# Overcoming the barriers to research productivity

## A case study in immunology and microbiology

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# Executive summary and key findings

Increasingly we look to scientific research and development to drive economic growth. With public expenditure on R&D making up an increasing proportion of GDP, governments and research funding bodies everywhere want to maximize the return on their investment. Until now most studies of research productivity have looked at aggregate inputs and outputs, often employing complex economic models to try to understand the factors that drive or inhibit research. We have taken a different approach, using modern large-scale survey techniques to understand the concerns of principal researchers in two specific related biomedical disciplines: immunology and microbiology. Rather than trying to fit our data into a preconceived model, we adopted a more direct approach: we asked researchers themselves to identify the kinds of measures that they would like to see, both in the workplace and in the wider environment, to support their productivity. A more specific aim was to find out where possible problems in accessing the journals literature ranked in their concerns.

Using an online survey, designed by academics at UCL and managed by GfK NOP, we polled the views of 883 randomly selected senior researchers. We used a trade-off analysis technique so that we could avoid the danger, seen in many so surveys, of simply generating an unstructured wish list of `would be nice to see' issues. Our findings identify the policy measures upon which there is the greatest level of agreement among the scientific community. And because we used trade-off analysis, we are able to place these issues in a clear preference order with a numerical weighting attached to each.

Our research finds that the perceptions of researchers are remarkably consistent: there is a clear consensus around the issues that really matter to them: few differences in views can be attributed to age, sex or location. There is much in our findings to gratify research funders and university administrators. By and large, our respondents feel good about themselves, about the work they do and about the environment in which they work. While North Americans are generally more upbeat about themselves and their own performance than Europeans, this may be a cultural difference. Europeans tend to be more critical of the support and leadership provided by their universities; whereas Americans find grant applications more cumbersome.

Naturally, they told us that they need more research funding. Money is of course an issue. Research is expensive and resources are tight for everyone. However, the absolute level of resourcing is by no means the only issue. Many respondents pointed out that low success rates for their proposals and short-term funding have combined to create a `stop go' culture that is out of synch with the natural research cycle.

Under these conditions, it is very difficult think strategically and to retain and nurture mission-critical research staff and technicians.

But many of the barriers to scientists becoming more productive could be addressed very effectively without throwing huge amounts of money at the problem of declining European research productivity. Nearly all our respondents feel they are on top of what is happening in their field. Nevertheless, a majority want to spend more time communicating informally through ad hoc networking and formally through public presentations and attendance at conferences. Ninety percent agreed that greatly expanded access to online journal content had made them more effective researchers. Although access to the literature came far down the pecking order of productivity issues, a third of respondents still can't get hold of everything they need. For the most part these are younger and less productive researchers working in Europe. Interestingly, despite the enormous amount of time that researchers invest in formal peer review and the burdens this places on their time, none of the respondents alluded to this issue in the context of the many pressures on their time.

Four of the top six issues that researchers highlight concern the organisational and human resource context for successful research. They want to be able to attract and retain suitably qualified research staff and to offer them greater job security: this suggests that reform of the career structure and opportunities for young researchers is well overdue. Recent figures in The Economist (2005) suggest that Europe needs another 700,000 researchers if it is to meet its overall target of raising spending (private, national and EU) to 3% of GDP by 2010. Scientists also want to be freed from the burden of red tape: are we guilty of over-regulating the life of the intellect? They want more autonomy and the freedom to develop their own ideas, perhaps through new seed corn funding mechanisms. At the next level down, it is clear that greater networking opportunities, giving scientists time to breathe and talk to other researchers, especially in other disciplines, might pay handsome dividends.

A rather mixed picture has emerged from this study for journal publishers. Researchers clearly appreciate the investments made in digital libraries of journal articles, realise the huge convenience benefits, yet are still not wholly satisfied. It is quite likely that the gap identified in this study is more a function of raised expectations than really fundamental problems relating to literature access. However, we should not be complacent, and there is clearly a role for publishers, librarians and the policy community to engage constructively in bridging this gap.

It's time we took a good hard look at maximizing return on scientific research. We don't need yet another public forum to talk about open access. We need a genuine dialogue with librarians, universities, and funding bodies (with scientists involved) to examine the complete R&D value-chain, from research proposal through citation to exploitation. Changing work practices, addressing productivity bottlenecks, or

coming up with alternative output measures may contribute more to scientific and economic progress than publishing model changes or even increased funding.

Finally, how will we know whether these initiatives, were they to be implemented, will actually deliver? We need more creative ways to evaluate research productivity in the internet age: measures that relate information production and consumption to innovation and real-world impacts.

# The broad context for the study

In the fevered atmosphere of the open access debate we sometimes seem to be in danger of losing sight of what the journals system is for, what value it adds, and where it fits into the bigger picture as a key element in keeping the whole research enterprise ticking over. This report was commissioned by the publishing industry, to open up a really important and exciting new research agenda: what contribution does the scholarly communication system make to the science base, and how can it be improved? How can we manage information flows for the benefit of higher quality, more productive and efficient research? This is a critical issue for publishers, librarians and research managers as well as for funding agencies, and one that is especially timely against the backdrop of the arguments being deployed in the cause of reader open access.

In preparing this report, we have drawn on a wide range of literature as well as undertaking primary research in the form of online, telephone and face-to-face interviews with European and North American researchers in immunology and microbiology to try to get a little closer to answering these questions.

*Information and research productivity*

Future economic performance is now seen as direct function of present research and development activity. Increasingly, governments and boards of management look to research and development to bring them success in the global knowledge marketplace. With corporate and national pride at stake, it is not surprising that there is plenty of performance anxiety around. ISI's aggregate publication figures show that the US share of world science article output is declining (National Science Foundation 2004), and Europe worries that its scientists generate fewer published papers per capita than their North American colleagues.

In response, the US Academies of Science recently warned that the US must dramatically increase its investment in R&D. And Europe worries that its scientists are less productive than those on the other side of the Atlantic. The EU Lisbon summit in 2003 agreed that the proportion of EU GDP spent on R&D must rise from 2 to 3 percent. None of this is lost on the emerging economies, especially in East Asia which, according to Nature (2005) now account for more than half of global GDP. Not surprisingly it is in this part of the world that R&D expenditure and corresponding journal article output are rising most quickly (Fig.1).

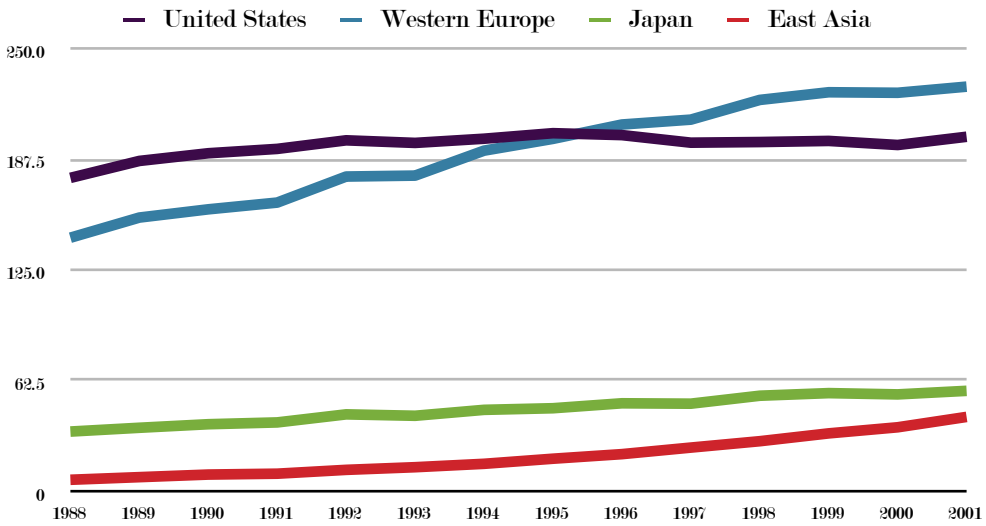



Figure 1: Article production in science and engineering, 1988-2001 (000s)

Source: National Science Foundation, Science and Engineering Indicators 2004, Figure 5.

For these reasons, it is important for all of us that we focus on what practical things can be done to maximize European return on investments in scientific discovery.

*What does research productivity mean?*

Like beauty, research productivity is easier to appreciate than to pin down. Ultimately, the only really meaningful measure has to be "truth per dollar". This is of course unknowable and so we turn to proxy indicators instead: typically numbers of publications, citations, research grant income, or even more abstract aggregations such as knowledge flows or contributions to human or intellectual capital. All are problematic and all offer a very partial view of that elusive measure, "truth", but what else can we do?

Scientific activity generates different kinds of outputs. Skilled graduates, new discoveries and treatments, patents, prototypes, inventions and publications. It is not at all easy to measure these outputs in any consistent way because they are usually delivered by the same person, a university professor perhaps. Not only is it difficult to specifically isolate his or her contribution to each of these outputs, an additional problem is that they are often co-products. So time spent advising a doctoral student (teaching) may in turn help to generate a new paper (publication) or spark an idea that leads to an invention.

Several approaches have been developed to assess scientific productivity, using methods as diverse as peer review, self-reporting, and composite indicators such as the `research quantum', a blend of research grants, numbers of publications and higher research degrees (Ramsden 1999). The problem, of course, is trying to find a generally accepted intellectual currency that adequately captures the essence of research productivity. In the absence of a generally agreed methodology, publication

and citation counts (and transformations such as the impact factor) have assumed prominence, to the point that a whole policy-related evaluation discipline, bibliometrics, has grown up.

> "Articles, patents, and citations provide indicators, albeit imprecise ones, of scientific output, the content and priorities of scientific research, the institutional and intellectual linkages within the research community, and the ties between scientific research and practical application ...used judiciously, enable meaningful comparisons of institutional sectors, scientific disciplines, and nations"
> National Science Foundation 2004

There are very good reasons to use publication counts, especially of articles and patents, as a measure of scientific production. The culture of the academy forces those who aspire to a scholarly career or a higher salary to engage in publication. To a considerable degree, articles capture the essence of other output forms (like conference papers and research seminars). Publication outputs act, in turn, as inputs into the work of other researchers, and so the whole journals system continually turns over and is renewed (and regulated by) the academic community. Numbers of publication outputs are, of course, not very helpful in establishing the absolute quality of those outputs, nor the relative contributions of co-authors. Citation data, often in standardised form as `impact factors', have received enormous attention in evaluation work because citations are perceived to reflect the influence that research findings have had on others, and they could therefore be regarded as an indirect measure of quality.

For all that it is important to be practical and to count what can be counted, there are very real disadvantages to publication-based measures. Citations are a by-product of the research process, *not its goal,* and `research impact' is a complex notion. Research impact should include all the measurable effects of research: whether it is read, cited, used in other research, practically applied, patented, or whether it helps its authors to garner prizes and awards. The current obsession with impact factors adds relatively little to the science policy debate because it confounds outputs with outcomes, and these are different notions. It is probably better to think of citations and impact factors as a measure of an author's or journal's visibility in the literature and not get too hung up about whether citations measure `quality' in the common sense meaning of that term.

There are technical reasons, too many to address here, that limit the application of bibliometric measures as a reliable and valid way of describing research productivity and impact. These limitations become acute if we try to make comparisons between disciplines or between countries or regions. There is, for example, a significant bias within the key data source used for bibliometric analysis, the citation indexes produced by the Institute for Scientific Information (ISI), towards English language materials. There are even more marked differences in national shares of global

article outputs and citations. Grupp and others (2001) found that while the USA accounted for 33.7% of articles produced by ten highly developed countries in 1997, it attracted a disproportionate 51.7% share of total citations. There is overwhelming evidence that nationality is a key factor in citation patterns: these tend to be more parochial than a purely rational view of science communication would suggest. In particular, there is a major citation deficit between the developed and developing nations and a sense that the whole system is driven by norms set by the US.

For example, a study by Braun and Diospatonyi (2005) points out that journal `gatekeepers' (editors-in-chief, deputy editors, managing editors and editorial board members) are predominantly US-based, far more so than the US share of world publications or citations might suggest.

> "The dominance of US gatekeepers ... is not a conspiracy with some hidden intentions, but a consequence of the self-organizing nature of science. Nothing needs to be done. However, it is an important reflection of the self-organizing mechanism which has allowed US gatekeepers to have a decisive influence on what, when and where worldwide research is published"
> Braun and Diospatonyi (2005)

For all these reasons, we should treat bibliometric measures of science productivity with great care, especially in a European policy context.

There are many reasons to think that European science and its information markets are very different from the North American situation. Linguistic and cultural differences are clearly a big issue and there is evidence that these shape knowledge flows. For example, a Swedish study on `knowledge spillovers' (Maurseth and Verspargen 2002) found that there are important barriers to patent citation flows within Europe: these tend only to be really effective within nation states and between regions with similar profiles of industrial specialisation.

There is a more fundamental problem. The frameworks used to evaluate scientific production and productivity emphasise the resource inputs into the system (e.g. national expenditures on civil R&D) and processes (e.g. PhD completion rates) which address the efficiency with which those resources are utilised. The economic thinking, perspectives and terminology behind these indicator systems are by no means adequate when thinking about knowledge production, consumption or impact. Crucially, we need to move on and focus on how and what scientists read, and why, and how this translates into `downstream' indicators of the impacts that our spending on R&D generate.

