would improve the efficiency of research, by increasing the amount of information that is readily accessible to researchers, and reducing the time spent sourcing it, as well as enhancing transparency and improving public engagement with research.[94]

77 Allowing wider access to the results of scientific research may also prevent the waste of public resources. Much scientific research is funded by the public sector, yet once it has been accepted for publication, journals control access to

[90] Joint Information Systems Committee (2013) *Gold and Green: the routes to open access*.
[91] The Directory of Open Access Repositoroies (Open DOAR) maintains a list of open access academic repositories: Directory of Open Access Repositories (2014) *The Directory of Open Access Repositories – DOAR*.
[92] Times Higher Education (5 July 2012) *Gold or green: which is the best shade of open access?*
[93] *Directory of Open Access Journals*.
[94] National Working Group on Expanding Access to Published Research Findings (2012). *Accessibility, sustainability, excellence: how to expand access to research publications. Report of the Working Group on Expanding Access to Published Research Findings*, available at: http://www.researchinfonet.org/wp-content/uploads/2012/06/Finch-Group-report-FINAL-VERSION.pdf.

it. Universities are then frequently charged what are often quite large amounts of money for access to the science that they may have initially funded.[95] However, it is likely that opening access would still require some public expenditure, since on most open access models, publication costs are adopted by the researchers' institution. It is unclear for that reason whether opening access will increase or lessen the financial burden science publishing imposes on the state.

78 Open access is an international issue, with active campaigns by a number of organisations round the world. Access2Research, based in the US, petition for free access to US publicly-funded research and collected 25,000 signatures in the first two weeks of their campaign.[96] The Scholarly Publishing and Academic Resources Coalition (SPARC), a coalition of 800 research libraries, similarly argue for immediate, barrier-free online access to scientific work.[97]

79 In the UK, the open access movement is backed by a number of interested organisations, including funders such as the Wellcome Trust[98] and RCUK[99]. Following the publication of the Finch report, the UK Government pledged to make publicly funded scientific research freely accessible by 2014, stressing the economic benefits of widening access to research.[100] RCUK currently favours the immediate open access of publication of work it has funded, and also supports Gold and Green open access models, making available funding for open access publishing through block grants awarded to research intitustions. Research funded through the European Horizon 2020 programme will similarly need to be published open access.[101] HEFCE have also said any work submissable for REF 2020 should be made available in an institutional or subject repository once accepted for publication.[102]

80 The putative benefits of opening access to research are not universally accepted, however, and there have been critics of the movement. Some have argued for instance, that whilst researchers should be able to make their research accessible if they choose, they should not be obliged to do so. This, critics say, is because the technical nature of much academic work means that

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[95] London School of Economics blog (20 January 2013) *Paying twice or paying thrice? Open access publishing in a global system of scholarly knowledge production and consumption*.
[96] Research Information (7 June 2012) *US open-access petition hits 25,000 signatures in two weeks*
[97] Scholarly Publishing and Academic Resources Coalition (2014) *About us*.
[98] Wellcome Trust (2013) *Position statement in support of open and unrestricted access to published research*.
[99] Research Councils UK (2014) *RCUK Policy on Open Access and Supporting Guidance*.
[100] Department for Business, Innovation and Skills (2012) *Letter to Dame Janet Finch on the Government Response to the Finch Group Report: "Accessibility sustainability, excellence: how to expand access to research publications"* .
[101] Research Europe (2 August 2012) *Horizon 2020 research will be open access*.
[102] Higher Education Funding Council for England (2012) *Policy for open access in the post-2014 Research Excellence Framework*, available at: file:///S:/Research%20culture/Literature/HEFCE%20Open%20Access%20Policy%202014.pdf.

simply making journal articles freely available would, in many cases, not amount to making the information contained within them available to the wider world. Effective dissemination of research findings may instead be better achieved by publishing within the traditional framework and undertaking separate activities tailored to spreading scientific knowledge more widely.[103] Concerns have also been raised about the costs and the sustainability of open access publishing in the long term.

81 A further issue relates to the potential conflict of interest for publishers created by open access models which involve journals receiving fees from authors, institutions or research grants. Some may be concerned that such a feature could undermine the integrity of the peer review process, by creating a financial incentive for editors to accept articles for publication. This may create a risk, it has been said, that the amount of published work will increase while the quality decreases.[104]

Authorship

82 A separate issue in publication relates to authorship, where concerns have been expressed over credit being fairly assigned for work. Author lists in published science may, in different circumstances, be thought to be either over-inclusive or exclusive. Authorship lists that do not accurately or fairly represent scientific achievement may be thought to undermine science as they have the potential to obscure genuine merit, making it more difficult to link quality published work with the scientists responsible for it.

83 In some areas of science, it has become common for author lists to be very long. Papers in highly collaborative fields typically involving large numbers of scientists and engineers, such as particle physics, frequently run into the hundreds.[105] One notable example of a paper on the Sloan Digital Sky Survey published in The Astronomical Journal credited 144 authors.[106]

84 However, in collaborative fields it may be difficult to determine whether a scientist making a contribution to a project is entitled to an authorship credit or not. Different proposals have been made for how to address this issue. Former Harvard Professor of psychology, Stephen Kosslyn, for example, has devised and advocated use of a ‘points systems’ to calculate whether an authorship credit is deserved in a given case.[107]

[103] Open and Shut blog (23 December 2013) *Robin Osborne on the state of open Access: Where are we what still needs to be done?*
[104] Osborne R (2013) Why open access makes no sense, in *Debating Open Access*, Vincent N and Wickham C (Editors) (British Academy) pp. 97-105.
[105] Science (April 16 2010) *Conventions of Scientific Authorship*.
[106] Times Higher Education (8 April 2010) *Phone book et al: one paper, 45 references, 144 authors*.
[107] Nature (26 September 2012) *Authorship: Who’s on first?*

85 On the other hand, there are also reasons to suspect that those who do deserve recognition for their work do not always receive authorship credits in published science. It has been pointed out that much of the work in biomedical research is conducted by scientists on short-term research contracts, which can result in discrepancies between those conducting research and those who receive acknowledgement in authorship credits. One paper looking at the experiences of such short term researchers reported that there are numerous cases where researchers contribute substantially to projects, but leave their institution before drafting of a final paper begins and are not given authorship credits. [108] In some cases departed researchers were refused authorship credits in spite of being involved in data collection, analysis and drafting. The same paper points out that it may be harder for short term researchers to find opportunities to be involved in the conception or design of research projects, which may create difficulties for attaining authorship credits given some of the current guidance on authorship criteria (see paragraph 88).

86 Also relevant here is the fact that appropriate norms governing how authorship credit is assigned are not universal across the different fields of science.[109] The different internal structures and conventions of collaborative working that exist in distinct fields of science may impact on the fairness of different ways of assigning credit to those involved. Such norms may be well understood by those working within the different fields, though given the wider role of publications in research assessment, academic appointments and other systems of appraisal, these activities would need to be sensitive to the conventions particular to different fields in order to be as fair as possible.

