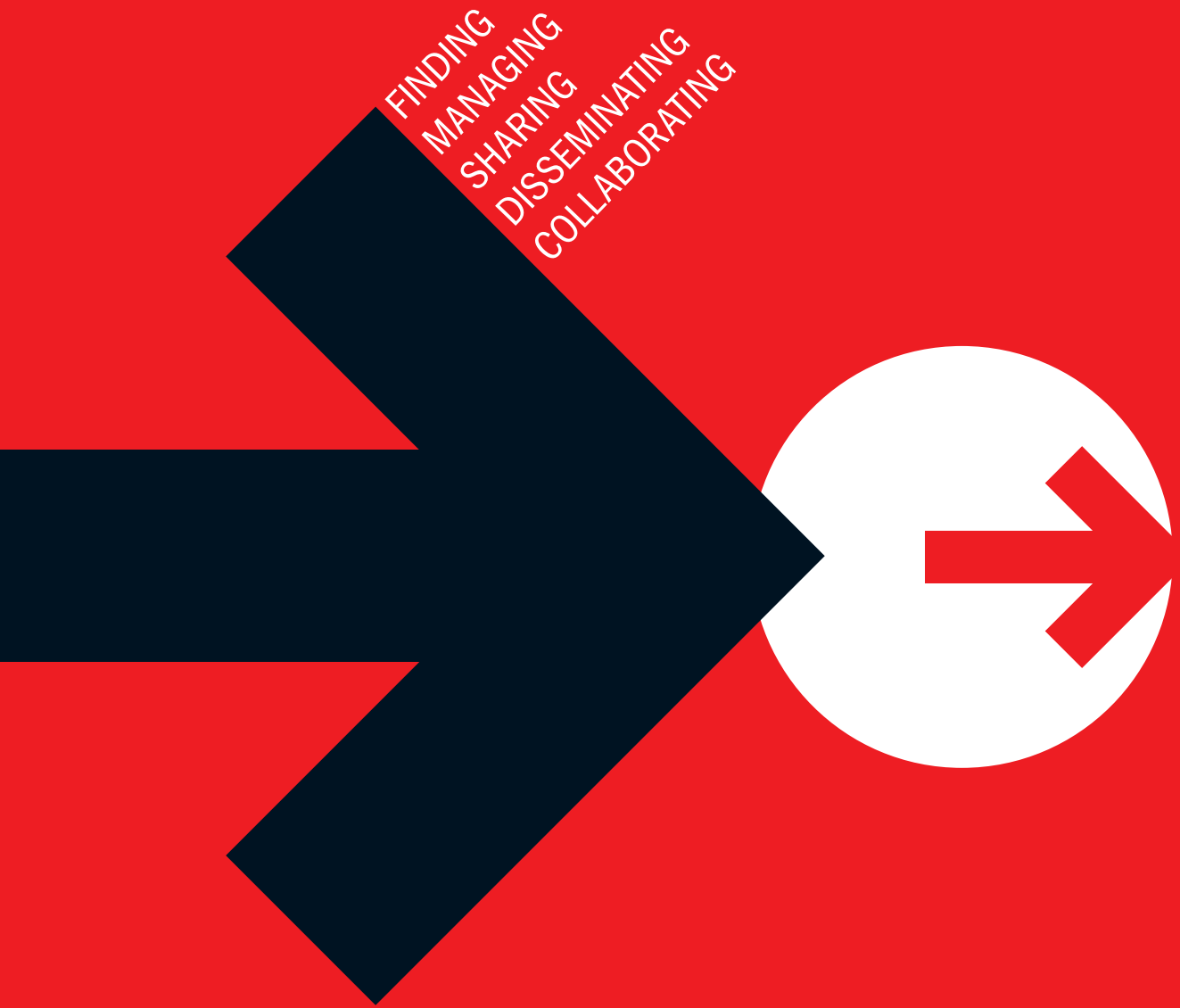
A report prepared by the Research Information Network and IOP Publishing | **October 2015**

Information practices in the physical sciences

A quantitative study to evaluate the impact of digital technologies on research in the physical sciences



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Introduction

Background

In 2011, RIN worked with a number of partners, including IOP Publishing, to produce a study on how physical scientists find, use and disseminate information. This study used a qualitative approach – interviews and focus groups – to understand groups of researchers working in different fields, disciplines and projects across the physical sciences.