*What drives research productivity?*

It is ironic that so much effort is spent on publication bean counting to try to evaluate the end product of the research process, and yet so little in trying to understand the

role of those same publications as a key *input* into the knowledge production process. There are thousands of papers in the former category (bibliometrics), a few dozen at most in the latter. That is not to say that there is not a considerable body of work on the economics of science and the factors that drive researchers to add new publications to their academic CVs, but these tend to be painted in broad terms without specific reference to information access and consumption.

Why is that some individuals, teams, even nations are more productive than others in research terms? What is that distinguishes academics who do and who not publish extensively? Why is it that, on a per dollar GDP basis, a small country like Israel produces five times the amount of high quality research than the international average? And, on the same basis, why is that Japan and Italy produce 40% less? The underlying human behaviour that gives rise to these patterns is far from being fully understood. The most convincing argument is that, independent of talent, authors require the right conditions to become productive: they need the confidence that feeds on success, access to research grants, freedom from teaching and administration, the esteem of their peers, access to specialist equipment, the stimulation of teams of fellow researchers, and a supportive and well managed research culture.

> "For whosover hath, to him shall be given, and he shall have more abundance: but whosoever hath not, from him shall be taken away even that he hath"
> Matthew xiii:7

These resources are all in scarce supply, and because publishing carries certain rewards (like credibility, standing), there is a virtuous circle whereby these necessary resources flow disproportionately to those that publish more. But since competition for resources is so tough, only a few manage to break away from the rest of the pack. This "success breeds success" phenomenon was certainly understood in principle, albeit in a different context 2,000 years ago as illustrated in the Parable of the Sower. The principle is deeply embedded in UK higher education policy which is to focus money where it will have the greatest immediate impact, through research selectivity mechanisms such as the RAE.

An alternative hypothesis has been proposed by Dogan and Parhre (1990) to explain the highly asymmetric contribution of authors to a given literature. All things being equal, one would expect that the more research effort that is applied to a particular set of problems, the greater the number and quality of research outputs. Dogan and Pahre argue that this may not necessarily be the case in particularly well researched (or "dense") subject areas. As more and more researchers and funding dollars pile into a given area, the amount of innovative work increases, but at a decreasing rate. In this "paradox of density", publishing opportunities also increase at a decreasing rate as the new recruits to the field find that most of the pioneering work has already

been achieved by those who first saw the opportunity and capitalised (i.e. published) on it. This is perhaps why it is so difficult for funders to `pick winners'.

The potential implications of these theoretical models, both for public policy and for publishing business development is enormous, yet sadly neglected by the research community itself. As we shall see later in this paper, scientists feel they do not have enough autonomy in terms of what they are able to research and dislike the increasingly prescriptive nature of research funding themes and priorities.

*The journals system and research production*

It seems clear that personality, organisational and environmental factors play a decisive role in shaping research activity, but there are really only a handful of studies that explicitly address the links between reading, access to the literature, and research productivity. Koenig (2001) found that research productivity in the pharmaceuticals sector is as a direct function of corporate information culture. He found that working environments characterised by openness, richness of information sources, plentiful communication tools and serendipity are more productive places to work. This is an interesting paper for our purposes because it suggests that research productivity could be enhanced simply by re-engineering the way that research information is managed: a more attractive intervention perhaps than throwing more money at sub-optimal systems.

Huge strides forward have been made by journal publishers in recent years with the development of searchable, deeply linked digital libraries. What effect is this having on the reading behaviour of researchers? A good starting point for tackling this question is the work of Tenopir and others (2003) who provide a rich synthesis of earlier (pre-digital access) and more recent post-Internet surveys and literature on reading behaviour. Their key findings are that:

- the number of personal subscriptions per scientist has decreased steadily from 5.8 (1977) to 2.2 (2003), signaling a shift from a journal economy to an article economy
- author web sites have not caught on, accounting for less than one percent of readings
- there has been a massive increase in electronic formats for reading
- journal publishers are making a big contribution to knowledge creation: average readings per scientist have increased from 87 (1977) to 148 (2003) per annum, the large majority of which are readings supplied from library collections in print or digital form
- the usefulness of the articles read and indicators of their value suggest that information content has not changed much, but its overall value to the scientific

community has increased as more articles are read and can be accessed more conveniently

It seems then that journal publishers' investments in new technology are having a significant impact on scientific workflow. It is also becoming clear that electronic desktop access to digital libraries is offering researchers something more than mere convenience. Certainly, electronic delivery can enhance the efficiency of the science base: for example, a study of the NASA Astrophysics Data System by Kurtz and others (2000) concluded that this tool alone saves astronomers the equivalent of 333 full-time research years per annum.

In a carefully controlled survey of European scientists, Barjak (2005) found a very striking relationship indeed between research productivity (measured by articles published) and how often researchers consulted electronic journals and article databases. No similar productivity-enhancing effects effect were found for the world wide web in general, so it would appear that access to the journals system is a key determinant of author productivity and quality.

> "The use of electronic journals and full text databases produces a significant positive effect [on research productivity], whereas the use of other organizations' websites has a significant negative effect on article output. It should be noted that this effect was recorded even though the estimation controlled for research discipline and research motivation" (Barjak, 2005, p. 13)

Of course, one of the problems in studying the relationship between the journals system and research productivity is the chicken-and-egg of cause and effect. Is enhanced productivity driving journal use or vice versa? At this point in time it is not possible to say with complete confidence.

We can conclude that digital libraries are delivering efficiency gains, but is there any evidence that journal use correlates with more and better quality research? Are super-users of content also super-producers? A range of studies indicate that both the quantity and the quality of output from those that read more intensively and more widely is enhanced. Tenopir and King (2000), for instance, discovered:

- a strong correlation between reading journal articles and professional achievement: award winning scientists read 53% more articles than non-winners
- scientists who serve on high-level projects or special committees read around 21% more journal articles than those who do not
- scientists who are considered high achievers by their peers read 59% more articles than their colleagues even when other variables are held constant
- university scientists who have won awards for their teaching or their research read roughly 26% and 33% more articles, respectively, than their cohorts

For all these reasons, we need to revisit the research productivity debate from publishing and information science perspectives. We need to develop a better understanding of the role of journals in supporting the workflows of scientists and what kinds of interventions can be made by publishers, librarians and research managers to maximise the value of what is clearly an important productivity tool for knowledge workers.

The implications of digital access are potentially profound and a fundamental shift in attitudes to knowledge production may be taking place. The introduction of digital libraries signals a major shift from browsing to search behaviours, supported by reference linking. This makes possible much deeper and more comprehensive treatments of the literature. Brennan and others (2002) point to the explosion of meta-analyses in recent years, a research form that was previously so cumbersome as to be impractical. They argue that access to knowledge and its re-aggregation is becoming paramount. In this sense, we may for the first time, be moving into an era where new advances in science will come from having a much better grip on what we - collectively but not individually - already know.

## The primary research

This report comprises the preliminary findings of a study commissioned by the Publishers Research Consortium (PRC) with additional support from Blackwell Publishing into the factors, including journal provision, that affect the ability of top biomedical scientists to remain fully research productive. The findings should be of general interest to the research policy community, to scientists in biomedical and other fields, and to publishers, since they touch on issues which are crucial to society's ability to understand the world around us, conquer disease and generate new wealth and jobs.

The research design for this project comprises an online survey of 883 senior researchers in immunology and microbiology conducted during the late summer of 2005. The survey was designed and piloted by CIBER, a publishing industry think tank based in the Centre for Publishing at University College London and was administered its behalf of Blackwell by GfK NOP, a leading polling organisation. Initial research for the questionnaire took the form of a survey of the published literature on scientific productivity and a series of fifteen face-to-face and telephone interviews with immunologists and microbiologists to validate the earlier conclusions from the desk research. Much of the existing work on the factors that determine productivity is very mechanistic: research is conceptualised as a closed system, a kind of black box with inputs in at one end (funding, human resources) and research deliverables (papers, patents) out at the other. Few studies have asked direct questions of researchers as to the problems and issues that they face every day in the

workplace: the kinds of factors that impede their ability to be as fully research productive as they might otherwise be.

The survey asked four kinds of questions:

- structured basic demographics (gender, age, broad subject and region, predominant research mode and numbers of recent published articles)
- structured attitudinal questions relating to researchers' behaviour and perceptions of issues such the effectiveness of the journals system and learned societies in supporting scientific activity
- a conjoint analysis experiment, in which the underlying utility value that researchers attach to a series of statements designed to improve their research environment was determined
- unprompted free text comments

In framing our interviews we established from the outset that we wanted to understand scientific working patterns and what scientists themselves feel are the main issues that impact on their ability to carry out research: we only mentioned our specific interests in journal-related issues right at the end of the interviews so as not to lead the discussion in that direction. Our purpose was to validate, from the horse's mouth, a short list of the key barriers to research productivity we had gleaned from the literature. The interviews were wide-ranging, but a number of common themes emerged. They are summarised below, in no particular order:

***Proposal writing*** researchers complained of a lack of support and training in writing grant proposals, the burden of associated paperwork and bureaucracy, the quality of reviewers, the time delays between submission and approval, and low success rates which increase the time they have to spend on proposals

***Interdisciplinary work*** researchers complained that the learning curves for writing joint proposals with other disciplines is very steep, of difficulties in getting the parties together, financial and administrative complexities, and concerns about finding suitable journal outlets for interdisciplinary work

***Research staff*** researchers complained that recruiting research staff is difficult: often not enough money or time is available to advertise posts, and that the human resource issues are very complicated

***Ethical approval*** researchers complained of too many regulations, nit-picking forms, political correctness, the length of time taken to reach a decision, and a perception that ethics committees sometimes seemed `intent on sabotaging research'

***Research management and direction*** researchers complained of ad hoc decision making and a lack of clear strategic direction and leadership, too much micro-management, poor communication and a lack of constructive criticism

***Conferences and networking*** researchers complained of a lack of opportunity to attend conferences and, if or when they do, problems arranging the travel and sorting out the financing

***Bureaucracy and red tape*** researchers complained of the enormous burden of paperwork and regulation that academics face, excessive and sometimes duplicate internal reporting, too many meetings, and a lack of clerical and administrative support

***Time for research*** researchers complained of the many time pressures bearing down on their research time (clinical, teaching and administrative duties in particular) and of a shortage of administrative and technical staff to support them

***Funding*** researchers complained of poor success rates for competitive grants, insufficient allowances for staff and consumables, short-term funding and a `stop-go' research culture in which it is impossible to make plans, the difficulty of finding bridging finance, and the small size of many grants (which exacerbates the need to carry on writing more proposals)

***Getting new ideas off the ground*** researchers complained that the funding system discourages `risky' projects (i.e. those not based on strong preliminary data), that funding mechanisms are too project- (rather than research-) oriented, making it difficult to follow up new leads as they emerge, and of the scarcity of seed corn money to help them to mature their ideas

***Equipment and materials*** researchers complained of under-investment in the fabric of their laboratories and research infrastructure (more space, equipment, consumables and technicians are needed)

***Management skills*** researchers complained that they did not have enough training in management techniques, specifically time management skills

***Research staff*** researchers complained of a shortage of suitably qualified young research staff and funding at PhD and post-doctoral levels

***Time to think*** researchers complained of a lack of freedom and autonomy in their work and that research funders' priorities discouraged creativity and original ideas

***Job security and prospects for research staff*** researchers complained of the difficulty of attracting and retaining research staff, given the acute shortage of permanent and tenure-track positions, and the problem of `stop-go' funding

The interview issues raised specifically about the journals system were mainly concerned with author-facing issues such as the incessant pressure to publish, the time spent on writing and preparing manuscripts for publication, slow publication speeds, and the problems of getting work, especially interdisciplinary work, accepted. The main reader-facing complaint was that not enough literature was available in electronic form..

To explore these productivity-related issues more systematically, we designed an online questionnaire. The survey was distributed (as an email message from CIBER containing an embedded link to the GfK NOP survey database) to a random sample of 10,000 biomedical scientists drawn from the mailing list services provided by ISI, the Institute of Scientific Information. These email addresses were those of corresponding authors: typically the principal investigator or team leader and derive from the details provided in the top journals that ISI indexes for such familiar products as the Web of Knowledge and the Science Citation Index. The initial lists were de-duplicated, and then checked against preference data, so that authors who had previously indicated that they did not wish to take part in such surveys were excluded. The sample included 2,500 addresses for each of the four survey sub-populations: North American and Western European immunologists and microbiologists respectively. Authors were selected on this basis, further limited to those who had published an article in an ISI-indexed journal during 2004.

The effective response rate for this survey was nearly nine percent (Table 1).

| | |
|---|---|
| Invitations sent | 10,000 |
| Full completed responses | 883 |
| Response rate | 8.83% |

Table 1: Online survey response rate (frequencies)

Although low by the standards of postal surveys, this is unusually high for a web-based industrial survey, where response rates typically cluster around 4-6 percent. There is inevitably a high degree of wastage with these surveys (for example, it is impossible to be sure how many emails actually arrive, given the elaborate spamming algorithms that are now in common use) and so `response rates' can be a pretty rough and ready indicator.

Subsequent data analysis was carried out by CIBER using standard statistical tools (Statistical Package for the Social Sciences XII). We are indebted to Laura Pennells and Rajiv Dale at GfK NOP for their assistance with the preparation of the conjoint data and for their general advice on rating scales and question phraseology.

Because of the particular method used to identify and invite responses (selected from the most senior researchers in top journals), the findings in this report carry

particular authority. That same point also means, however, that the findings should not be generalised to all biomedical researchers: certainly not outside the specific geographic and specialty focus of this study, and nor should the views and attitudes of senior researchers be projected onto their more junior colleagues such as doctoral students, post-doctoral researchers or research assistants.