87 The International Committee of Medical Journal Editors (ICMJE) has published recommendations for assigning authorship credits, which suggest authorship be construed as depending on certain criteria. This advice suggests that authorship requires all of the following: substantial contributions to conception or design of the work, or acquisition, analysis or interpretation of the work; drafting or revising the work, approving the final version and accepting accountability for the work in its entirety.[110] A number of journals also now issue their own guidance on both author and contributor credits. Contributors are those who have been involved in planning, conducting or reporting a piece of work, but who may nevertheless fail to meet all of the ICMJE authorship criteria. Some journals such as the BMJ specify that contributors might not be authors and now require that contributors are listed

[108] Newman A and Jones R (2006) Authorship of research papers: ethical and professional issues for short-term researchers *Journal of Medical Ethics* **32(7)**: 420-423.
[109] Jacob M (2011) But What Does Authorship Mean, Indeed? *The American Journal of Bioethics* **10(11)**: 28-30.
[110] International Committee of Medical Journal Editors (2014) *Defining the Role of Authors and Contributors*.

separately from authors, with particular contributions described in detail separately.[111]

Peer review and publication ethics

88 A distinct issue relating to science publishing, and a further consideration in questions over whether researchers' peer reviewed publication outputs should be used to resolve competition for resources, relates to the fairness and effectiveness of peer review.

89 The peer review process used by many journals to select submitted articles for publication is intended to identify sound science which meets standards of both rigour and of significance. The journal Science, for instance, describes its objectives as publishing papers that are most influential in their fields, specifying that articles should present "novel and broadly important data, syntheses or concepts".[112] At Nature, the publication criteria are that papers be of "outstanding scientific importance".[113] Whilst some degree of disagreement over what constitutes 'important' science may be inevitable, many nonetheless think that some form of assessment of the significance of a piece of science is a worthwhile feature of peer review. As such, journals provide a service to the scientific community in guiding readers through the large volumes of science produced, which may now be simply too large for individual scientists to navigate independently.

90 Notably some journals, such as PLOS ONE, now take an approach of publishing all submissions which meet standards of rigour (as well as other criteria around clarity, originality and presentation) and dispose with the role of 'significance' in editorial decision making.[114] The BioMed Central group, which has over 300 journals, adopts a policy of finding places for submitted articles which satisfy the rigour, but not the interest (of subject area) criteria, of a given journal. Their guidance on peer review states in such circumstances authors are offered the opportunity to have that work published in a different BioMed Central journal. [115]

91 Serious doubts have been raised over the adequacy of current peer review processes and their effectiveness in maintaining standards. Fiona Godlee, current editor of the British Medical Journal, undertook some well known work in this field, deliberately inserting eight errors into a study circulated for peer review by 221 reviewers. The average number of errors picked up by

[111] See for instance the British Medical Journal's policy which makes use of the International Committee of Medical Journal Editors' 2013 recommendations: British Medical Journal (2014) *Authorship and contributorship*.
[112] Science (2014) *General information for Authors*.
[113] Nature (2014) *Getting published in Nature: The editorial process*.
[114] PLOS ONE (2014) *Guidelines for Reviewers*.
[115] BioMed Central (2014) *Editorial Policies*.

reviewers was just two.[116] More recently a French researcher, Cyril Labbe of Joseph Fourier University, exposed cases of over 120 'gibberish' papers, generated by computer programmes being accepted for publication in peer reviewed journals.[117]

92 A 2011 report of the House of Commons Science and Technology Committee found that there is little evidence of the efficacy of pre-publication editorial peer review and exposed a range of areas where peer review was seen to fall short. The report cites a range of common criticisms relating to bias, inefficacy, expense and others.[118] A study conducted over a period of 14 years showed evidence that the quality of peer reviewers' work tended to deteriorate slowly over time, with no mechanisms in place to address this decline.[119]

93 Whilst the identification of research misconduct is not seen as the primary focus of peer review, the system has nevertheless been criticised for failings in the general oversight of research integrity.[120] High profile cases of research misconduct have typically been exposed by other researchers or third parties conducting their own investigations[121], rather than by journal peer review processes (though it is, of course, difficult to determine the levels of misconduct concerning unpublished work that journals expose and address privately).

94 A further criticism of current publishing systems concerns what are seen by some as the disproportionate costs to universities, libraries and other subscribers, given that much of the work of peer review is conducted by researchers volunteering their time free of charge. In 2008, a study aiming to assess the full, real costs of science communication worldwide, including the financial value of researchers' contribution to the peer review process, placed it at £1.9 billion globally and £165 million in the UK.[122] This suggests that significant proportions of the real costs of science publishing are being absorbed by universities, or academics working for them, which then pay a second time for journal subscriptions to access published science.

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[116] Smith R (1997) Peer review: reform or revolution? *British Medical Journal* **315 (7111)**: 759-760**.**
[117] Nature (24 February 2014) *Publishers withdraw more than 120 gibberish papers.*
[118] Science and Technology Committee (2011) *Peer review in scientific publications: Eight Report of Session 2010-12*, available at:
http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/856/856.pdf.
[119] Callaham M and McCulloch C (2009) Longitudinal trends in the performance of scientific peer reviewers *Annals of Emergency Medicine* **57(2)**:141-8.
[120] Science and Technology Committee (2011) *Peer review in scientific publications: Eight Report of Session 2010-12*, available at:
http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/856/856.pdf.
[121] The Guardian (13 September 2012) *False positives: fraud and misconduct are threatening scientific research*.
[122] Research Information Network (2008) *Activities, costs and funding flows in the scholarly communications system in the UK*, available at:
http://www.rin.ac.uk/system/files/attachments/Activites-costs-flows-report.pdf.

95 A number of proposals for ways to improve the peer review process have been made in the context of these debates. They include that peer reviewers undertake training, and that full data be presented alongside research findings to enable other scientists to scrutinise work after it has been published. The latter has already been adopted by some journals in an attempt to redress biases potentially introduced to the system through peer review, and increase access.

96 Post publication peer review is another model that has received increasing attention in recent years where an ongoing review of scientific work would take place after it has been put into the public domain. An organisation that has implemented this idea is the US National Centre for Biotechnology Information (NCBI), a biomedical research database that now maintains PubMed Commons. This is a forum where members are encouraged to engage in open discussion and criticism of scientific ideas, and where they are able to make public comments on any published work held on the database.[123] Alternative models, such as one advocated by the scientist and blogger Nikolaus Kriegeskorte, propose more radical changes to the status quo, involving the elimination of traditional journals and editing roles altogether.[124]

97 Dedicated organisations also exist to promote awareness and good practice in academic publishing. The Committee on Publication Ethics (COPE) in the UK is a membership body for editors and publishers of peer reviewed journals, which provides guidance on publication ethics. It publishes a code on good practice in publishing[125], as well as decision making flowcharts and discussion documents on the ethical issues raised in publishing and peer review. The International Association of Scientific, Technical and Medical Publishers is a trade organisation representing academic and professional publishers globally, which aims to support publishers and authors.[126] The International Committee of Medical Journal Editors (ICMJE) and World Association of Medical Editors (WAME) are voluntary organisations, promoting standards and international cooperation amongst editors of medical journals.