We found huge variety among the scientists that we interviewed. Some methods of finding, sharing and using information were common to researchers in many sub-fields of the physical sciences, but the relative importance of these methods varied. Other methods were specific to a certain discipline, or even research group – often developed to meet their specific needs and therefore not widely used across the physical sciences as a whole.

But these results, though fascinating, could only tell us about the people that we interviewed. So in late 2013, RIN and IOP Publishing began a new collaboration to deepen our understanding of the findings from the first study. We wanted to learn how widespread the attitudes, behaviours and priorities that we found in our qualitative work are within a bigger community of physical scientists.

Method

Working together, RIN and IOP Publishing developed a survey of physical science researchers. This was piloted with a small number of respondents, developed and subsequently released. We did not attempt to create a probability sample for our study: rather, we used convenience sampling by promoting the survey through IOP Publishing networks and publications and through external social media. While this sampling method has many limitations, it was successful in attracting a large number of respondents from a wide range of disciplines and countries.

The survey was open from December 2013 to February 2014 and we received 5,939 usable responses.

Analysis

Data were analysed using the SPSS statistical package. We undertook frequency analysis and cross-tabulations to understand the scope of the responses and the differences between groups. Because we did not use a probability sample, we did not undertake any statistical testing.

There are two important issues to note before reading the analysis presented in this report.

1. Not all respondents answered every question. We did not exclude these incomplete responses from the analysis; instead, we analysed the data on a question-by-question basis. This means that the base for the percentages is slightly different for every graph or table in the report. For cross-tabulations, we have only included the survey respondents who provided an answer to all relevant questions. In the case of multiple choice questions, an 'answer' constituted selecting at least one response.

2. To account for the known interdisciplinarity in the physical sciences, we allowed respondents to select as many disciplines as they felt appropriate to describe their research. We asked them to state whether all, most or some of their research fell into each area (they could also leave an option blank to indicate that none of their research fell into that area). When classifying responses for analysis, an 'all' or 'most' response means the respondent is counted within that discipline. A 'some' or blank response means that they are not. Some respondents fall into several disciplines, which is why the sum of respondents in each disciplinary category will amount to more than the total number of responses to the survey. If a respondent had not marked 'all' or 'most' of their research as falling into any category, they are classified as 'interdisciplinary'.

1

Open access is moderately important for most respondents

Around two thirds of respondents consider open access options important when selecting a journal in which to publish their research