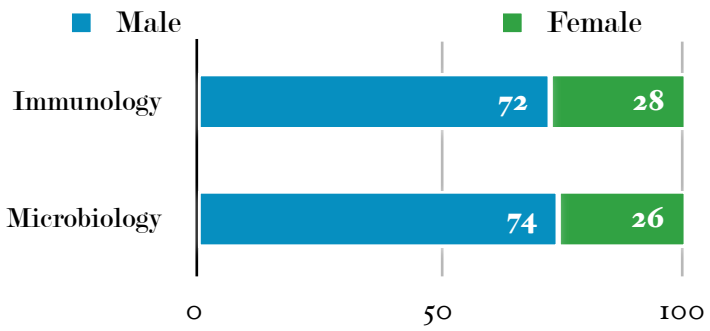
## Survey demographics

In this section of the report, we present the key demographic characteristics of the survey respondents as a context for the later, more substantive findings. The data presented here falls within 95% confidence limits.

### GENDER (Q21)

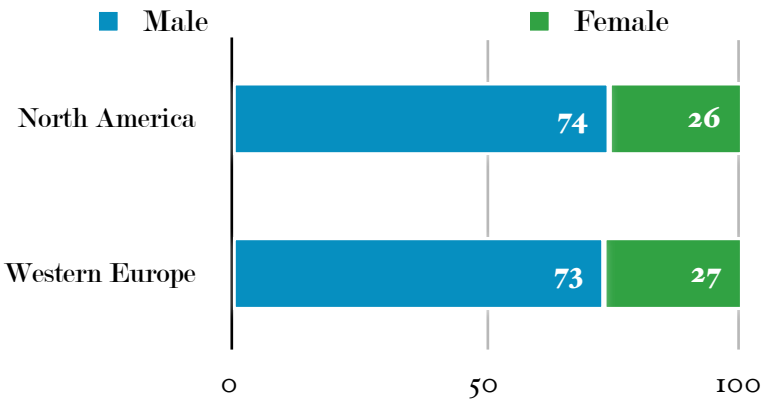
The gender profile of the survey sample is very similar, both by subject (Fig.2) and regional distribution (Fig.3), with a significant bias towards male researchers who out-number females by around three to one, as in many other areas of science.

Figure 2: Gender profile by subject (percentages, n=879)




Note: Four respondents refused to disclose their gender

Figure 3: Gender profile by region (percentages, n=879)



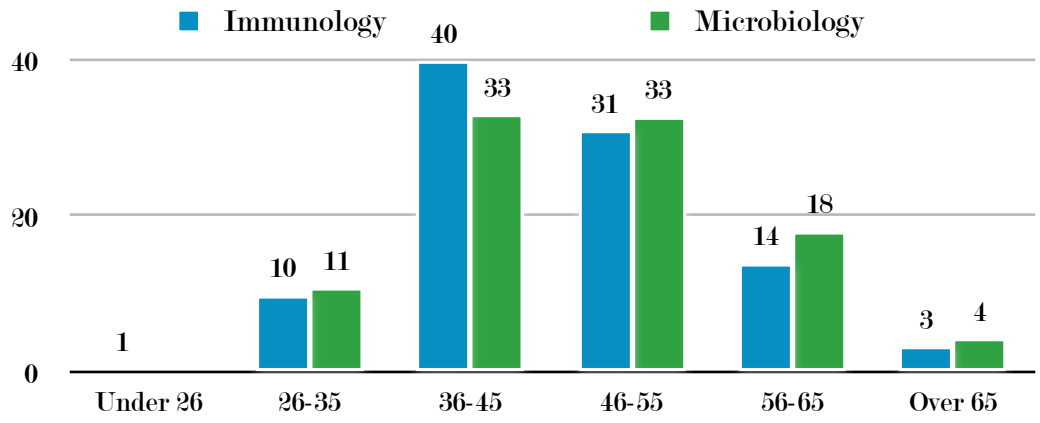

Note: Four respondents refused to disclose their gender

Women tend, in our survey sample, to be slightly younger and slightly more likely than men to be working in a mixed research mode (i.e. using both clinical and basic techniques).

## How old are you? (Q22)

As might be expected given the methodology used to select respondents (senior authors in top journals), the age profile of the sample reveals a mid-career peak.

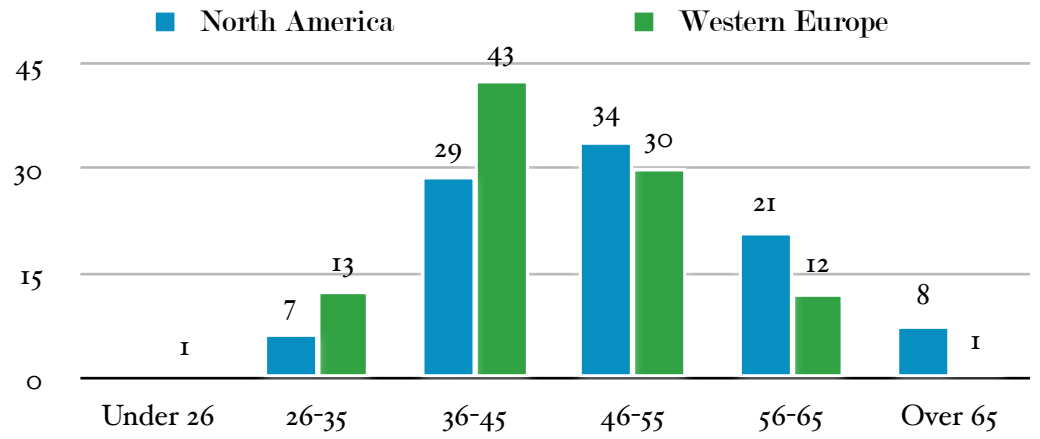
Figure 4: Age profile by subject[1] (percentages, n=874)




Note: Nine respondents refused to disclose their age

There is no significant difference in terms of age profile by subject (Fig.4), but the age profiles of Western European and North American researchers (Fig.5) are very different.

Figure 5: Age profile by region [2] (percentages, n=874)




Note: Nine respondents refused to disclose their age

[1] $\chi^2 = 7.12$ , d.f. = 6, $p = 0.31$, not significant

[2] $\chi^2 = 57.75$ , d.f. = 6, $p < 0.001$, significant at the 0.1% level, reject null hypothesis

Europeans have the younger profile (56% are under 46 compared with 36% of North Americans.

## WHERE ARE YOU BASED? (Q23)

To meet an acceptable level of confidence (95%) in our survey findings, we were aiming for a minimum response of 240 completed online interviews, distributed evenly across each of the four cells in Table 2. In fact, the final response was 883, a response rate of nearly 9 percent, which is very high, as noted earlier.

| | North America | Western Europe |
|---|---|---|
| Immunology | 170 (6.8%) | 410 (16.4%) |
| Microbiology | 153 (6.1%) | 150 (6.0%) |

Table 2: Regional and subject sample profile (frequencies and partial response rates, n=883)

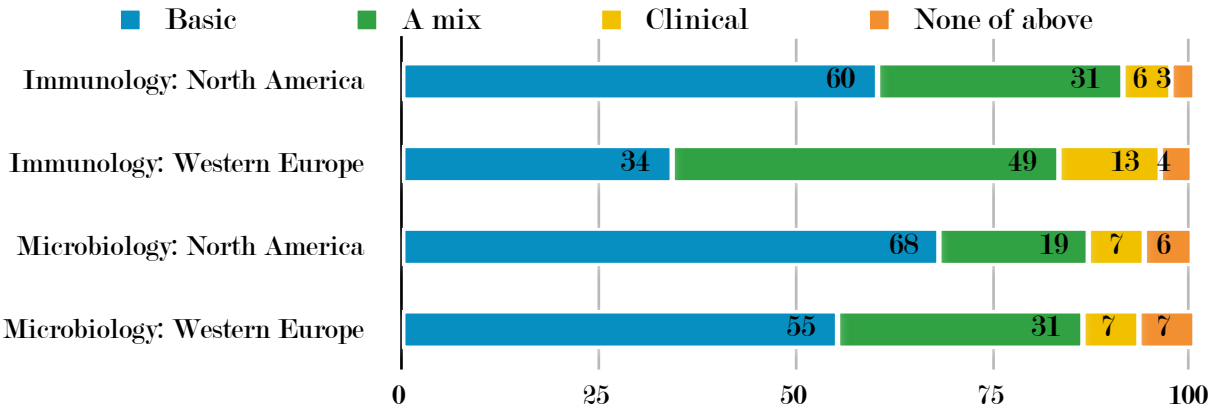
This itself may be an indication of a high level of interest in the issues raised by this study: these are, after all, very close to the day-to-day concerns of scientists in the workplace. The response rate from European immunologists was startlingly high for an online survey, well over twice that for the other groups, and this is an issue that requires further investigation: perhaps they feel these issues very acutely?

## MODE OF RESEARCH (Q24)

*"What kind of research do you do?"*

Striking differences emerge between Western Europe and North America in respect of the modes within which researchers work.

Figure 6: Profile by mode of research [3] (percentages, n=883)




For both immunology and microbiology, North American researchers are much more likely than their European counterparts to be engaging in basic research (Fig.6). It

[3] $\Sigma^2 = 48.30$ , d.f. = 3, $p < 0.001$, significant at the 0.1% level, reject null hypothesis

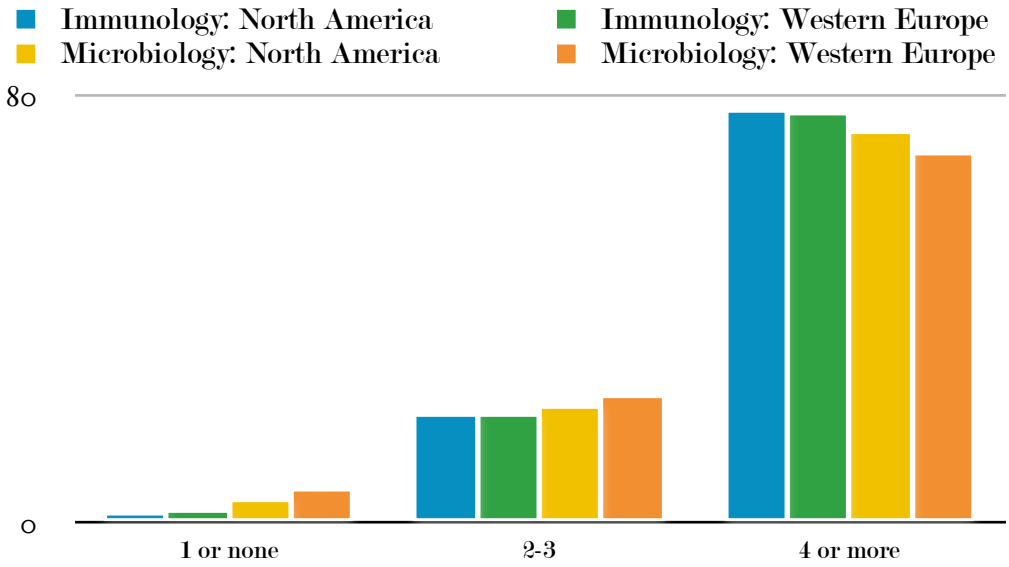
should be stressed that this is merely descriptive of the (randomly selected) sample population and further desk research is needed before larger claims can be made about the nature of the respective biomedical research bases. This finding does however support the widely-held perception that North America, and more specifically the USA, enjoys a very strong position in basic biomedical research.

## RESEARCH PRODUCTIVITY (Q25)

*"How many refereed papers have you published in the past two years?"*

In the next question, we asked our researchers to say how many papers they had published recently. Unsurprisingly, given the provenance of the email addresses for our respondents, they prove to be a highly productive group, with three-quarters claiming to have published 4 or more papers in the past two years (Fig.7). This seems a little high: the scale used in the survey was `1 or none', '2-3 papers' or `4 or more' and had been derived from a preliminary analysis of the ISI database for the two two subject literatures considered here. A more normal distribution had been expected, with about 50% of authors in the middle category. This kind of issue is not at all atypical of the self-reporting biases that may come into play in surveys of this type. It is equally possible that the survey response may have attracted a higher return from more senior and eminent scientists with significant management responsibilities, who may be more attuned to the policy significance of the important issues raised in this study.

Figure 7: Article productivity [4] (percentages, n=883)




[4] $\Sigma^2 = 57.75$ , d.f. = 6, $p < 0.001$, significant at the 0.1% level, reject null hypothesis

## Single biggest issue facing researchers (Q1)

*"What is the single most important thing that your manager, employer or funding body (or indeed any other body) could do to help you to become a more productive researcher?"*

The first substantive question in the online interview was a pretty challenging one! The reason we asked such a difficult question at this point was that we wanted to be sure that the issues flagged up in the subsequent conjoint analysis experiment were valid and that we had not missed anything really important. It was also felt that this would be a useful way to test the temperature of researcher opinion: by asking for spontaneous, tip-of-the-tongue reactions.