Conducting scientific research

98 A number of factors contribute to the way that science is carried out in the UK and the context in which it is conucted, including trends toward interdisciplinary initiatives, the international nature of science, training provision and commercialisation of the field.

[123] National Center for Biotechnology Information (2014*)* *PubMed Commons*.
[124] Kriegeskorte runs a blog on the science publishing, 'The future of scientific publishing', in which he advocates a journal-free system of post publication peer review.
[125] Committee on Publication Ethics (2011) *Code of Conduct and best practice guidelines for journal editors*, available at: http://publicationethics.org/resources/code-conduct
[126]Association of Scientific, Technical and Medical Publishers (2014) *About the Association*

Interdisciplinarity and team science

99 In many fields of research, skills from other disciplines are increasingly important in making scientific progress. Consequently, interdisciplinary research involving teams of researchers is expanding and new areas of science combining expertise from several distinct domains are emerging, such as synthetic biology. A study conducted in 2009 looked at a range of recognised fields, including biotechnology, physics and neuroscience, and found that each was gradually becoming more interdisciplinary over time, with each field of science drawing on knowledge and expertise primarily from neighbouring fields. [127] Dedicated journals to report the findings of interdisciplinary research now exist, such as Interdisciplinary Sciences, Interdisciplinary Science Reviews and the Royal Society's journal, Interface.

100 In many areas, it is felt that interdisciplinary approaches are constructive and have a positive effect on the science produced.[128] Some have argued that the growth of interdisciplinarity is connected with increased accountability of science to society and a closer relation to the needs of research-users.[129] For instance, there is some evidence that the 'impact' of certain areas of interdisciplinary research, within the environmental sciences for example, is higher than more strictly single-discipline approaches.[130]

101 It has been suggested that interdisciplinary approaches in the sciences may be beneficial not simply for their contribution to the science produced, but also for the experience they give scientists of team working. This kind of work may be beneficial to researchers' professional development and careers. Engaging in interdisciplinary work can give scientists experience of research in other fields, which may furnish them with options to pursue research in related but distinct areas of science. It can also improve their communication skills and develop their knowledge and understanding of research fields outside their own.[131]

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[127] Porter A L and Rafols I (2009) Is science becoming more interdisciplinary? Measuring and mapping six research fields over time *Scientometrics* **81(3)**: 719-745.
[128] Though some also have concerns that trends towards interdisciplinary research may be detrimental in areas where the focus of research should be on the development of specialist, disciplinary expertise. Others suggest that the development of interdisciplinary areas, such as research into global warming, may result in a proliferation, rather than consolidation, of specialisms (see, for instance, The Chronicle Chronical of Higher Education (22 November 2009) *Interdisciplinary Hype*).
[129] Barry, A (2007) *Interdisciplinarity and Society: A Critical Comparative Study: Full Research Report. ESRC End of Award Report*, available at: http://www.esrc.ac.uk/my-esrc/grants/RES-151-25-0042-A/outputs/read/947bd7ad-fd30-41c9-bce5-1f861307c0b7.
[130] Hicks C, Fitzsimmons C and Polunin N (2010) Interdisciplinarity in the environmental sciences: barriers and frontiers *Environmental Conservation* **37(4)**: 464-77.
[131] Science Careers (January 17 2003) *The Benefits of Interdisciplinary Research: Our Experience With Pathogen Bioinformatics*.

102 On the other hand, there are concerns that trends towards interdisciplinary research may be detrimental in areas where research focus should be on the development of specialist, disciplinary expertise and it has been suggested that the development of interdisciplinary areas, such as global warming research, may result in a proliferation, rather than consolidation, of specialisms.[132]

103 In spite of these trends, there are concerns that neither interdisciplinary nor team science is being fully supported by existing funding structures. For instance, it has been suggested that research assessment exercises, such as the REF, are not always sensitive enough to capture the value of interdisciplinary work.[133] A recent Royal Society report looking at emerging areas of science found that the existence of newer multi-disciplinary fields, such as nanotechnology, which cross boundaries between science and engineering, challenge the way that science is funded, conducted, communicated, evaluated and taught and recommends that new, more proactive approaches be adopted to address these issues.[134]

104 Team science initiatives aim to encourage collaboration and interdisciplinary approaches to scientific challenges. 'Trans-disciplinary teams' which collect the expertise of scientists from different backgrounds to address multi-faceted problems are also increasingly common in industry and healthcare science.[135] However, it has been argued that systems are not currently set up to encourage or reward this style of working, focusing as they do currently on the achievements of individual scientists, with comparable challenges in securing funding, appropriate training and gaining recognition for team-working skills.[136]

Internationality

105 Today's research environment increasingly involves collaborations between researchers based in different countries. Improvements in global communications and increasing ease of travel have combined to create a background against which researchers are more easily able to work together, share ideas and collaborate formally and informally on science. International conferences, visiting positions and communication through the internet create opportunities for researchers to discuss their work and develop proposals for joint projects. One study found that international collaboration, when

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132 The Chronicle Chronical of Higher Education (22 November 2009) *Interdisciplinary Hype*.
133 The Guardian (21 November 2013) *Research that doesn't belong to a single area is deemed 'too risky'*.
134 The Royal Society (2012) *Science as an open enterprise*, available at: https://royalsociety.org/~/media/policy/projects/sape/2012-06-20-saoe.pdf.
135 Academy of Medical Sciences (2012) *Team science: a discussion paper,* available at: http://www.acmedsci.ac.uk/viewFile/publicationDownloads/135394023027.pdf.
136 Academy of Medical Sciences (2012) *Team science: a discussion paper,* available at: http://www.acmedsci.ac.uk/viewFile/publicationDownloads/135394023027.pdf.

measured by co-authorship on published articles, grew linearly between 1990 and 2005 in terms of the number of published papers, but exponentially in terms of the number of international addresses.[137]

106 Some of the best known science projects have been conducted as international collaborations, involving researchers of multiple nationalities, working in different locations around the world. The Human Genome consortium, for instance, combined work conducted at universities and research centres round the globe, including the US, UK, France, Germany, Japan and China.[138] The Large Hadron Collider at CERN is another large scale project which similarly combines the expertise of scientists of many different nationalities.

107 Furthermore, many science research teams based in the UK are populated by scientists of a wide range of nationalities and UK universities have historically accepted significant numbers of overseas students into STEM subjects at undergraduate and post graduate level. Many feel that that this feature of contemporary research facilitates the pursuit of quality science.