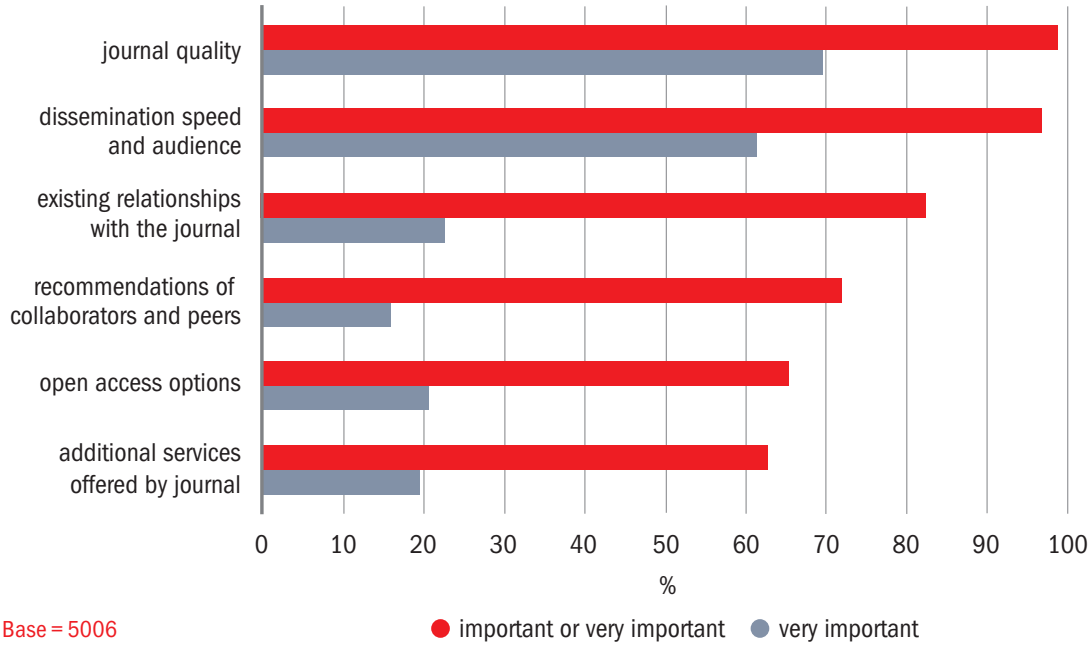
We asked respondents how important a range of factors were when selecting a journal in which to publish. We have grouped their responses into six main categories for analysis (See Figure 1). Taken together, 65% of respondents considered an open access option – Green or Gold – to be important or very important. However, 99% of respondents felt it was important or very important that the journal was the best in their academic field. In total, 21% of respondents selected open access options (Green or Gold) as very important factors when selecting a journal. By contrast, 69% of respondents considered a measure relating to journal quality to be very important.

Only a third of respondents deposited their last article in a repository

However, when asked how their last article was made available, 14% of respondents said they had used an institutional repository, while 26% had used a subject repository. There was relatively little crossover between these groups – only 4% had used both an institutional and a subject repository. This means that in total 36% of respondents had pursued some kind of Green open access route to share their last article (See Figure 2).

Levels of institutional repository use were fairly consistent across disciplines, but subject repository use varied a great deal between different disciplines. For example, 62% of respondents who said that all or most of their research was in astronomy and astrophysics had used a subject repository, while only 4% of respondents who said all or

Figure 1: Important or very important reasons for selecting a journal in which to publish



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1: Open access is moderately important for most respondents

Figure 2: Sharing methods for last article published

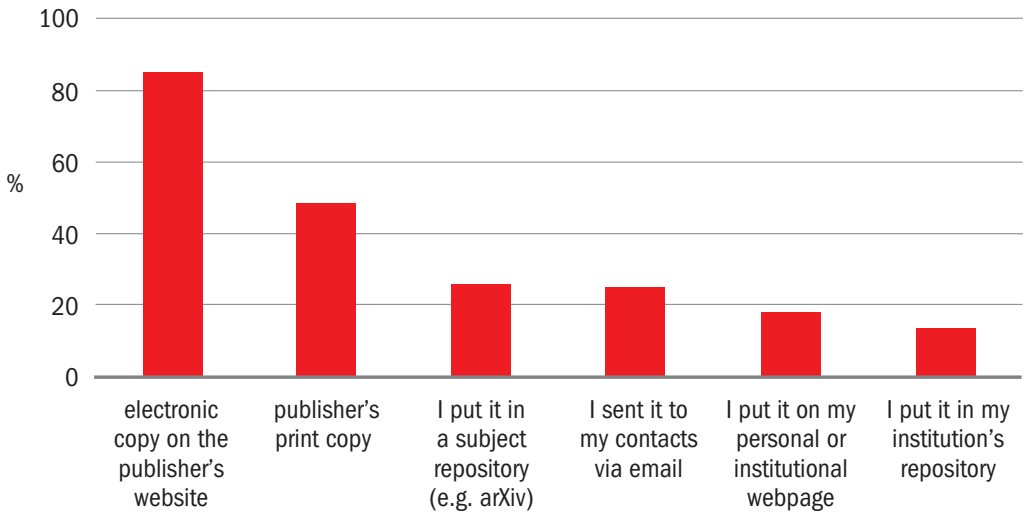

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Table 3: Subject and institutional repository deposit by discipline