The responses were provided as free text comments (see Annex 3 for the full verbatims), usually very short and to the point. These were coded up and classified, using the conjoint questions (Q2-Q17) as a coding frame. Table 3 shows how our respondents ranked these issues (numbers in bold). The figure in brackets shows how that same issue was ranked by respondents under the very different conditions of the conjoint analysis experiment. There seems to be very broad agreement between the two independent data sets: especially at the very top and towards the bottom end of the distribution.

| ISSUE | RANK | % |
|---|---|---|
| Access to more research funding | 1 (1) | 26.8% |
| More time for research relative to other duties | 2 (7) | 20.9% |
| Mechanisms to cut down form--filling and bureaucracy | 3 (5) | 17.0% |
| The ability to recruit highly qualified and motivated research assistants* | 4 (2) | 9.8% |
| More help and support in writing research proposals | 5 (9) | 7.1% |
| More effective leadership and guidance on priorities from above | 6 (14) | 4.9% |
| Access to the latest specialist equipment and materials** | 7 (10) | 4.3% |
| Better job security and prospects | 8= (6) | 2.0% |
| More freedom to pursue your own ideas | 8= (4) | 2.0% |
| More opportunity to simply talk about research ideas with colleagues | 10 (8) | 1.7% |
| Clearer legal and ethical frameworks for your research | 11 (16) | 1.3% |
| Initial funding to get your ideas off the ground | 12 (3) | 1.0% |
| More help and support to work with researchers in other disciplines | 13 (11) | 0.5% |
| Immediate access to a wider range of full text journals on your desktop | 14 (12) | 0.4% |
| Training in general management techniques | 15= (15) | 0.2% |
| Attending more conferences and other networking events | 15= (13) | 0.2% |

*Includes technicians
**Includes general infrastructure issues, including better office space
Table 3: Unprompted issues (ranks and percentages, n=818)

For the vast majority of comments (92%), it was a fairly simple task to decide into which of the 16 categories they belonged. Some issues emerged which suggested that

the wording of three of the questions (Q2, Q5,Q8) could and perhaps should have been broader in scope. The vast majority of respondents made comments like `more money' or `more resources' were needed. A significant minority also made the point that funding horizons are very short, typically three years, and this makes longer-term planning very difficult. So, the problem isn't simply `more money' but `more money and more certainty over funding' (Q2). A number of respondents made the point that they are facing a shortage of trained laboratory technicians, as well as research assistants, and so these comments were coded up under Question 5. Similarly, several researchers made more general observations about the limitations of the physical infrastructure within which they worked (e.g. cramped lab and office space) and so these have been added to Q8. The remaining 65 comments were impossible to classify according to this coding frame. Some were inconsequential (`don't know'), others were difficult to comprehend ('leave me alone!'). Several respondents mentioned the need to improve scientific pay, the need for society to recognise the value of research, the need to deal with the endless pressure on researchers to get grants, and the perceived nepotism of grant-awarding panels.

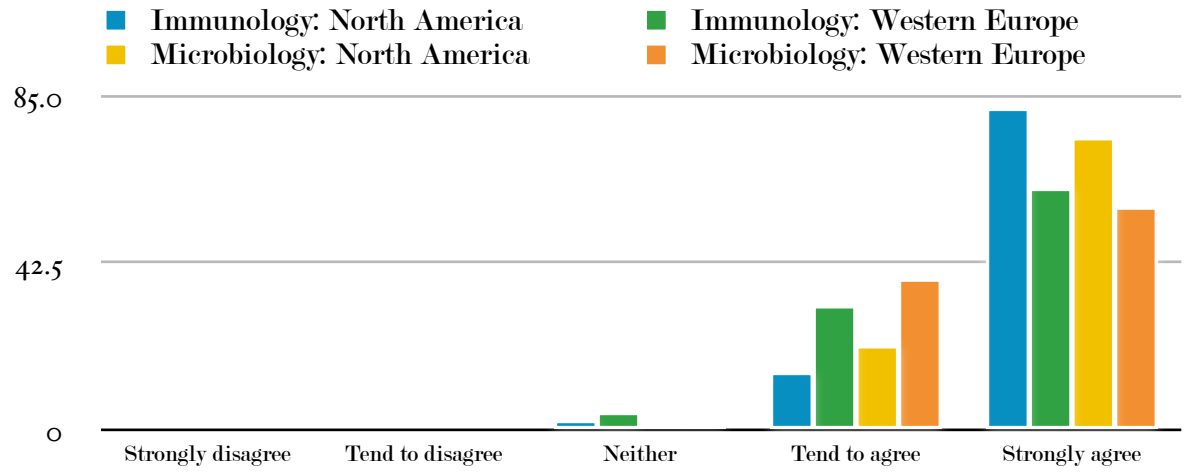
## How researchers see themselves

In the next section of the online survey, we explore how researchers see themselves, starting with how motivated they are to rise to a research challenge.

### MOTIVATION (Q18A)

*"I would describe myself as being internally driven to conduct research"*

Figure 8: Degree of self-reported research motivation[5] (percentages, n=883)




This (Fig.8) is an interesting finding. North American researchers are much more likely to respond bullishly to this question about their level of motivation. The extent

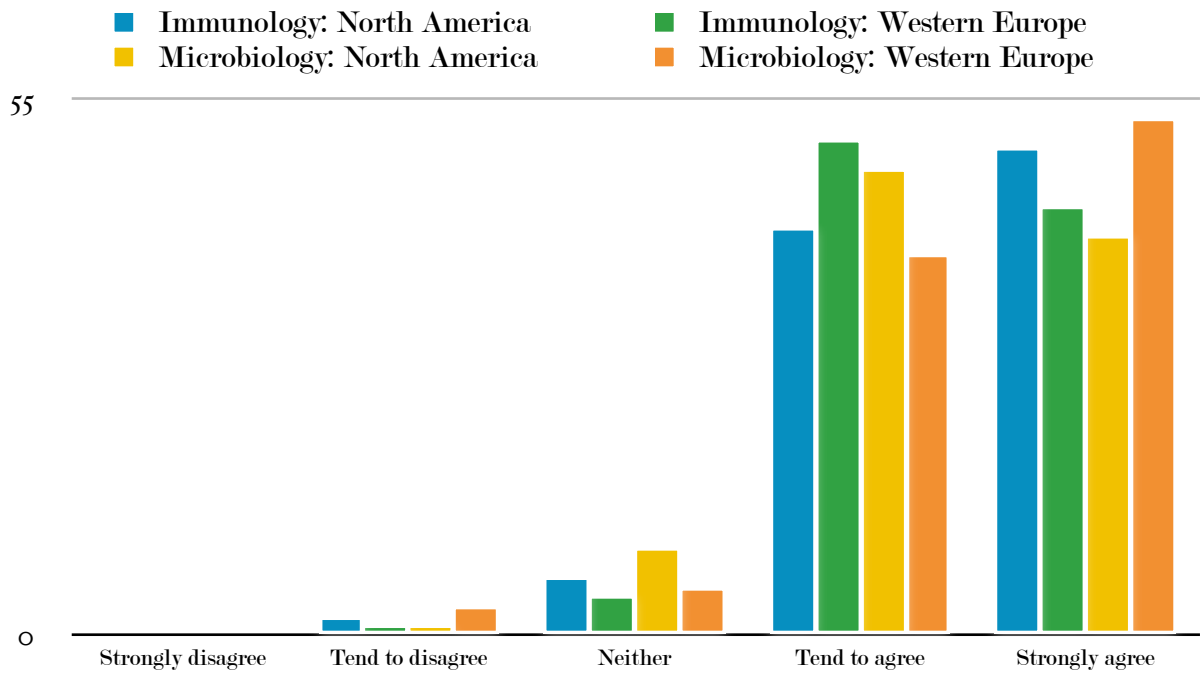
[5] $\sum^2 = 38.68$ , d.f. = 12, $p < 0.001$, significant at the 0.1% level, reject null hypothesis

to which this reflects a cultural difference, it is hard to say. However, the bigger picture is one of a highly enthusiastic population on both sides of the Atlantic, clearly enjoying and fired up by their research.

## CURRENT AWARENESS (Q18B)

*"I keep very up-to-date with the current literature in my research area"*

Figure 9: Knowledge of the current literature[6] (percentages, n=883)




Irrespective of subject or broad region, researchers feel that they are well on top of the current literature in their field (Fig.9), and this would appear to be a difficult issue for only a very small minority of respondents (i.e. the 3 percent who disagreed with this proposition). However, as we shall see in relation to Q19c/Q19D, this may not be the whole story.

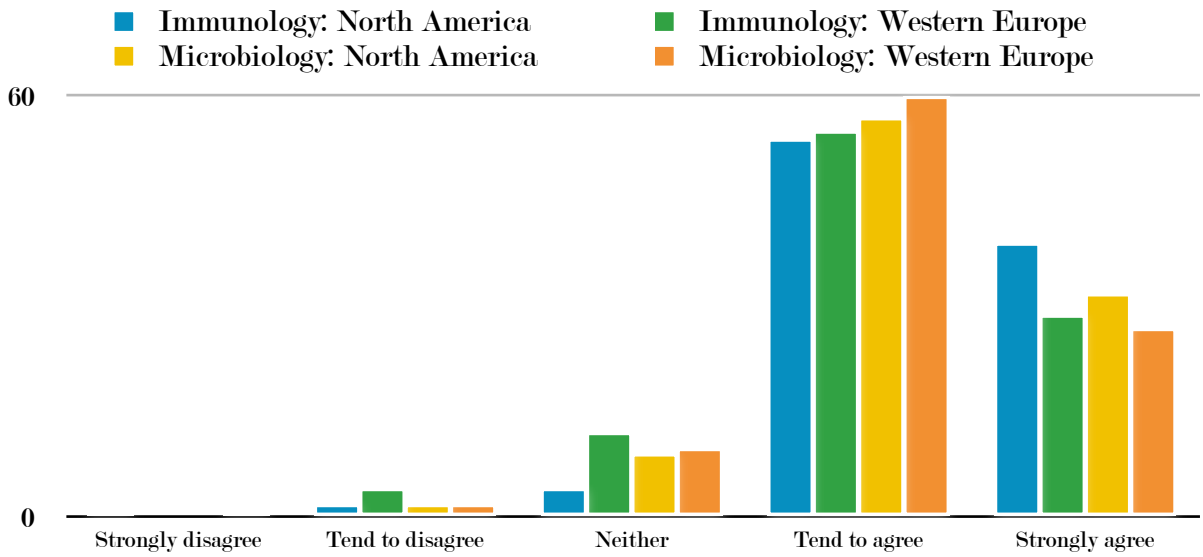
## RESEARCH SKILLS (Q18C)

*"I make sure that my research skills and knowledge are always up-to-date"*

Our researchers are similarly confident that their research skills and knowledge are current and up-to-date, with no discernible differences between the four populations (Fig.10).

[6] $\sum^2 = 14.31$ , d.f. = 12, p = 0.28, not significant

Figure 10: Currency of research skills[7] (percentages, n=883)

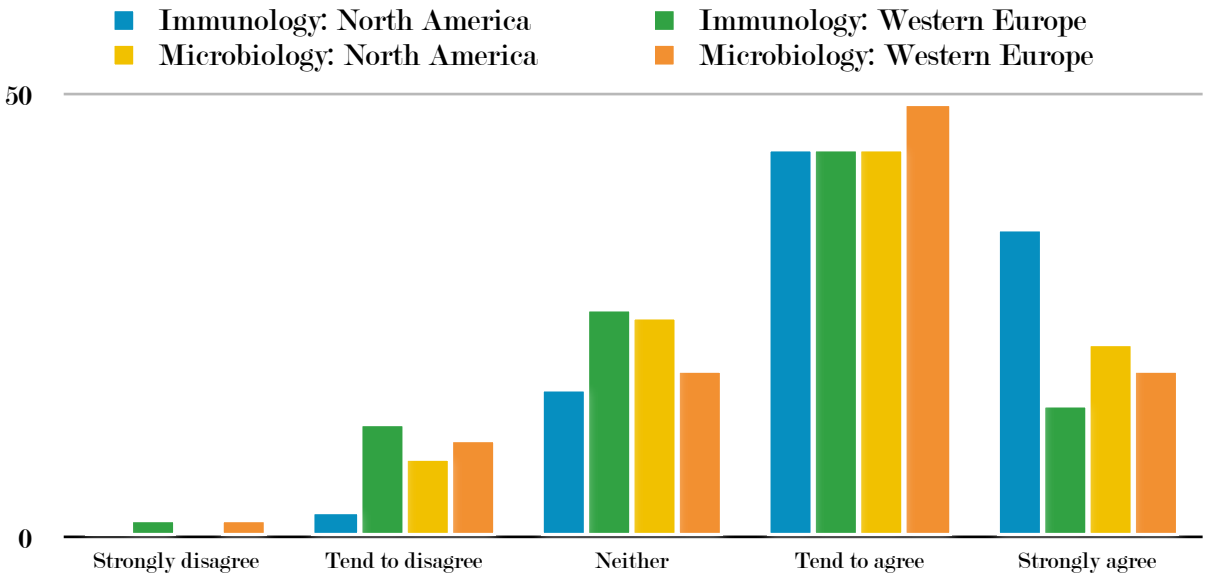



## GRANTSMANSHIP (Q18D)

*"I make sure that my grant-getting skills and knowledge are always up-to-date"*

On the issue of their grant-getting skills, however, our researchers are less confident, with a third either disagreeing or sitting on the fence on this issue (Fig.11).