108 Changes to UK immigration policy in 2010 gave rise to concerns that science may be adversely affected by the more stringent rules around working in the UK. Combined with what are seen by some to be uncompetitive salaries and working conditions, there is a concern that the UK may struggle to attract the best scientists from overseas and that the quality of science will be adversely affected.[139] In addition, the stricter immigration rules may be making UK institutions less desirable locations to study for international students, at both undergraduate and postgraduate levels. A 2014 HEFCE analysis of international student entry to higher education found that there had been a 50 per cent decrease in 2012/13 in numbers of students from Indian and Pakistan starting postgraduate studies in England. These decreases had affected mainly STEM courses.[140]

Training

109 Training provision for researchers varies across the different fields within which they work, with different arrangements being made in academic research, clinical research and the private sector. Lack of adequate training for scientists may mean that scientists are not equipped with the skills they need

[137] Leydesdorff L (2008) International collaboration in science and the formation of a core group *Journal of Infometrics* **2(4)**: 317-25.
[138] National Human Genome Research Institute (2010) *The Human Genome Project Completion: Frequently Asked questions*.
[139] The Guardian (25 November 2010) *Immigration policy 'will keep talented scientists out of UK'*.
[140] Higher EducationFunding Council for England (2014) *Global demand for English higher education: An analysis of international student entry to English higher education courses*, available at: http://www.hefce.ac.uk/media/hefce/content/heinengland/HEFCE2014_08a.pdf.

to do their jobs and, in certain areas of science, it has been suggested that there are gaps in training that scientists feel impact directly on the quality of science they are able to produce.[141]

110 In academia, whilst there is an expectation that normal activities associated with conducting research will themselves provide opportunities for professional development many universities also make available training opportunities for staff. Training in research methods are also typically offered to PhD students during their period of study. Some of the learned societies also support ongoing training and continuing professional development (CPD) activities for researchers in the the relevant fields.[142]

111 Nevertheless training provision within universities can be a source of dissatisfaction amongst academic researchers. A 2004 report found that 37 per cent of academic and academic-related staff, across all disciplines, felt that opportunities for training in their institutions were inadequate.[143] Researchers, on the other hand, may not always be aware of the opportunities open to them and others may not perceive structured training and development programmes to be as important as other factors such as their publication record or success rate in winning grants – in career progression.

112 Doctors pursuing a career in clinical research are able to seek funding for training. Training fellowships normally last around 3 years and doctors must apply for them individually.[144] The NIHR, for instance, runs a national training programme supporting training of doctors working on NHS relevant research,[145] and training opportunities in clinical academia are also made available through the Wellcome Trust and other funding bodies.[146] Science jobs in industry tend to be accompanied by structured training programmes that may include completing placements in different parts of the organisation, working with a mentor or buddy, and drawing up personal development plans with line managers.[147]

Commercialisation of research

113 A cademic science provides a source of new ideas of which commercial organisations can make use when seeking solutions for technological

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[141] Barraquand F *et al.* (2013) Lack of quanitative training among early-career ecologists *PeerJ* **2** 285.
[142] For instance, information about The Society of Biology's training events and continuing professional development scheme can be found on their website.
[143] University and Colleges Union(2004) *Working to the Limit: Stress and work-life-balance in academic and academic-related employees in the UK*, available at: http://www.ucu.org.uk/media/pdf/4/7/workingtothelimit.pdf.
[144] Medical Careers (2014) *Academic Medicine*.
[145] NHS Careers (2014) *Clinical Academic Careers.*
[146] Wellcome Trust *Clinical Postdoctoral Training Fellowships*.
[147] Prospects (2014) *Research scientists (life sciences): Training*.

challenges. UK science is seen as a source of significant potential economic benefits to the British economy.

114 The UK Government has expressed support for strengthening links between science and commerce, and promoting 'knowledge transfer' between the two sectors. For instance, initiatives such as the Higher Education Innovation Fund, administrated by HEFCE, are intended to support and develop the interaction between universities and colleges and the commercial world, with the aim of promoting economic and social benefit in the UK.[148] The Technology Strategy Board, the UK's innovation agency, has also funded programmes such as the Biomedical Catalyst,[149] which aims to create opportunities for businesses and researchers to work together on developing solutions to healthcare challenges.

115 Science commercialistation relies on effective links between academia and industry. Recent work has found evidence that university-industry collaboration is important for turning commercial opportunities into patents.[150] A 2013 Parliamentary report looking at ways to improve the commercialisation of research, however, found a number of key areas where links between academia and industry could be better developed.[151] The report suggested that interaction between universities and commercialisation could be improved and that research centres should be challenged to become more open to recruiting academic staff from non-traditional backgrounds. The report warned, however, against imposing an 'innovation agenda' too forcefully on the academic field, which may undermine the quality of science produced.

116 Some have also raised concerns about the long term consequences of the commercialisation of science. Commercialisation in the biomedical sciences can lead to the issuing of patents for medical procedures and techniques. In some cases this may mean that fees would be introduced such that patient access to them would be restricted.[152] Some academics have also reported feeling uncomfortable about being put under pressure by their institutions to engage with industry and forge commercial partnerships as a means of generating extra institutional income.[153] It may also be possible that commercial influences could inhibit valuable communication between groups

[148] Higher Education Funding Council for England (2014) *Funding for knowledge exchange – Higher Education Innovation Funding (HEIF)*.
[149] Medical Research Council (2014) *Biomedical Catalyst*.
[150] Lawson, C (2013) Academic patenting: the importance of undustry support *J Technol Transf* **38(40)** 509-35.
[151] Science and Technology Committee (2002) *Bridging the valley of death: improving the commercialisation of research: Eight Report of Session 2012-13*, available at: http://www.publications.parliament.uk/pa/cm201213/cmselect/cmsctech/348/348.pdf.
[152] British Medical Journal (2010) *Why are we copyrighting science?*
[153] The Guardian (28 March 2011) *Pressure on academics to generate alternative income for universities*.

of researchers, with competing financial objectives, and ultimately impede the rate of scientific progress.

117 A recent study examining the relationship between research grants and research content at engineering at German universities found evidence of both positive and negative effects of industry on academic science.[154] It reports that where the share of industry funding in a research grant is greater, the higher the probability that large corporations will exert influence on the research agenda, though research teams supported by industry in this way may also be more likely to source ideas from the private sector.

Media coverage of science

118 The most recent of the Public Attitudes to Science reports show that public interest in science has increased over the last 26 years, with 72 per cent of people now saying that they think it important to know about science, compared with 57 per cent in 1988.[155] This interest may be reflected in the increased levels of coverage science receives in the media. As well as the news sections of journals such as *Science* and *Nature,* it is now common for mainstream print and broadcast media to have sections and programmes reporting developments in science and technology to the wider public. Most research institutions and funding bodies provide support and guidance to their researchers to help them work with journalists and engage the wider public through the media.

119 Although the media can play an important role in publicising and promoting debate about scientific work, the media has been criticised for exaggerating claims about scientific findings and creating 'hype' before work has been properly scrutinised and tested. A recent high profile example concerned reporting on the announcement from the BICEP2 team which claimed in March 2014 to have identified cosmic gravitational waves. The findings potentially provided scientific evidence to arbitrate between competing accounts of the origins of the universe. The result was widely reported in the science[156] and mainstream media,[157] with many reports making predictions about the awarding of a Nobel prize.[158] However a few months later doubts emerged about the implications of the data and the nature of the analysis.[159]

[154] Hottenrott H and Lawson C (2012) Research grants, sources of ideas and the effects on academic research *Economics of Innovation and New Technology* **23(2)**: 109-33.
[155] Ipsos MORI Social Research Institute (2014) *Public Attitudes to Science 2014,* available at: https://www.ipsos-mori.com/Assets/Docs/Polls/pas-2014-main-report.pdf.
[156] Nature (21 March 2014) *Gravitational-wave finding causes 'spring cleaning' in physics*.
[157] For instance, BBC (17 March 2014) *Cosmic inflation: 'Spectacular' discovery hailed* and The Guardian (14 March 2014) *Gravitational waves: have US scientists heard echoes of the big bang?*
[158] The Guardian (21 March 2014) *Gravitational waves give Nobel prize committee another headace*.
[159] Nature (3 June 2014) *Big Bang blunder bursts the multiverse bubble*.