	Subject repository	Institutional repository	Base
Applied physics	9%	14%	1344
Atomic, molecular and optical physics	20%	11%	695
Astronomy and astrophysics	62%	10%	628
Chemical physics	9%	14%	447
Computational science	18%	13%	700
Condensed matter and materials science	20%	13%	1386
Earth systems and environmental science	6%	17%	337
Engineering	4%	12%	1120
General physics	16%	10%	393
High-energy and nuclear physics	40%	11%	525
Mathematics, applied mathematics and mathematical physics	32%	11%	730
Measurement science and sensors	6%	16%	583
Medical and biological sciences	4%	11%	734
Plasma physics	14%	17%	370

Base = 5005

most of their research was in engineering had used one (See Table 3).

Levels of repository use, both subject and institutional, were higher in universities than in other non-commercial research organisations, and respondents in both these locations showed higher use than those in commercial research organisations (although note the very small number of respondents based in such organisations). It is not clear

1: Open access is moderately important for most respondents

Table 4: Subject and institutional repository deposit by place of work

	Subject repository	Institutional repository	Base
University	26%	12%	3517
Other non-commercial research organisation	10%	6%	1236
Commercial research	1%	1%	223

whether researchers in non-commercial organisations who use institutional repositories are referring to deposit in university repositories by co-authors in academia, or whether their own non-university employers run their own repository (See Table 4).

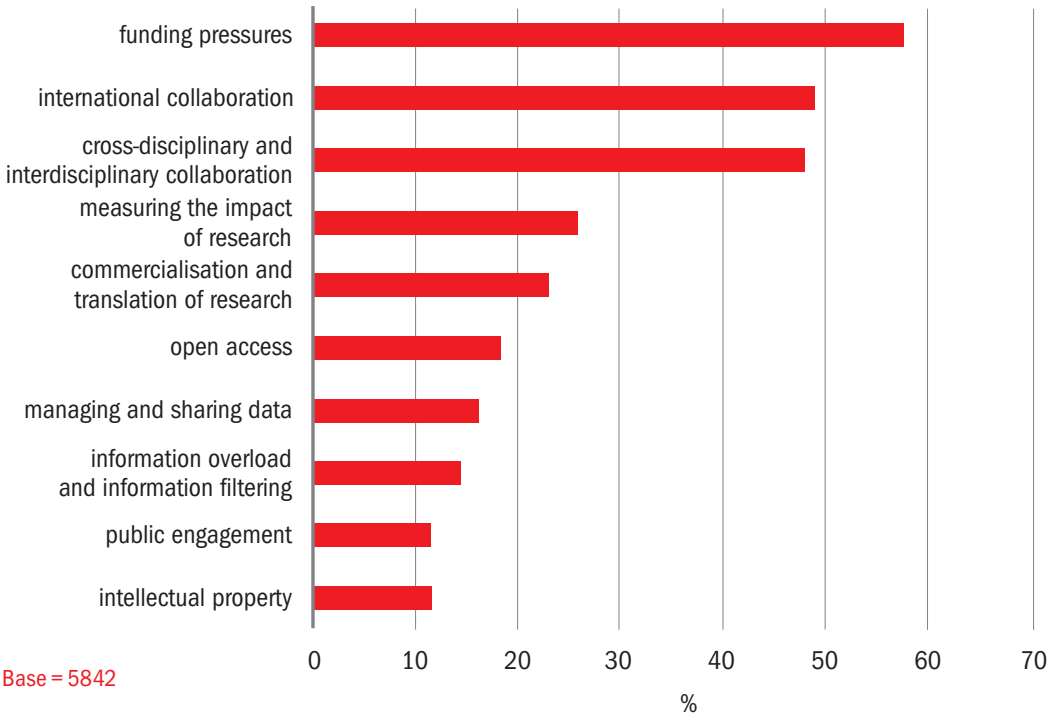
Gold open access is rarely used

62% of respondents said they had never published using Gold open access: only 4% said that they used it frequently. 44% of respondents said they had used Green open access, with 13% using it frequently. A significant minority of respondents (19% for Gold, 25% for Green) did not know whether they had used the respective route to open access, suggesting that it is not something that they routinely think about when publishing articles, or are particularly aware of in their working lives.