Figure 11: Grantsmanship[8] (percentages, n=883)




[7] $\sum^2 = 18.35$ , d.f. = 12, p = 0.105, not significant

[8] $\sum^2 = 42.96$ , d.f. = 15, p < 0.001, significant at the 0.1% level, reject null hypothesis

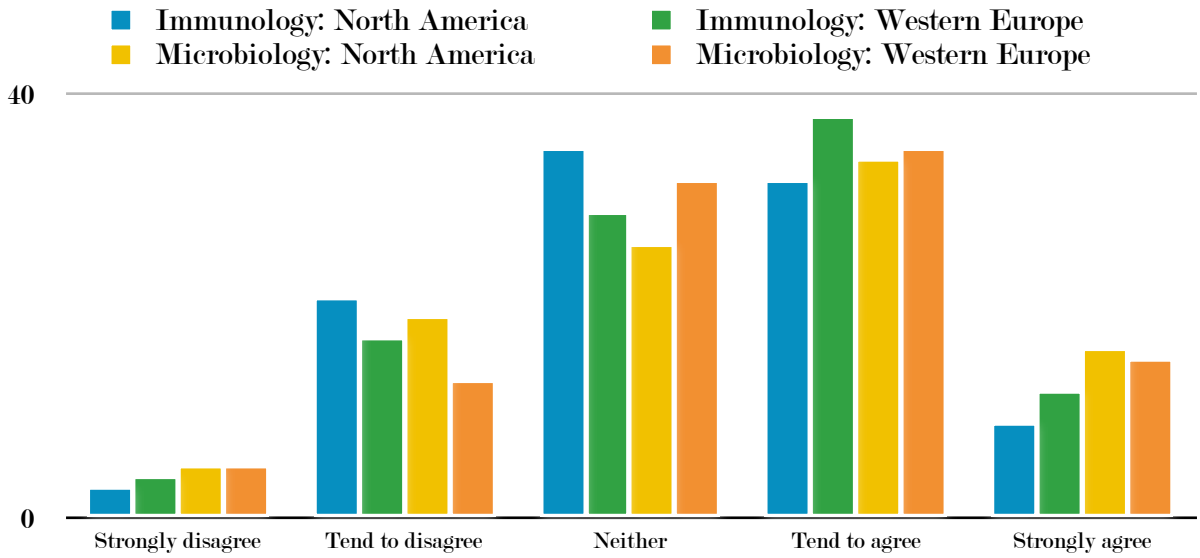
Again, there is a split by region. When the two disciplines are compared, North Americans are more likely to report positively on this crucial issue. Whether this another cultural phenomenon or whether it refers to deeper-seated problems about the way that research funding in Europe is organised will require further analysis (there is certainly a possibility that the European research system is more fragmented).

## Professional networking (Q18e)

*"I spend a lot of time and effort developing my professional contacts"*

Contacts are an essential part of any professional activity and science is no exception. There is clearly room within the findings presented here (Fig.12) for more to be done to support researchers on both sides of the Atlantic in developing their invisible colleges through attendances at conferences, seminars, exchanges and other network-building activities. Just under half (48%) of our respondents said that they agreed, strongly or moderately with the statement.

Figure 12: Professional networking[9] (percentages, n=883)



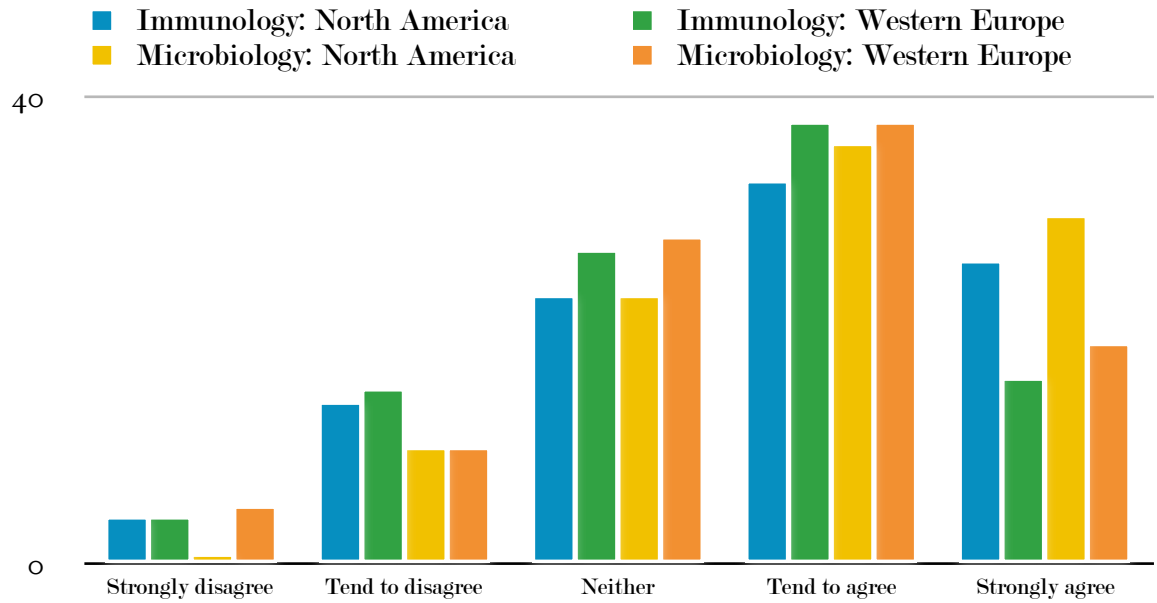

## Dissemination (Q18f)

*"I disseminate my work at every opportunity"*

Finally, in respect of the importance that they attach to active dissemination of their work (Fig.13), there appears to be another significant transatlantic difference.

[9] $\sum^2 = 57.75$ , d.f. = 15, p =0.39, not significant

Figure 13: Importance attached to research dissemination [10] (percentages, n=883)




Subject for subject, North American respondents report lower agreement scores: they would clearly like to do more on this vital aspect of their work.

Figure 14: Summary values for Q18

*Mean values, where 1=Strongly disagree, 5=Strongly agree (all disciplines and regions, n=883)*

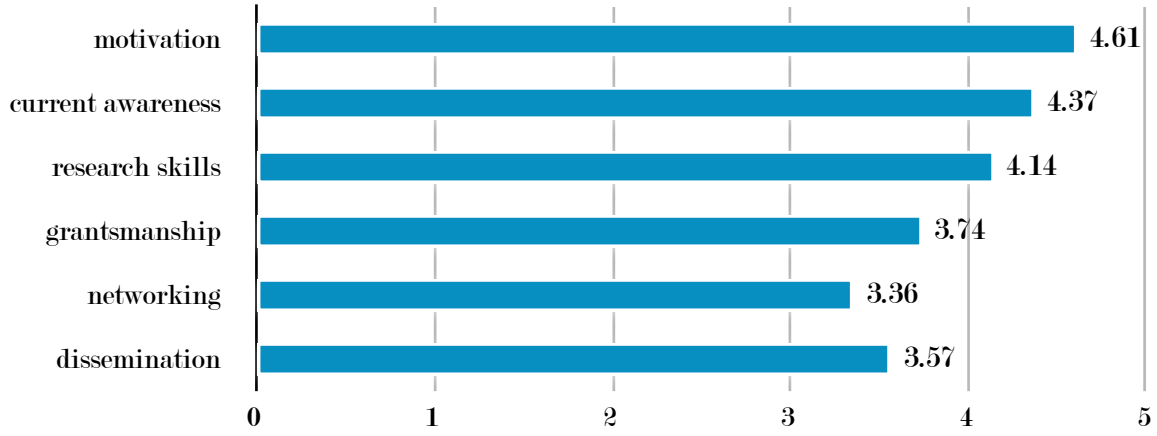



Figure 14 offers an overview of the general perceptions of the survey sample. They are very highly motivated and perceive that they have no problems in keeping themselves at the forefront of new knowledge and research methods. This would hardly be possible without good access to the journals literature. They are less confident about their grant-getting skills and they would welcome greater opportunity to spread the word about their research and to build up their

[10] $\sum^2 = 29.10$ , d.f. = 15, p = 0.016, significant at the 5% level, reject null hypothesis

professional contacts. These are of course things that could be accomplished relatively cheaply: this survey dispels the myth that the only effective driver of more and better research is to throw more and more money at the system.

## Use of the journals literature

Discussion of dissemination and communication issues naturally leads us to consider the role that the formal journal publication system plays in sustaining and encouraging research activity. In this section, we explore the extent to which the current system supports (or limits) these objectives. Researchers were presented with the following statement ...

*"Over the past few years, publishers have made large numbers of journals available in full text from your desktop computer"*

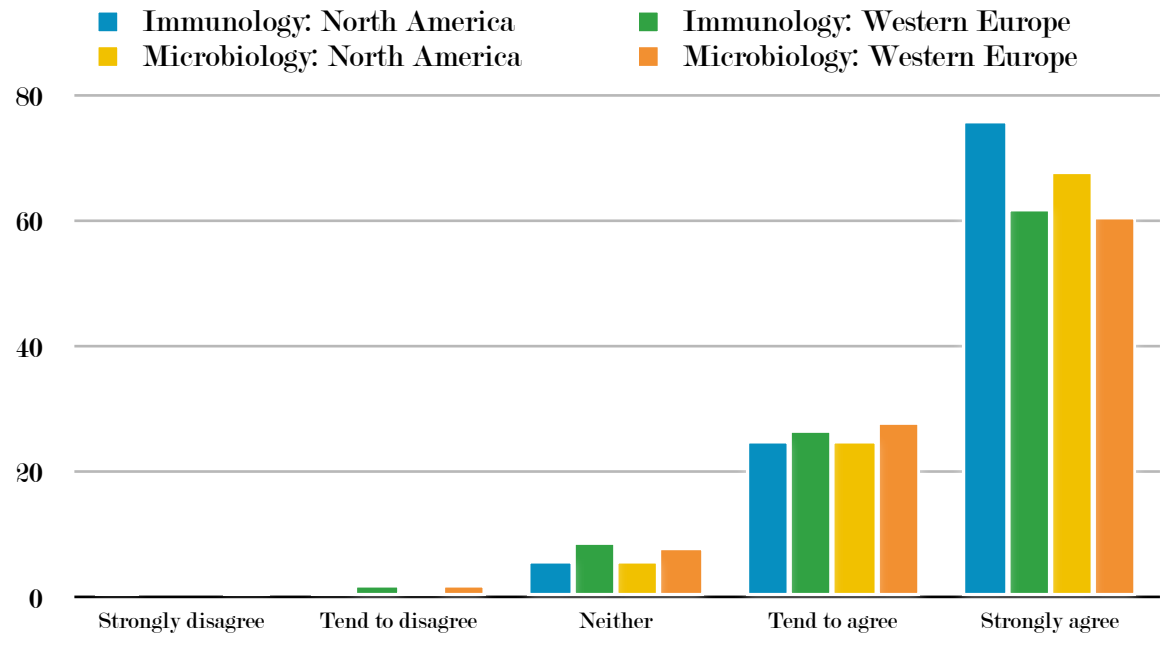
... and were then asked to rate various facets of this statement in respect of how this had impacted on their work.

### EFFECTIVENESS (Q19A)

*"This has helped me to become a more effective researcher"*

By a very large majority (90%) and by general agreement (no differences are evident between the four sub-populations), researchers agree that desktop access to journal full text has enabled them to become more effective researchers (Fig.15).

Figure 15: Journals and research effectiveness[11] (percentages, n=883)



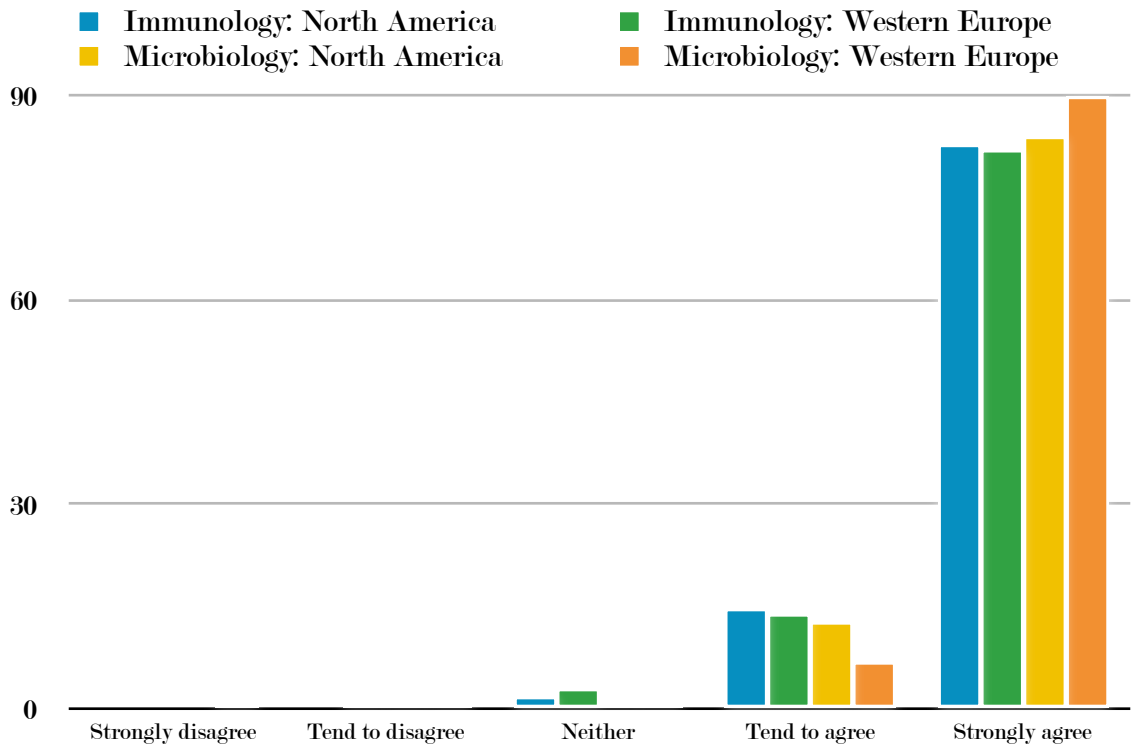

[11] $\Sigma^2 = 10.88$ , d.f. = 15, p = 0.761, not significant

## TIME SAVINGS (Q19B)

*"This has saved me considerable amounts of time in finding and retrieving articles"*

They similarly perceive that digital library platforms have enabled them to realise significant time savings in terms of document discovery and delivery (Fig.16).