120 It also has been suggested that the media can misrepresent the views of the scientific community in attempting to present a balanced report. For example, in television news, it was common for reports to interview two experts with conflicting opinions, even if the majority of the scientific community were in agreement. The BBC was criticised by the Science and Technology Committee in 2011 for presenting scientific evidence as on a par with opinion, in the name of providing a 'balanced' account.[160]

121 Media coverage is perceived by some to have the power to increase the popularity of different areas of science. Some fields of science receive higher levels of media coverage than others and may consequently become fashionable and attract more people to the area. The popularity of scientist and broadcaster Brian Cox, for instance, who frequently appears on television and radio, has been credited with playing a role in the growing numbers of applications to study physics at undergraduate level university, increasing the flow of students into that field.[161]

122 Another issue concerns the scrutiny function that the media exerts on science. Science journalism is considered to be less well-resourced than in previous years, with science journalists reporting increased workloads and less time to fact-check stories on scientific developments.[162] This may have consequences for the degree to which scientists, and scientific claims, are challenged and held to account. It has also been argued that under-resourced science journalists may be less able to hold the scientific community, as spenders of public money, to account.[163]

Careers

123 A number of recent studies have explored the effects of the research environment on who enters or stays in science, how scientists view science as a career, and the nature of science as a profession.

124 Science is a competitive field and not all of those who train in scientific research go on to secure a career in research. A 2004 report found that only 42 per cent of physical sciences and engineering PhD graduates remained in research roles following graduation in the UK; for biological and biosciences

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[160] Science and Technology Committee (2014) *Communicating climate science: Eight Report of Session 2013-4*, available at: http://www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/254/254.pdf.

[161] BBC (18 August 2011) *Has physics become cool again?*

[162] Williams A and Clifford S (2009) Mapping the Field: Specialist science news journalism in the UK national media, available at: http://www.cardiff.ac.uk/jomec/resources/Mapping_Science_Journalism_Final_Report_2003-11-09.pdf.

[163] Murcott THL and Williams A (2013) The Challenges for science journalism in the UK *Progress in physical geography* **37(2)**: 152-160.

PhD graduates the figure was 44 per cent.[164] A report conducted six years later by the Royal Society looking at the proportion of science PhD graduates going to postdoctoral positions found that 30 per cent take such positions, with only four per cent proceeding to permanent academic research posts and fewer than half of one per cent becoming professors.[165] This trend is reflected outside of the UK – in 2011 it was estimated that 100,000 PhD degrees were awarded between 2005 and 2009 in the US, whereas only 16,000 new professorships were made available in the same period.[166] A recent article looking at growth in the biomedical sciences in the US, which argues that the current system has become hypercompetitive and unsustainable, recommended that the numbers of PhD students in the field be gradually reduced, in order to better align the numbers of those entering research, and the career opportunities available to them, as well as supporting young people with scientific training into a range of careers.[167]

125 Nevertheless recently published HEFCE statistics show that the number of those working in academic research roles (across all areas) at English universities has increased dramatically in the last ten years and at a higher rate than other areas of university staffing. HEFCE's information shows that academic staff have increased by 20 per cent in that period, while research support staff have increased by eight per cent.

Doctoral students

126 A 2013 study looked at the role that 'structural dynamics' – such as job market, grant funding and post-doctoral pay - play in determining PhD graduates' levels of interest in a career in biomedical science research. The study found that those less interested in pursuing a career in scientific research listed poorly structured career development, long hours and the likelihood of securing a permanent position as key considerations for them.[168]

127 A report commissioned by the Wellcome Trust in 2014 identified a range of issues as potential deterrents to pursuing research careers including challenges in securing funding, pressures to publish, long working hours,

[164] Shinton S (2004) *What do PhDs do?2004 analysis of first destinations for PhD graduates*, available at: http://heer.qaa.ac.uk/SearchForSummaries/Summaries/Pages/GLM239.aspx.
[165] The Royal Society (2010) *The Scientific Century: securing our future prosperity*, available at: https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2010/4294970126.pdf.
[166] Though note that the term 'professor' has broader scope in the US, referring to academic positions of a range of levels of seniority: The Economist (16 December 2010) *The disposable academic*.
[167] Alberts B, Kirschner M, Tilghman S and Varmus H (2014) Rescuing US biomedical research from its systemic flaws *PNAS* **111(16)**: 5773–5777.
[168] Gibbs K and Griffin K (2013) What do I want to Be with My PhD? The Roles of Personal Values and Structural Dynamics in Shaping the Career Interests of Recent Biomedical Science PhD Graduates *Life Sciences Education* **12(4)**: 711-23.

pressure to move and lack of stability.[169] It concludes that a number of changes to academic culture and working practices may make research careers more attractive. These include targeting longer term funding awards at early career researchers, considering ways of introducing family-friendly innovations from other sectors, and challenging the perception that moving institutions is important for career development.[170]

Early career researchers and short-term contracts

128 Though short-term positions are not unique to junior scientists, researchers in the early stages of their careers are more likely to work in short term post-doctoral positions. Temporary or fixed-term employment contracts are widely used in academia and are often connected to fixed term grants for particular projects. It has been reported that 68 percent of research staff across all sectors in higher education were on fixed-term contracts in 2013.[171]

129 A 2013 report found that many of those working in science were concerned about short-term funding, with a number saying that concerns about the nature of science funding in the UK had contributed to decisions they had taken to seek research positions abroad.[172] On the other hand, there is no clear evidence that the situation is more stable in other parts of the world. A study looking at similar issues in the US, for instance, found that perceptions around success in grant applications were similarly negative, following cuts imposed in the US in 2010, with 18 per cent of respondents reporting that they were considering pursuing their careers outside of the US.[173]

130 It is not uncommon for early career researchers to take several consecutive post-doctoral positions after completing study, and they may remain in these temporary roles for a number of years. These positions often do not offer the same advantages, in terms of salary levels, pensions and other benefits, as those provided by permanent positions and working on a series of short term

[169] Ipsos MORI Social Research Institute (2012) *Risks and rewards: How PhD students choose their careers: qualitative research report*, available at: http://www.wellcome.ac.uk/stellent/groups/corporatesite/@sf_central_grants_admin/documents/web_document/wtp053947.pdf.

[170] Though the report notes that it there is a need for more investigative work to be conducted on the topic of whether moving institutions and countries is actually beneficial for a scientists' career or not: "More research is needed on whether moving posts or institution, if pursuing a career in academic research, is actually of long term value to researchers. As science becomes more international, virtual technologies are helping to forge collaborations without the requirement for face-to-face contact.": Ipsos MORI Social Research Institute (2012) *Risks and rewards: How PhD students choose their careers: qualitative research report*, available at: http://www.wellcome.ac.uk/stellent/groups/corporatesite/@sf_central_grants_admin/documents/web_document/wtp053947.pdf).