Open access isn't a top priority for the future

When asked to select three factors that would drive developments in their main discipline in the next ten years, only 18% of respondents chose open access as one of their three options (See Figure 5).

Figure 5: Ten year priorities for respondents



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Motivations for publishing in specific journals vary by discipline, territory and especially career stage

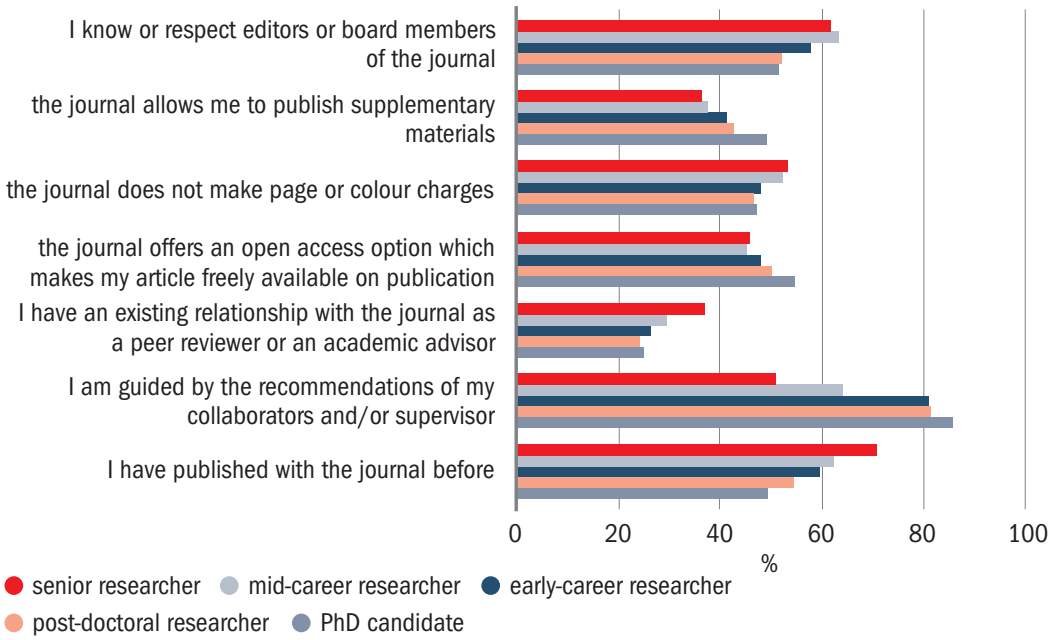
Early- and late-career researchers have different reasons for selecting the journals in which they publish

Some priorities, such as journal quality, impact factor and acceptance time, are consistently important for researchers at all stages of their careers. But others show increasing or declining importance as researchers establish themselves in their work. Although the differences between each career stage are not always particularly large, they become more evident when comparing the most senior researchers with PhD candidates, and the increasing or decreasing importance of an individual factor is remarkably consistent across career stages.

Perhaps unsurprisingly, motivations that relate to a researcher's professional experience become more important over time – knowing or respecting editors or board members of the journal, previous experience of publishing with the journal, and existing relationships with the journal as a peer reviewer or academic advisor are all more important to senior researchers than to PhD students. Conversely, students are much more likely to be guided by the recommendations of their collaborators or supervisors.

Considerations to do with finance become more important for more senior researchers, perhaps because they are the ones with responsibility for project or departmental budgets. Senior researchers place more emphasis on not paying page or colour charges, compared to their more junior colleagues, and are less likely to consider a Gold open access option important or very important – interestingly, there was no difference between groups in relation to the importance placed on the ability to post pre-prints online (See Figure 6).