Figure 16: Journals and time savings[12] (percentages, n=883)




Text here

## INFORMATION OVERLOAD (Q19C)

*"This has made me feel anxious about how much I don't know"*

A rather unwelcome corollary of the ease and convenience with which journal articles can now be identified as being potentially or actually useful, is the phenomenon of information anxiety (Fig.16). Almost a third (30%) responded that this was an issue for them (however 43% disagreed).

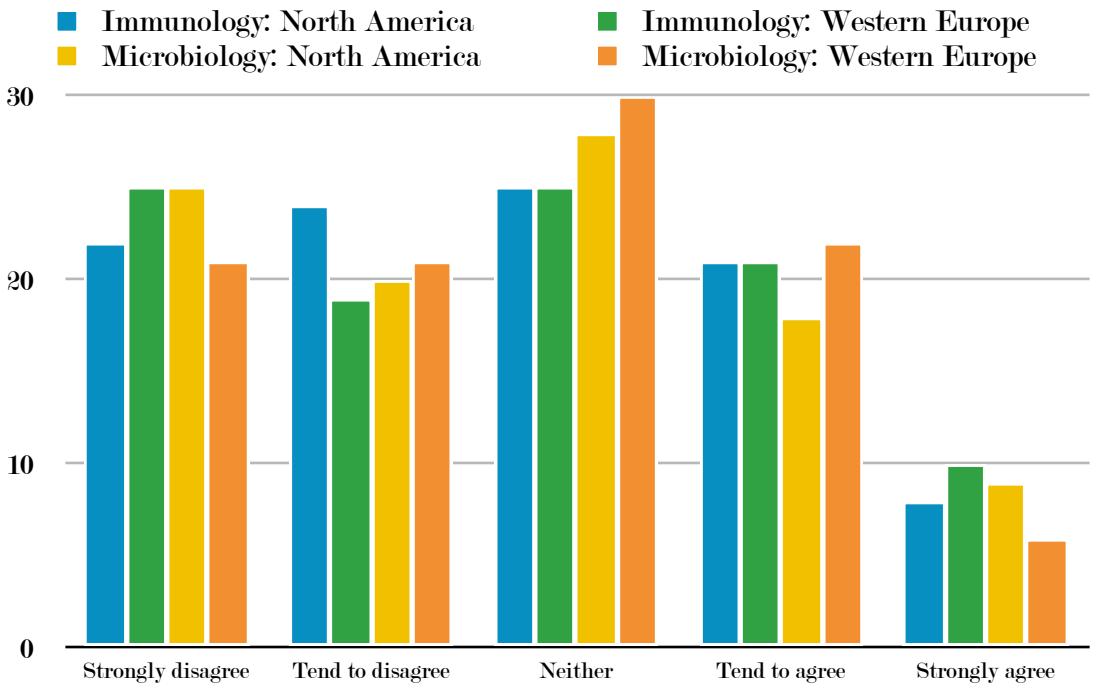
Western European scientists in both disciplines were more likely to agree strongly with this proposition, suggesting perhaps that the documentary system works rather less well for them than for their North American colleagues. There is certainly much evidence that the European information industry is more fragmented and less efficient than it could be. Among the possible explanations are linguistic differences and the inevitable tension between an activity (science) which is global and knows no

[12] $\sum^2 = 27.41$ , d.f. = 15, p = 0.026, significant at the 5% level, reject null hypothesis

territorial borders and the practical arrangements (notably funding and strategic direction) which are, to a very large extent determined locally, country by country.

There is an interesting difference[13], significant at the 1% level, between members and non-members of learned or professional societies: members are much less likely to experience the `information anxiety' as indicated by their answers to this statement.

Figure 17: Journals and information overload[14] (percentages, n=883)




## DISSEMINATION (Q19D)

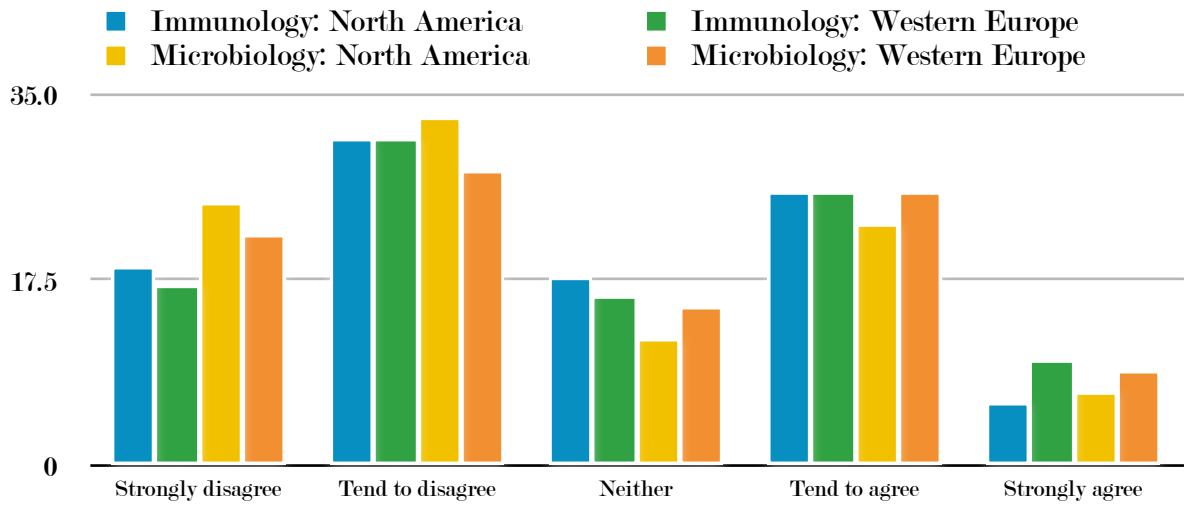
*"I still find it difficult to get hold of all the articles I need"*

The final issue to consider in this part of the survey is actual experience on the ground as researchers try to get hold of the full text of articles that they need.

[13] $\sum^2 = 15.71$ , d.f. = 5, p = 0.008, significant at the 1% level, reject null hypothesis

[14] $\sum^2 = 6.71$ , d.f. = 15, p = 0.965, significant at the 95% level, accept null hypothesis

Figure 18: Accessing journal full text[15] (percentages, n=883)




Again, there is a very high level of agreement (97%) on this perception, confirming that convenience is a key issue for research users and that electronic delivery fits very well into their patterns of work.

There is evidence here (Fig.18) of a substantial degree of dissatisfaction with the current level of provision in this area: slightly over a third (35%) of respondents agreed with this statement and it is clear that, subject for subject, dissatisfaction is higher among European (36%) than among North Americans (32%).

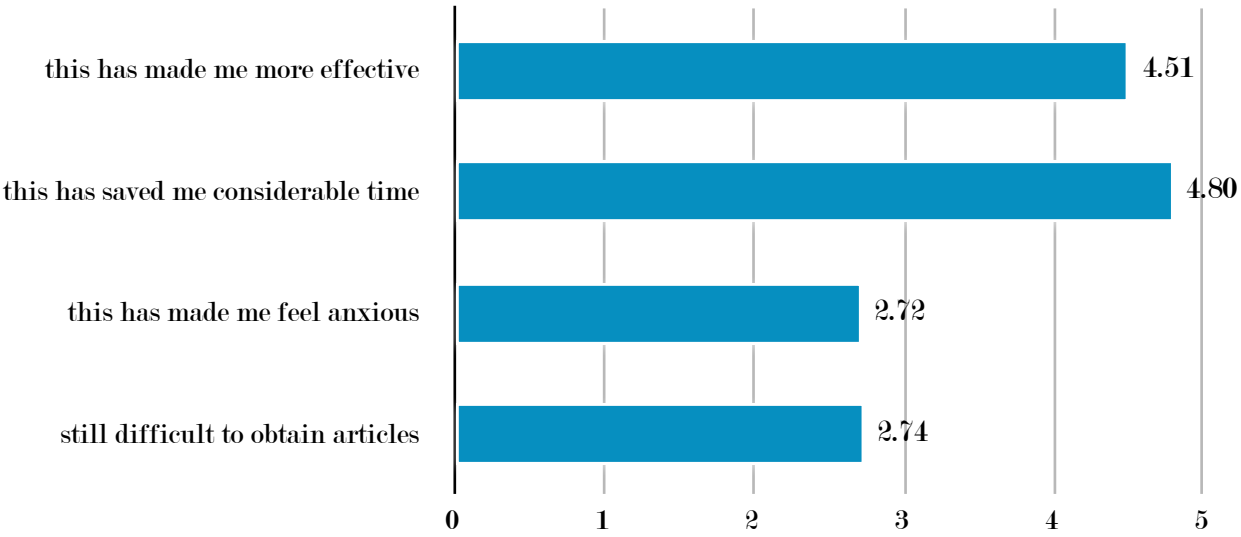
A closer examination of the responses to this question shows that the other key demographic drivers of this outcome are age, article productivity and research mode. Younger authors (aged 45 and below) voice stronger agreement (36%) with the proposition, and the effect is very marked indeed for those authors who, measured by their peers in this group, are less productive (i.e. those who have published less than four articles over the past two years). Here the agreement rises to 43%. Access to full text also appears to be more of perceived problem for those engaged in clinical research activities, possibly a function of the particularly acute time pressures felt in this sector.

A rather mixed picture has emerged in this section: researchers clearly appreciate the investments made in digital libraries of journal articles, realise the huge convenience benefits, yet are still not wholly satisfied. It is quite possible that the gap identified in this question is more a function of raised expectations than really fundamental problems relating to literature access. However, we should not be complacent, and there is clearly a role for publishers, librarians and the policy community to engage constructively in bridging the gap.

[15] $\sum^2 = 11.68$ , d.f. = 15, p = 0.703, not significant

Figure 19: Summary values for Q23

*Mean values, where 1=Strongly disagree, 5=Strongly agree (all disciplines and regions, n=883)*

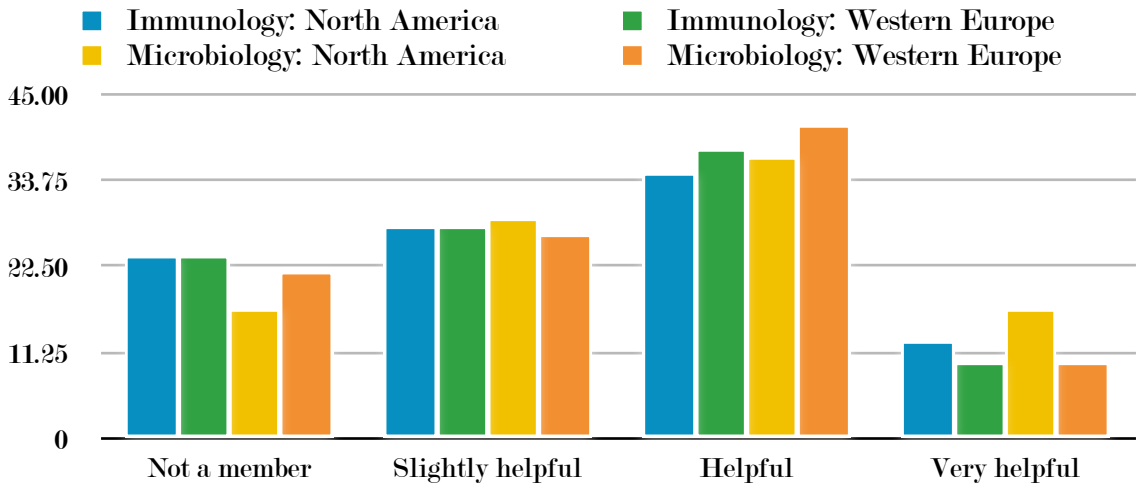



Overall, it seems that user satisfaction with publishers' offerings are fairly high: they are saving researchers time and helping them to be more effective but there are issues peculiar to the European context in particular that require further investigation.

## Role of learned societies (Q20)

*"To what extent do you find membership of a learned society helpful for your research?"*

Figure 20: Perceived value of learned societies[16] (percentages, n=883)




North American respondents are very much more likely[17] to be members of a learned society than Western Europeans, although there is no discernible difference between

[16] $\sum^2 = 34.64$ , d.f. = 15, $p < 0.001$, significant at the 0.1% level, reject null hypothesis

[17] $\sum^2 = 20.14$, d.f. = 1, $p < 0.001$, significant at the 0.1% level, reject null hypothesis

immunologists and microbiologists. Of those who are members, 54% find them `very helpful' or `helpful'. And, as noted earlier, members seem to suffer less from `information anxiety'.

## What determines biomedical research productivity?

In order to answer this question using the available survey data, authors were divided into two groups of `high' and `low' article productivity (as indicated by the number of papers published in the previous 24 months). The higher productivity category includes those authors (79.6%) who published four or more papers; the lower productivity category those (20.4%) who published three or fewer (it should be recalled that these are self-reporting data and possibly exaggerated[18]).