[171] The Guardian (4 February 2013) *Why are many academics on short-term contracts for years?*

[172] Science is Vital (2013) *Legacy of the 2010 Science Budget Cash Freeze*, available at: http://scienceisvital.org.uk/wp-content/uploads/2013/06/SIV_170613a_Legacy.pdf.

[173] Huffington Post (29 August 2013) *Nearly 20 Percent of Scientists Contemplate Moving Overseas Due In Part to Sequestration.*

contracts may also create challenges for scientists looking for promotion and career progression. Short-term contracts can make borrowing money more difficult for postdoctoral researchers too – banks and other lenders may have preferences for arranging mortgages with individuals on permanent employment contracts, for instance. There may also be financial costs to researchers of retraining if they do not ultimately secure permanent science posts.[174] Working in less well paid roles with lower levels of security may mean that early career scientists have less opportunity to save or invest money, and are less well off financially as a result of this system.[175]

131 Many of these issues are reflected at an international level. A recent report on this topic looked at the experiences of young scientists around the world and concluded more acceptable workloads, more focused training and more systematic support and mentoring activities were needed for young researchers.[176]

132 Others have suggested ways of improving the situation. One proposal is to 'professionalise' the post-doctoral role, by creating permanent post-doctoral positions at universities.[177] A 2014 Parliamentary report, looking at a range of issues in science research, also advocated a review of academic career paths and called on the UK Government to work with universities to increase the number of longer-term positions for post-doctoral researchers.[178] It has been pointed out, however, that implementing this kind change would inevitably reduce funds for contract roles, and there may be fewer available research positions overall.[179] The reduced movement within the system may also have an impact on the availability of roles for recently graduated PhDs.

133 An alternative suggestion is to broaden the career paths of young scientists by supporting the movement of of those with scientific training into a wide range of different careers.[180] Fields such as science policy and administration, science commerce, science writing, the law and education are all areas where, it is argued, science graduates should be supported to seek work opportunities. This may mean making available more information about alternative career paths to young scientists and introducing clearer pathways

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[174] Nature (2 March 2011) *Give postdocs a career, not empty promises*.
[175] Gibbs K and Griffin K (2013) What do I want to Be with My PhD? The Roles of Personal Values and Structural Dynamics in Shaping the Career Interests of Recent Biomedical Science PhD Graduates *Life Sciences Education* **12(4)**: 711-23.
[176] Global Young Academy (2013) *'The Global State of Young Scientists': Project Report and Recommendations*, available at: http://www.interacademies.net/File.aspx?id=23352.
[177] Nature (2 March 2011) *Give postdocs a career, not empty promises*.
[178] Science and Technology Committee (2014) *Women in Scientific Careers: Sixth Report of Session 2013-14*, available at: http://www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/701/701.pdf.
[179] Wellcome Trust blog (28 January 2013) *Postdoc Plan B: the elephant in the lab*.
[180] Alberts B, Kirschner M, Tilghman S and Varmus H (2014) Rescuing US biomedical research from its systemic flaws *PNAS* **111(16)**: 5773–5777.

for entry into alternative areas of work. Those supporting this idea clain that increasing the number of programmes combining science with training in other areas, such as leadership, project management, teamwork and communications skills, for instance, or ensuring graduate students have access to experience in these different work environments may support such changes.

Research assessment and workloads

134 Increased competition for short term funding has resulted in Principal Investigators (PIs) spending more of their time writing grant applications, a significant proportion of which inevitably are unsuccessful. A 2013 Australian study calculated the amount of time researchers spent writing applications for the country's National Health and Medical Research Council annual funding round, finding that over 500 years worth of researchers' time had been spent on the process in a single year.[181] The same issue was identified in a 2013 survey of UK scientists, which highlighted wasted time as a concern for many respondents. Questions were raised about the overall expense associated with competitive systems where a significant proportion of work is perceived to go to waste, although it is unclear what proportion of work involved in unsuccessful funding bids is ultimately incorporated into other proposals which subsequently receive support from other sources, or are utilised in other ways. Respondents also complained about procedural features of UK systems which make application processes longer, without improving the standards of funded science.[182]

135 The REF has been a key source of dissatisfaction amongst academic scientists in recent years. A survey conducted in 2013 reported numerous complaints about the impact of the REF, relating to career development, workload and equality and diversity. A high proportion of respondents reported that undertaking work necessary to meet REF requirements involved working excessive hours (68 per cent), and that the REF created unreasonable expectations about the research output of academic researchers (62 per cent). Respondents also expressed concerns about adverse effects on their careers, with some saying that they thought it unlikely they would be supported to do research in the future if their work was not included in their department's submission (45 per cent) and that they would be transferred to a teaching-

[181] Since only 20 per cent of the applications were successful this can be interpreted as a waste of over 400 years worth of researcher time: Herbert D, Barnett A, Clarke P and Graves G (2013) On the time spent preparing grant proporsals: an observational study of Australian researchers *British Medical Journal Open* **3(5)**: e002800.

[182] Science is Vital (2013) *Legacy of the 2010 Science Budget Cash Freeze*, available at: http://scienceisvital.org.uk/wp-content/uploads/2013/06/SIV_170613a_Legacy.pdf.

focused contract (21 per cent) or lose their job (25 per cent) if their work was deemed not to have met REF expectations.[183]

136 A separate study from 2012 reported that researchers felt the REF had increased existing pressures to publish and meant they had less time for research itself. It also found evidence that the REF placed additional strains on working relationships, sometimes increasing tensions amongst individual staff members. Women were disproportionately adversely affected, this study found, with evidence that longer hours and stress were felt more strongly by women than men.[184]

Women in science

137 It is well recognised that women are not proportionately represented throughout the career ladder in the sciences and that women face particular issues when pursuing science careers. Work on this area has indicated that women are, for instance, less likely than men to progress to senior roles. A model recently developed for making predictions about scientists' long term careers (see paragraph 46) found that being male was a key indicator for success, with women who hold very similar publication records to men having a seven percent lower chance of becoming a PI than their male counterparts.[185]

138 A 2014 Parliamentary report on women in science similarly concluded that bias towards men still exists within decision-making processes for academic science appointments and recommends that equality and diversity training be made mandatory to recruitment and promotion panels. The report also concludes that the short-term contracts characteristic of early academic careers (see paragraphs 129-134) can particularly disadvantage women, due to the fact that these years often coincide with the time that many women are considering starting a family.[186]

139 The 2014 Wellcome Trust report (see paragraph 128) also found issues distinctive to women. The study reports that a lack of role models, competitive culture, requirement for self promotion and lack of mentoring were particular issues for women. It suggests that women considering a career in research

[183] University and College Union (2013) *The Research Excellence Framework (REF) UCU Survey Report*, available at: http://www.ucu.org.uk/media/pdf/0/q/REF-survey-report-September-2013.pdf.

[184] Society for Research into Higher Education (2012) *Final report: Assessing the impact of developments in research policy for research on higher education: an exploratory study*, available at: http://www.srhe.ac.uk/downloads/Leathwood_Read_Final_Report_16_July_2012.pdf.