Figure 6: Reasons for journal choices, by career stage



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2: Motivations for publishing in specific journals vary by discipline, territory and especially career stage

Differences between disciplines and territories are not so pronounced

Although there were differences between disciplines, most prioritised similar considerations when selecting journals in which to publish. For every discipline, journal quality was the number one consideration. Partnership with a learned society and existing relationships with the journal as a peer reviewer or academic advisor were the least important considerations in every discipline.

The consideration which showed most variability was the ability to post pre-prints online. 64% of researchers who considered that most or all of their research falls into astronomy and astrophysics said this was important or very important to their decision to publish with a particular journal. By contrast, only 38% of researchers who considered that most or all of their research falls into chemical physics considered this to be important or very important (See Table 7).

Equally, across different territories researcher priorities remain quite similar, with almost universal agreement that factors relating to journal quality or ability to disseminate to the right audience are important or very important. Guidance from collaborators appears to be particularly important in North America, but otherwise most factors are rated similarly across territories (See Table 8).

Table 7: Importance of posting pre-prints, by discipline

	The journal does not restrict my ability to post pre-prints online	Base
Astronomy and astrophysics	64%	551
High-energy and nuclear physics	58%	440
Mathematics, applied mathematics and mathematical physics	55%	621
General physics	50%	292
Computational science	48%	594
Earth systems and environmental science	47%	273
Measurement science and sensors	45%	474
Plasma physics	44%	309
Interdisciplinary	44%	385
Engineering	43%	888
Applied physics	41%	1147
Atomic, molecular and optical physics	41%	600
Condensed matter and materials science	41%	1241
Medical and biological sciences	40%	602
Chemical physics	38%	388

Respondents see impact factor and journal quality as similar but not interchangeable

In general, respondents rated both these factors as important reasons to choose a journal in which to publish. But they are not seen as exactly the same thing. Overall, 57% of respondents either rated both factors as important or both factors as very important. But 31% of respondents rated one factor as important and the other as very important, showing that they make a distinction between the two options. A further 9% rated one factor as important or very important but the other as unimportant.

Table 8: Reasons for journal choice, by territory

	Europe (inc UK)	North America	Asia	Rest of world
Journal quality	99%	99%	98%	98%
Dissemination	98%	97%	95%	96%
Networks	82%	84%	81%	83%
Collaborators and peers	70%	79%	69%	72%
Open access	66%	66%	62%	66%
Additional services	61%	66%	63%	64%
Base	2190	1060	1140	616

3

Researchers in physics and related disciplines have a very interdisciplinary outlook