The research question posed here is, "is it possible to predict an author's level productivity level based on a knowledge of the other questions in the survey?". The tool used here (Table 4) is a binary logistic regression.

| PREDICTOR | B | WALD $\Sigma^2$ | P | ODDS RATIO |
|---|---|---|---|---|
| Grant-getting skills (Q18d) | -0.32 | 15.54 | ‹ 0.001 | 0.72 |
| Gender (Q21) | -0.61 | 12.52 | ‹ 0.001 | 0.54 |
| Motivation (Q18a) | -0.49 | 15.40 | ‹ 0.001 | 0.61 |
| Research type (clinical / basic) (Q24) | -0.32 | 7.74 | ‹0.01 | 0.73 |
| Availability of e-journals (Q19d) | 0.19 | 8.54 | ‹0.01 | 1.21 |
| Professional networking (Q18e) | -0.24 | 8.05 | ‹0.01 | 0.79 |

Table 4: Logistic regression model predicting author productivity (n=883)

Given their answers to the six questions above, we can correctly predict whether an author exhibits high or low productivity 77 times out of a hundred (this is a pretty good result for fuzzy, attitudinal data). It is possible to add extra variables to the model, they improve the predictive ability of the model by such a small margin as to be unhelpful. The key indicator is the `odds ratio'. If we take gender as an example, the odds are 1.85 (1/0.54) to 1 that a higher productivity author will be male than female.

In summary, we can predict high research producers to a surprising extent when the author exhibits the following characteristics:

[18] The categories used for reporting numbers of publications in the survey were 0, 1, 2-3 and 4+ and were based on a preliminary bibliometric analysis of publication patterns in immunology and microbiology in ISI's Science Citation Index. The categories were designed to capture roughly equal numbers of publications. This seems to point to exaggerated levels of self-reporting.

- high levels of (self-reported) grant-getting skills and knowledge
- male
- high levels of (self-reported) motivation
- pursue a mix of clinical and basic research (researchers who classified themselves at either extreme of the research type spectrum, i.e. wholly clinical, or wholly basic, seem to be less productive)
- report fewer problems gaining access to "all the articles they need"
- report spending a lot of time and energy developing their professional contacts

These are interesting findings which raise major policy issues, urgently in respect of the gender productivity gap in biomedicine. There is also a hint that problems in accessing the journals literature may be a barrier to scientific productivity.

## Why are some researchers dissatisfied with the journals system?

To explore this issue, the sample was divided into those researchers (300) who reported that they found it "difficult to get hold of all the articles I need" (Q19d) and those (443) who disagreed.

| PREDICTOR | B | WALD $\Sigma^2$ | P | ODDS RATIO |
|---|---|---|---|---|
| Availability of funding (Q12) | 0.19 | 11.85 | ‹ 0.001 | 1.21 |
| Interdisciplinary work (Q3) | 0.14 | 7.63 | ‹ 0.01 | 1.15 |
| Information anxiety (Q19c) | 0.14 | 6.16 | 0.013 | 1.15 |
| Bureaucracy (Q11) | 0.10 | 12.69 | ‹ 0.001 | 1.10 |

Table 5: Logistic regression model predicting level of satisfaction with journal access (n=743)

This time, a model (Table 5) based on four variables is able to predict the answer to that question 63 time out of 100. Researchers who reported a problem in accessing the literature are:

- more likely to perceive that access to research funding is a problem
- more likely to agree that they feel anxious about how much they don't know
- more likely to need help and support to work with researchers in other disciplines
- more likely to perceive that bureaucracy and form-filling is a problem

This is difficult to interpret, without access to more data. Simple crosstabs suggest further significant differences (at the 1% level) between `contents' and `discontents'.

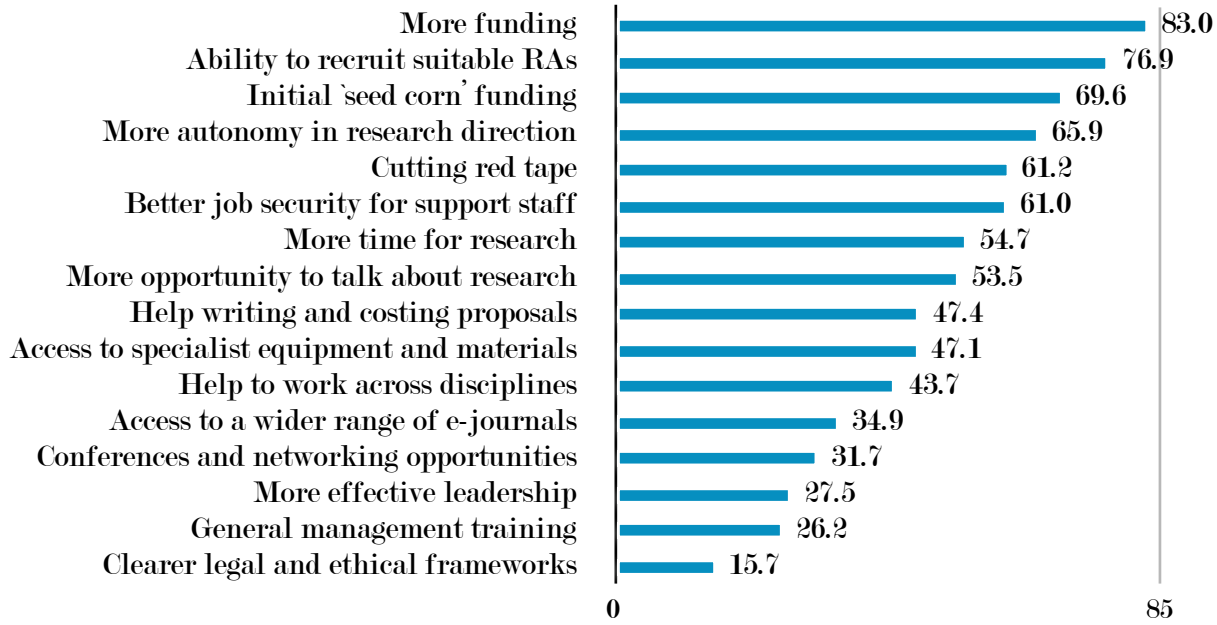
Discontents are much more likely to be based in smaller European countries, to exhibit low article productivity, and to report that they have a problem attending conferences and other networking events. It is impossible to establish the direction of causality here, if there is any, but there does seem to be a specifically regional dimension to this issue.

## What would help make researchers more productive?

In this final section, we turn to the results of the conjoint analysis experiment (Q2-Q17). Conjoint analysis is a survey technique that is widely used in product development. It is often used in the early stages of a product design to discover the real value that consumers attach to various features. Consider a manufacturer who wants to place a new budget MP3 player in the marketplace. What are the features that consumers really want, and what can they do without, at a given price point? It is very difficult, probably impossible, to use standard survey techniques to get at the complex trade-offs that consumers make between product features that this example implies. One way to discover the real value (or `utility') that consumers might attach to, say, cheap MP3 player with a built-in camera, as opposed to one with greater memory, or built to a high quality level, is to create a statistical model using conjoint methods. This can be achieved by asking respondents to indicate their preferences between all possible pairs of attributes (memory versus camera facility, memory vs build quality, build quality versus camera facility) and to subsequently model these preferences using a form of trade-off analysis.

This is the general approach we used in this experiment. A list of 16 factors was identified from the research literature and verified during interview. These factors were identified as those which are most likely to promote rather than inhibit research productivity: things like cutting bureaucracy or providing better research management and direction. Because 16 factors generate 120 possible factor pairs, we divided the questions into six blocks of 20 questions and assigned authors at random to these blocks.

Figure 21: Conjoint analysis of research liberators (average utility scores, n=883)




This meant that each respondent was asked to comment on 20 pairs of factors only (out of 120) and to indicate, on a 5-point scale, which of the two factors would make the greater difference to their ability to become more productive. The aggregated results for all four sub-populations can be seen in Figure 20. The data are the mean utility scores for each question (theoretically, these range between 0 and 100).

A high score indicates that respondents place a high value on that particular aspect. There appear to be a couple of natural breaks in this ranked ordering: the top four issues being of critical importance, followed by a `second division' of a seven further issues, and a third-division tail, starting at `Access to a wider range of e-journals'.

The next seven Figures present the findings of the conjoint analysis broken down by population, subject, mode of research, region, author productivity, age and gender in a highly visual form, using radar charts. (For those unfamilar with this kind of graphical representation, a radar plot is effectively a stacked bar chart with the bars acting as spokes radiating from a central point.

Figure 22: Subject by region conjoint analysis (n=883)

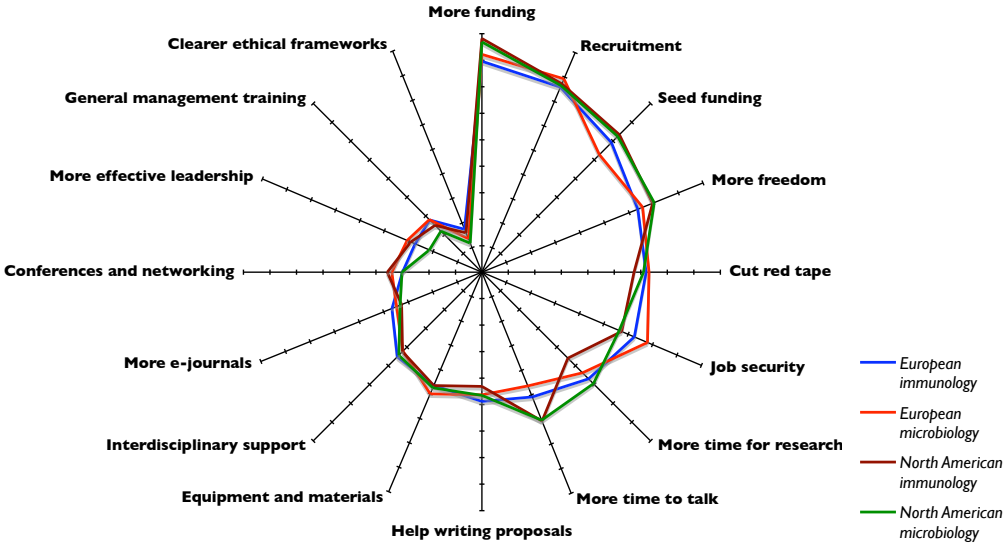



Figure 23: Broad subject conjoint analysis (n=883)

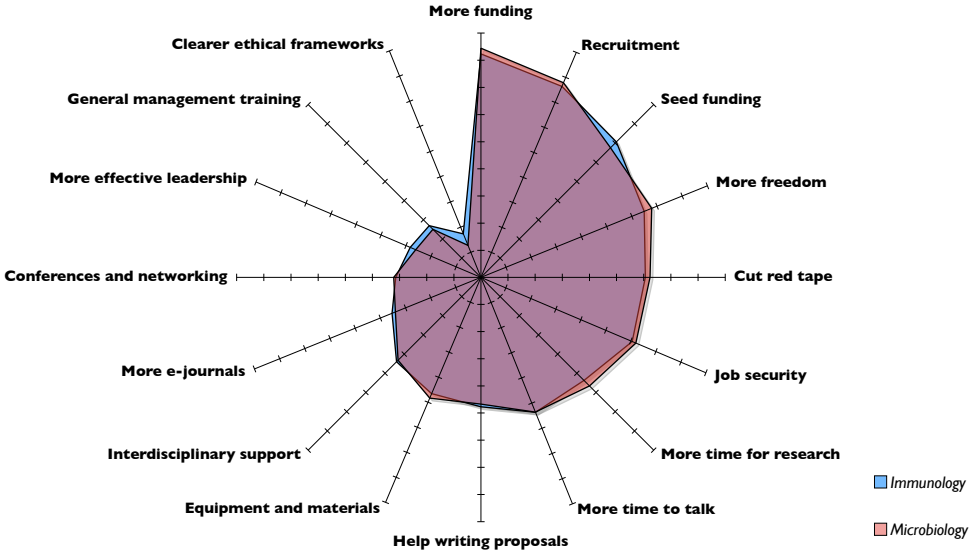


Figure 24: Clinical vs basic conjoint analysis (n=883)

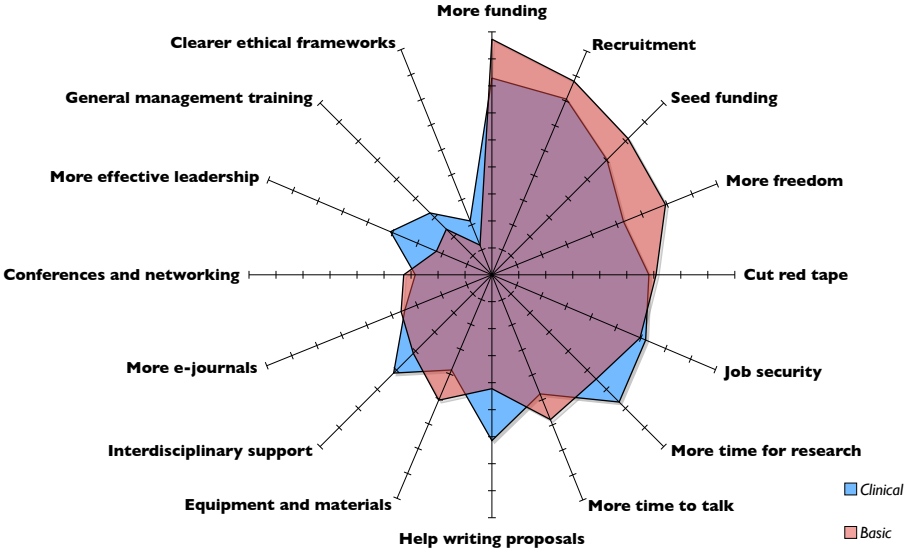



Figure 25: Regional conjoint analysis (n=883)