[185] Van Dijk D, Manor I and Carey L (2014) Publication metrics and success on the academic job market *Current Biology* **24(11)**: pR516-7.

[186] Science and Technology Committee (2014) *Women in Scientific Careers: Sixth Report of Session 2013-14*, available at: http://www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/701/701.pdf.

may benefit from seeing more women in research roles and increased facilities for mentoring and support.

140 The Athena project, funded by HEFCE, was set up in 1999 in order to address disparities in the numbers of men and women in science, engineering and technology in UK higher education, and to support women in progressing to more senior positions. The associated Athena ASSET Survey found in 2010 that women are more likely to work on temporary or part time contracts, and are less likely to hold positions of power and influence. It found interesting differences in how women perceive themselves within professional structures too; women were less likely than men to feel valued, socially integrated into their departments or visible to mangers. They were also more likely to attribute their success to support they had received (compared with male scientists, who are more likely to attribute their successes to their own efforts, plus luck). The survey findings also suggested that women are becoming more ambitious.[187]

141 A 2004 report found few significant differences between men and women in how they experienced stress in academic and related roles in the UK, though it reported that women were more likely to report inappropriate behaviour of colleagues, such as bullying, and a greater proportion of women than men reported wanting to leave the higher education sector.[188]

Leadership and organisational culture

142 Research has shown that UK scientists perceive there to be increasing levels of management intervention in their work, and suggest there is a keen sense amongst researchers of the tension between their own professional scientific interests, and the interests of management.[189] There is a wider theoretical literature on how these kinds of interaction affect researchers, organisational culture and the nature and character of scientific endeavour.[190]

143 The character of science management within universities and different models of leadership have been found to have an impact on the success of institutions. Research suggests that universities benefit from having

[187] Athena Forum (2010) *The 2010 Athena ASSET Survey: Summary Report,* available at: http://www.bath.ac.uk/equalities/news/pdf/DES2210ASSETreportAthena.pdf.
[188] The Higher Education Union (2004) *Working to the Limit: Stress and work-life-balance in academic and academic-related employees in the UK*, available at: http://www.ucu.org.uk/media/pdf/4/7/workingtothelimit.pdf.
[189] Cohen L, Duberley J and McAuley J (1999) Fuelling Discovery or Monitoring Productivity: Research Scientists'Changing perceptions of Management *Organization Studies* **6(3)**: 473-97.
[190] See for instance, Duberley J, Cohen L and Mallon M (2006) Scientific Careers: change, continuity and context *Organization Studies* **27(8)**: 1131-51, Cohen L (2006) 'Remembrance of things past: cultural process and practice in the analysis of career stories *Journal of Vocational Behavior* **69(2)**: 189-201 and Cohen L, McAuley J and Duberley (2001) Continuity in Discontinuity: Changing Discourses of Science in a Market Economy *Science Technology and Human Values* **26(2)**: 145-66.

experienced and successful researchers in leadership and management roles.[191] It has been suggested that this may be related to successful scholars being viewed as more credible leaders by their university workforces and by the fact that they have a better understanding of the university's core business.

Impact on wellbeing

144 A 2004 report, looking at stress amongst academic researchers, across all sectors, found evidence of significant levels of stress, relating to increasing numbers of students and excessive levels of administrative work. Almost a half of respondents felt that they had unmanageable workloads, with over 21 per cent of respondents claiming to work more than 55 hours each week.[192] Over half of respondents displayed borderline levels of anxiety and depression.

145 Outside the UK, recently published Australian research explored the relationship between academic deadlines imposed by one of the country's major grant schemes and workloads, stress and family relationships.[193] It found evidence of a range of adverse effects, including 93 per cent of researchers taking part in the study reporting stress as a result of workloads and 88 per cent restricting their holidays during the proposal writing period. The study also reported a range of impacts on family life, including on relationships with partners and friends, and on researchers' caring relationships, for children or older relatives.

Research integrity, regulation and governance

146 Questions have been raised about how some of the features of the UK research environment outlined above, such as scarcity of funding and jobs, pressure to publish and the nature of science careers, may be impacting on ethical conduct within science. Particularly, some have raised concerns that intense levels of competition may be providing incentives for cutting corners, exaggerating findings or compromising on research integrity in other ways.

Misconduct in science

147 The scale of scientific misconduct and poor practice is hard to assess since it is likely that much goes undetected and observed misconduct is not always reported. In the UK there is no single body with oversight of scientific research as a whole and no official source of statistics on the prevalence of research

[191] Goodall A (2009) Highly Cited Leaders and the Performance of Research Universities *Research Policy* **38(7)**: 1079-92.

[192] The Higher Education Union (2004) *Working to the Limit: Stress and work-life-balance in academic and academic-related employees in the UK*, available at: http://www.ucu.org.uk/media/pdf/4/7/workingtothelimit.pdf.

[193] Herbert D, Coveny J, Clarke P, Graves N and Barnett A (2014) The impact of funding deadlines on personal workloads, stress and family relationships: a qualitative study of Australian researchers *British Medical Journal Open* **4 (3)**: e004462.

misconduct. However a survey conducted by the BMJ in 2012 of UK-based medical researchers found that 13 per cent had witnessed colleagues altering or fabricating data and six per cent had observed misconduct within their own institutions that went uninvestigated.[194]

148 Statistics from the US suggest that instances of fraud and serious professional misconduct in the sciences are relatively rare. However, one US study which asked researchers about observed behaviour of colleagues suggested that around 1.5 per cent of research may be fraudulent, greatly exceeding statistics collected by the US Office for Research Integrity.[195] There is also evidence that types of research misconduct falling short of fraud, which might be considered less serious, are more common and may, together, pose a greater risk to science.[196] These include questionable relationships with research participants, using others' ideas without obtaining permission or crediting them, changing the design, methodology or results of a study in response to requests from a funder or failing to present data that conflict with researcher's previous work.[197]

149 Retractions of published science have increased in the last decade. The blog Retraction Watch[198], launched in 2010, publicises details of retracted science and reported on 200 retractions in its first year – over twice as many as the 80 that was estimated before the project began. For 2013, the figures were closer to 500.[199] Research has shown that the rise in the number of retractions is considerable, though there is debate over whether this indicates an increase in the amount of scientific misconduct taking place. It has been argued, for instance, that lower barriers to publication of flawed science, and the fact that flawed studies are retracted more quickly than they once were, may be responsible for this rise.[200]

150 Some have drawn connections between scientific misconduct and pressure to publish in certain journals and the importance of producing positive or novel research findings for securing funding, permanent positions and promotions.[201] It has been argued in the past that funders, institutions and senior investigators all have responsibilities to minimise and properly manage the factors that may incentivise ethically problematic practices, including expectations around