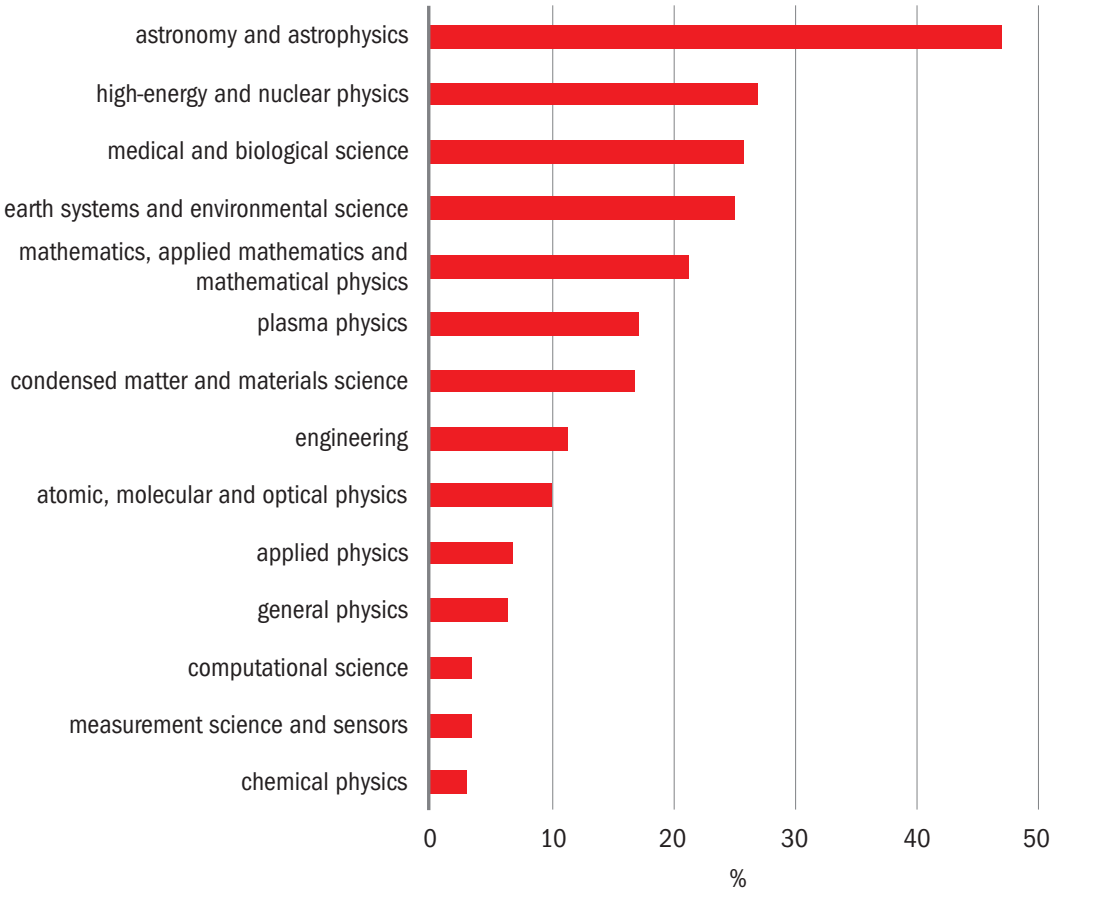
As individuals, 39% of the respondents to our survey undertook all or most of their research in more than one discipline, and 70% undertook at least some of their research in a discipline other than their 'main' one

Researchers who worked in astronomy or astrophysics for all or most of their research were least likely to consider that any of their work fell into other disciplines. Those working in chemical physics, computational science and measurement science and sensors for all or most of their research were most likely to consider that any of their work fell into other disciplines (See Figure 9).

And collaboration is a priority for the future

When asked to select three issues, challenges and opportunities that would drive developments in their discipline in the next ten years, a total of 48% of researchers chose cross-disciplinary and interdisciplinary collaboration as one of their three options: it was in the top three responses overall (See Figure 5).

Figure 9: Respondents, by discipline, who felt that none of their research fell into another discipline



Collaborations are important for researchers in physics and related disciplines

Most respondents collaborate outside their own department

Overall, 71% of respondents had collaborated formally with researchers outside their own department in the last five years, and a further 16% had collaborated informally. On the whole, researchers were least likely to collaborate with other departments in their own institution, and most likely to collaborate with other institutions in their own country.

Responses varied by territory and career stage, particularly for collaborations outside the respondent's own country. Respondents based in Europe were particularly likely to say all or most of their work involved collaboration with researchers in other countries, while international collaboration is much less common for PhD candidates than respondents at any other career stage. These conclusions are drawn from respondents who said that 'all' or 'most' of their work involved collaboration (See Tables 10, 11 and 12).

Table 10: Collaboration types, of respondents who collaborated outside their own department

	Amount of research with collaborations outside department			
	All	Most	Some	None
Other departments within my own institution	4%	17%	44%	18%
Other institutions in my own country	6%	21%	51%	9%
Other institutions in a different country	5%	22%	50%	11%

Base = 4218

Table 11: Collaboration types, of respondents where all or most of their work involved collaboration, by country

	Europe (inc UK)	North America	Asia	Rest of world
Other departments within my own institution	20%	22%	23%	19%
Other institutions in my own country	25%	30%	28%	24%
Other institutions in a different country	36%	20%	18%	26%
Base	1951	935	824	508