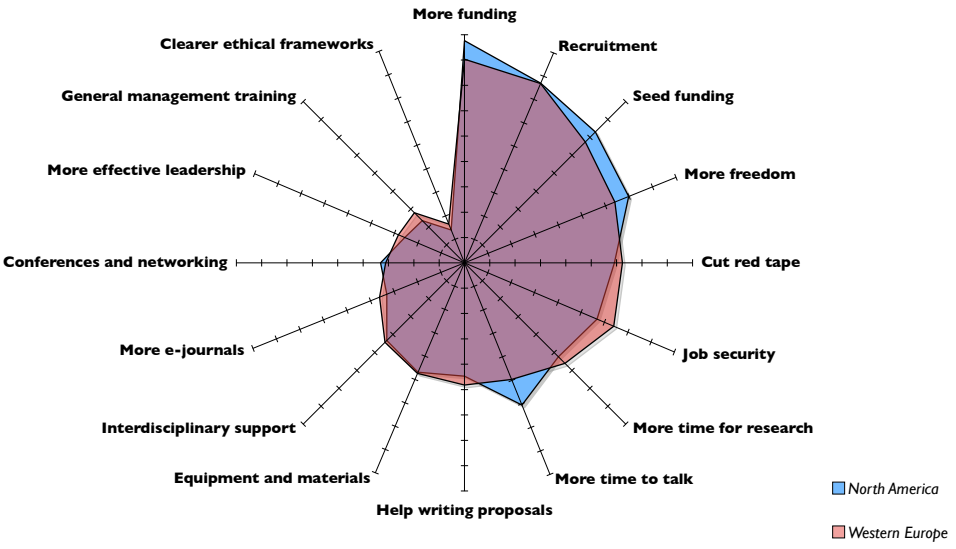


Figure 26: Article productivity conjoint analysis (n=883)

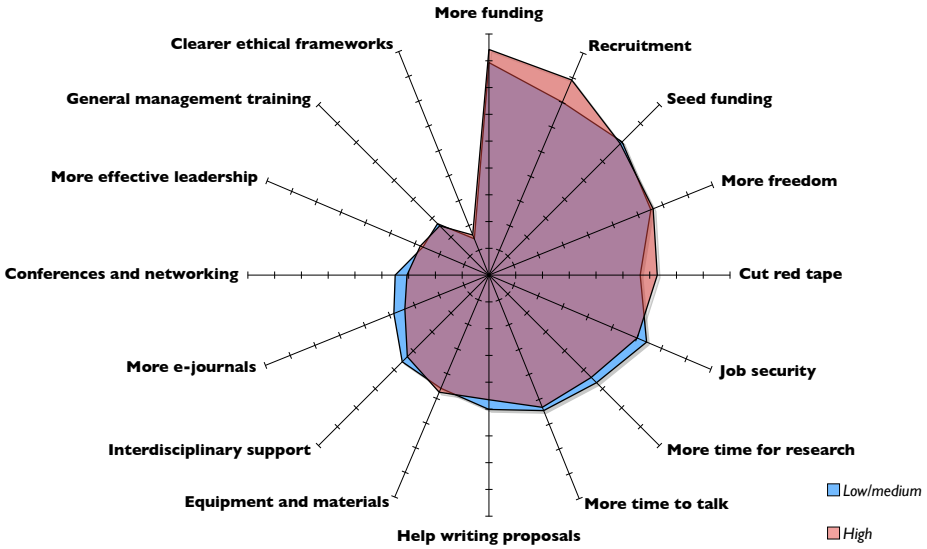



Figure 27: Age conjoint analysis (n=883)

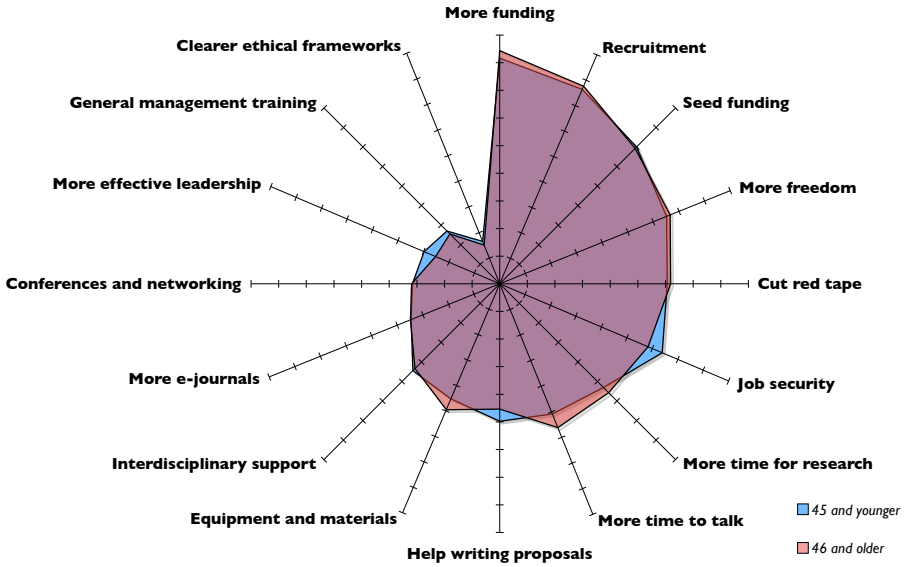
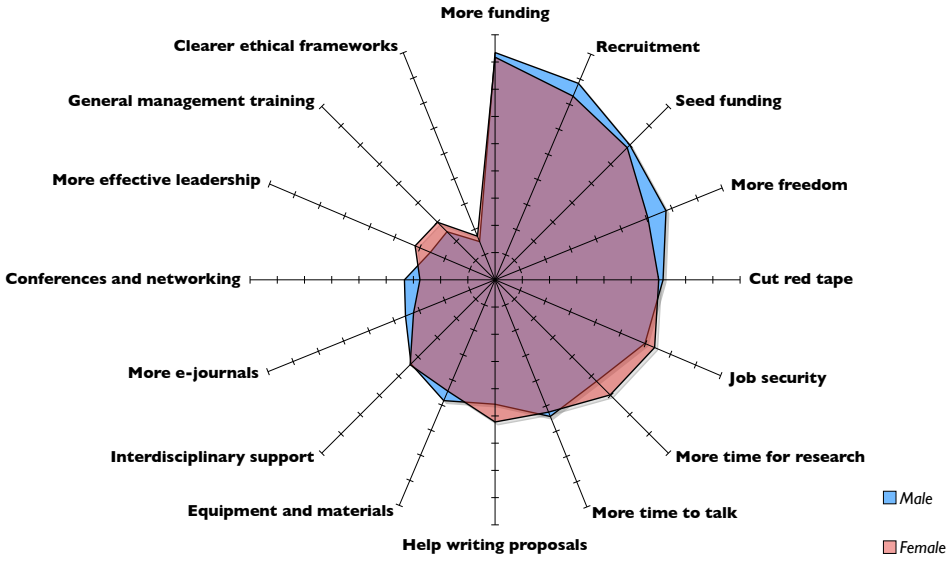



Figure 28: Gender conjoint analysis (n=883)




A number of conclusions may be drawn from this analysis. The most striking is the remarkable consistency with which these issues are valued and ordered: it seems there is general consensus on the policy solutions that could enhance research productivity. There are subtle differences (for example, European researchers seem to place a higher utility value on seed corn funding , North Americans on conferences and networking, Fig.25) but these are slight. The only really major differences between utility values so far identified are those expressed by researchers working in predominantly basic or applied research modes (Fig.24).

These findings present a consensus view of the research productivity barriers facing biomedical researchers. The utility scores in the right-hand column allow us to rank-order these barriers and to indicate the relative weight that the community attaches to each. Relative to other productivity-limiting issues, the ability to be able to source to a wider range of journal materials, a key argument for reader open access, can be seen to be a third-division concern. Other issues are much more pressing: notably the need for better funding, research staff recruitment and retention, seed corn funding to help `risky' new areas of research to reach early maturity, and a clear message that research funders' priorities are stymying individual creativity.

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# Annex 1: Survey invitation email

Subject line
BIOMEDICAL RESEARCH: WHAT CAN BE DONE TO HELP YOU BE MORE PRODUCTIVE?

From line
Professor Dave Nicholas, University College London

Body of message

We are contacting you as a senior biomedical scientist to invite you to take part in an important international study being conducted by CIBER, a public policy research group at University College London.

Our aim is to gain a better understanding of some of the factors, both in the workplace and in the wider environment, that distract researchers from being fully productive as they might otherwise be. With that in mind, we would like to invite you to complete a short online survey (this should take no more than five minutes of your valuable time) to help us to identify what really are the key problems facing biomedical researchers.

Your reply will be treated in complete confidence and will only be used in combination with those of other participants. You can read more about our survey site by clicking here. If you have any concerns about this survey not being genuine, or would like further information about CIBER, please contact Professor Dave Nicholas at UCL.

Your views are very important for influencing the public debate and we shall be bringing them to the wider attention of the scholarly and policy communities through conferences, peer-reviewed articles and the media.

Please click here to proceed with the online survey.

If you have any problems or technical issues with the survey please click here.

If you would prefer not to receive messages from the CIBER Research Group inviting you to participate in research projects, please email us by clicking here.

CIBER Research Group, School of Library, Archives and Information Studies, University College London, Gower Street, London WC1E 6BT, UK.

http://www.ucl.ac.uk/ciber/ciber.php

You have received this email in the genuine belief that its contents would be of interest to you. If you do not want to receive these messages from Thomson ISI or other carefully selected organisations, please go to our preference page.

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Thank you for your attention.

# Annex 2: The questionnaire

The purpose of this online interview is to seek your views on the issues that most distract you from your research. Your answers will be treated with the utmost confidentiality and only highly aggregated findings will be disseminated.

We hope to give a voice to some of the problems that the scientific community raises by bringing the evidence to the attention of policy makers.

Question 1

What is the single most important thing that your manager, employer or funding body (or indeed any other body) could do to help you to become a more productive researcher?

Enter your comment here: [FREE TEXT ENTRY]

Questions 2-17

We would now like you to think about some broad factors that could help you to achieve your full potential as a researcher.

We will present you with a series of statement pairs. By considering each pair in turn, please indicate which of the two statements you feel would contribute more to your research performance.

For example, if you think the left hand statement is much more important than the right hand statement, select the box on the extreme left. If you think however that the right hand statement is much more important, select the box on the extreme right. You may also select boxes in between if your preference is less strong.

TICK ONE BOX IN EACH ROW

Training in general management techniques (e.g. personnel, financial and project management)

More help and support to work with researchers in other disciplines

More help and support in writing and costing research proposals

More effective leadership and guidance on priorities from above

Immediate desktop access to a wider range of full text journals in your field

Access to the latest specialist equipment and materials

The ability to recruit more highly qualified and motivated research assistants

More help to attend conferences and other networking events

Clearer legal and ethical frameworks for your research

Mechanisms to cut down the form-filling and bureaucracy associated with your job

Access to more research funding

More opportunity to simply talk about research ideas with colleagues

Better job security and prospects for research support staff

Seed corn funding to help get your ideas off the ground

More freedom to pursue your own ideas rather than research funders' priorities

More time for research relative to other duties (e.g. teaching or administration)

Question 18

How would you describe yourself as a researcher?

1 = Strongly agree
2 = Tend to agree
3 = Neither agree nor disagree
4 = Tend to disagree
5 = Strongly disagree

TICK ONE BOX IN EACH ROW

I would describe myself as being internally driven to conduct research

I keep very up-to-date with the current literature in my research area

I make sure that my research skills and knowledge are always up-to-date

I make sure that my grant-getting skills and knowledge are always up-to-date

I spend a lot of time and effort developing my professional contacts

I disseminate my work at every opportunity

Question 19

Over the past few years, publishers have made large numbers of journals available in full text from your desktop computer. In general terms, how far would you agree or disagree with each of the following propositions:

1 = Strongly agree
2 = Tend to agree
3 = Neither agree nor disagree
4 = Tend to disagree
5 = Strongly disagree

TICK ONE BOX IN EACH ROW

This has helped me to become a more effective researcher

This has saved me considerable amounts of time in finding and retrieving articles

This has made me feel anxious about how much I don't know

I still find it difficult to get hold of all the articles I need

Question 20

To what extent do you find membership of a learned society helpful for your research?

1 = Very helpful
2 = Helpful
3 = Slightly helpful
4 = Not helpful
5 = I am not a member of a learned society

TICK ONE BOX

In this section we need to ask just a few more questions so that we can relate the survey findings to the population as a whole. We're nearly finished.

Question 21

Are you

TICK ONE BOX ONLY

Male
Female
I'd prefer not to say

Question 22

How old are you?

TICK ONE BOX ONLY

Under 26
26-35
36-45
46-55
56-65
Over 65
I'd prefer not to say

Question 23

Where are you based?

TICK ONE BOX ONLY

[Predetermined checklist of North American and Western European countries here]

Question 24

What kind of research do you do?

TICK ONE BOX ONLY

Clinical research
A mix of clinical and basic
Basic research
None of the above

Question 25

How many refereed papers have you published in the past two years?

TICK ONE BOX ONLY
1 or none
2-3
4 or more

Question 26

Finally, do you have any comments that you would like us to bring to the wider attention of science policy makers?

Enter your comments here: [FREE TEXT ENTRY]

Thank you for your time and patience.