[194] British Medical Journal (12 January 2012) *Scientific misconduct is worryingly prevalent in the UK, shows BMJ survey*.
[195] Titus S, Wells J & Rhoades LJ (2008) Repairing research integrity *Nature* **453(7198)**: 980-2.
[196] Martinson B, Anderson M and de Vries R (2005) Scientists behaving badly *Nature* **435**: 737-8.
[197] Martinson B, Anderson M and de Vries R (2005) Scientists behaving badly *Nature* **435**: 737-8.
[198] Retraction Watch (2104) *Retraction Watch*.
[199] The Indepenent (16 June 2013) *The bad science scandal: how fact-fabrication is damaging UK's global name for research.*
[200] Steen RG, Casadevall A, Fang FC (2013) Why has the Number of Scientific Retractions Increased? *PLoS ONE* **8(7)**: 68397.
[201] Lock S (1997) Fraud in medical research *Journal of research in Nursing* **2(3)**: 161-3.

publishing, financial pressures and researcher health problems that may affect how they respond to pressures.[202]

Regulation and governance

151 Governance, regulation and oversight of different groups of researchers comes from a range of different sources. Guidance on good research practice, for instance, has been published by a range of bodies. RCUK, [203] Wellcome Trust, [204] NIHR, [205] and Universities UK[206] all publish their own guidance, as do individual higher education insitutions.[207] Professional guidance for doctors conducting research is issued by the GMC.[208] Private companies conducting scientific research also commonly issue their own guidance.[209]

152 Research in universities is not overseen by a dedicated regulatory body, though individual institutions typically have their own local policies on good research practice, systems for the ethical approval of new projects and procedures for handling misconduct.[210] In 2012 Universities UK published the first sector-wide research guidance for universities, *The concordat to support research integrity*, which was developed in collaboration with the research councils, Wellcome Trust and a number of government departments.[211] HEFCE now requires that institutions eligible to receive its research funding comply with the concordat[212] and RCUK advise that the concordat should be read alongside their own advice.[213] The UK Office for Research Integrity (UKRIO) works on issues around research integrity and provides specific advice to institutions on individual cases.

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[202] Evered D and Lazar P (1995) Misconduct in medical research *The Lancet* **345(8958)**: 1161-1162.
[203] Research Councils UK (2013) *RCUK Policy and Guidelines on Governance of Good Research Conduct*.
[204] Wellcome Trust (2005) *Guidelines on good research practice*.
[205] National Institute for Health Research (2010) *Research in the NHS - HR Good Practice Resource Pack*, available at: http://www.nihr.ac.uk/documents/policy-and-standards/Faster-easier-clinical-research/Research-passports/Hr%20Good%20Practice%20Resource%20Pack/HR-Good-Practice-Info-for-researchers-RD-and-HR-staff-in-the-NHS-and-HEIs.pdf.
[206] Universities UK (2012) *The concordat to support research integrity*, available at: http://www.universitiesuk.ac.uk/highereducation/Pages/Theconcordattosupportresearchintegrity.aspx.
[207] For instance, see University of Oxford (2014) Academic integrity in research: Code of practice and procedure and University College London (2014*)* Ethical guidelines for research*.*
[208] General Medical Council (2010) *Good practice in research and Consent to research*, available at: http://www.gmc-uk.org/guidance/ethical_guidance/research.asp.
[209] See, for instance, GlaxoSmithKline's *Living our values: Our Code of Conduct* and supplementary guidance on conducting ethical research, available at: http://www.gsk.com/media/325203/code-of-conduct-policy-english.pdf.
[210] For instance, the University of Birmingham (2014) *University of Birmingham: Code of Practice for Research*, available at: http://www.birmingham.ac.uk/Documents/university/legal/research.pdf
[211] Universities UK (2012) *The concordat to support research integrity*, available at: http://www.universitiesuk.ac.uk/highereducation/Documents/2012/TheConcordatToSupportResearchIntegrity.pdf
[212] Higher Education Funding Council for England (2014) *The concordat to support research integrity: Compliance with the concordat.*
[213] Research Councils UK (2014) *Research Integrity: RCUK Policy and Guidelines on the Governance of Good Research Conduct.*

153 Doctors undertaking clinical or medical research are required to follow the guidance issued by the medical regulator, the General Medical Council, *Good practice in research and Consent to research*[214] which sets out expectations around seeking consent, avoiding conflicts of interest and respecting confidentiality, amongst other areas. Other guidance for doctors on conducting research is issued by the British Medical Association (BMA) and the Royal Colleges.[215]

Management of charges of misconduct

154 Procedures around misconduct or poor practice differ depending on the field within which the researcher is working. Amongst researchers, only doctors conducting medical research are subject to statutory regulated fitness to practice procedures overseen by the General Medical Council. They face conditions on, or removal of, their licence if their conduct falls below good practice standards. Academic researchers may face disciplinary proceedings, including warning, suspension or dismissal, initiated by their employers if their practice is seen to fall short of expected standards. Charitable trusts and grant givers may choose to take action against their funded researchers if their own guidance is not followed, though they are not able to take steps preventing or constraining future work as a researcher. These actions might include withdrawing funding and barring future applications or requiring that published articles relating to the work be withdrawn.[216]

155 There is a perception that the governance systems around scientific misconduct are not wholly effective and that misconduct in science research is not always dealt with robustly. Higher education institutions may sometimes be reluctant to tackle head-on charges of misconduct against staff members, which can be difficult for those involved in investigations.[217] Calls have been made for institutions to take a more proactive role in investigating and acting on charges of scientific misconduct, with research showing that in many countries institutions' official responses do not reliably lead to effective action being taken.[218]

[214] General Medical Council (2010) *Good practice in research and Consent to research,* available at: http://www.gmc-uk.org/guidance/ethical_guidance/research.asp.
[215] British Medical Association (2009) *Confidentiality and disclosure of health information tool kit,* available at: http://bma.org.uk/practical-support-at-work/ethics/ethics-a-to-z and Royal College of Psychiatrists (2011) *Ethics of psychiatric research*, available at: http://www.rcpsych.ac.uk/pdf/PS02_2011.pdf.
[216] Wellcome Trust (November 2005) *Statement on the handling of allegations of research misconduct.*
[217] Times Higher Education (4 January 2002) *Scientists fail to tackle fraud.*
[218] Breen K J (2003) Misconduct in medical research: whose responsibility? *Internal Medicine Journal* **33(4)**: 186-191.

156 Alongside the challenges relating to identifying misconduct through peer review (see paragraph 94) science journals do not typically have resources or internal infrastructure required to conduct full investigations into suspected research misconduct and are more likely to approach an author's institution, if it is raised at all. It has been suggested, nevertheless, that the peer review process should be made more sensitive to fraudulent submissions to journals and that more serious consequences for misconduct, such as making it a criminal offence, could be considered as options.[219] In medical research, complaints made against doctors on the grounds of scientific misconduct are not common and there is a perception that action is taken against doctors on these grounds only rarely.

157 There have been proposals for measures to be taken to protect whistleblowers. Researchers may feel hesitant to raise concerns about colleagues' conduct, given the perception that reporting suspicions of misconduct against colleagues may be damaging to one's career[220] though many institutions are now developing their own whistle-blowing policies.[221]

[219] The BMJ blog (9 December 2013) *Should scientific fraud be a criminal offence?*
[220] Nature (8 June 2011) *Whistle-blower claims his accusations cost him his job*.
[221] For instance see University of Cambridge (2014) *Public Disclosure by University Employees: 'Whistleblowing' Policy* and Oxford Brookes University (2014) *Whistle blowing procedure*.