Table 12: Collaboration types, of respondents where all or most of their work involved collaboration, by career stage

	PhD candidate	Post-doctoral researcher	Early-career researcher	Mid-career researcher	Senior researcher
Other departments within my own institution	23%	21%	21%	19%	20%
Other institutions in my own country	26%	27%	29%	28%	24%
Other institutions in a different country	18%	30%	29%	29%	34%
Base	862	817	603	726	933

4: Collaborations are important for researchers in physics and related disciplines

Varied reasons

Respondents collaborate for a number of reasons. When engaging in collaborations outside their own department, the most important motivations are either to do with what is normal or widely accepted within the discipline, or with acquiring skills or specialist subject knowledge that is not available within the department for a particular project (See Figure 13).

There was some variation between disciplines, reflecting the different ways that researchers in those disciplines carry out their work. For example, respondents who said most or all of their work was in mathematical physics were less likely than those in other disciplines to collaborate in order to share experimental equipment – probably because they rarely use experimental equipment – while respondents doing all or most of their work in astronomy and astrophysics were particularly likely to collaborate because they need to share data. This group of researchers, along with those undertaking all or most of their research in high-energy physics or computational science, were also more likely to collaborate in order to acquire skills for a particular project.

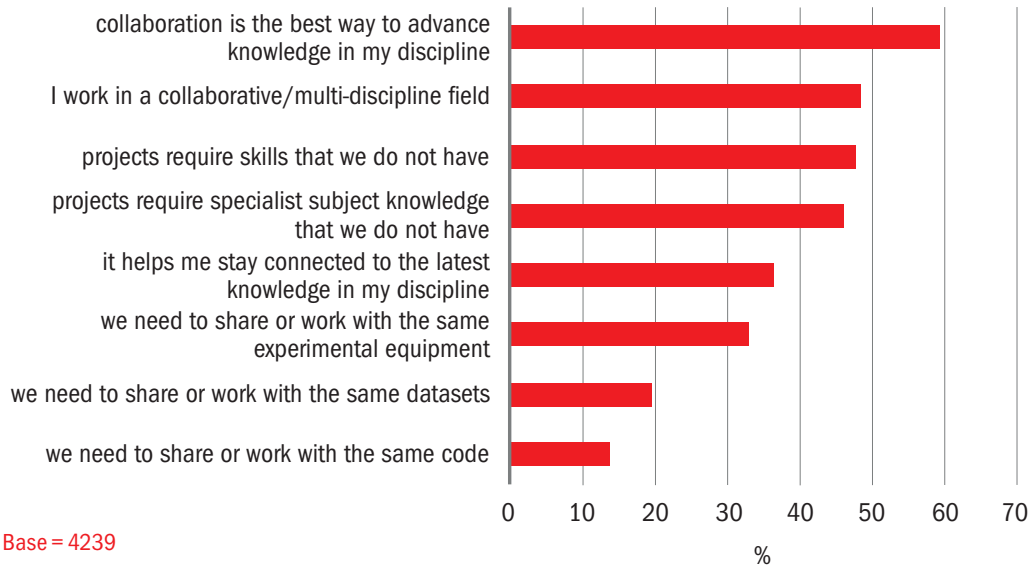
Communication within collaborations is quite traditional

The most popular ways of communicating within a collaboration are one-to-one emails and face-to-face meetings, at 87% and 71% of respondents to this question respectively. However, new technologies are making inroads – phone calls are only slightly more popular than online conference tools such as Skype, and cloud-based file storage systems such as Dropbox appear to have overtaken shared folders on a computer or server as a way of sharing information. Newer technologies such as social media or wikis remain very marginal ways of communicating (See Figure 14).

Researchers are generous in sharing their research outputs, within and sometimes outside collaborations

Researchers may create a number of different outputs within their collaborations. Most respondents to our survey expressed willingness to share their outputs with collaborators, and in some cases with a wider group of researchers as well. Overall, very few researchers felt they would not share the outputs they produce, although there was

Figure 13: Reasons to collaborate, of respondents who had collaborated outside their own department

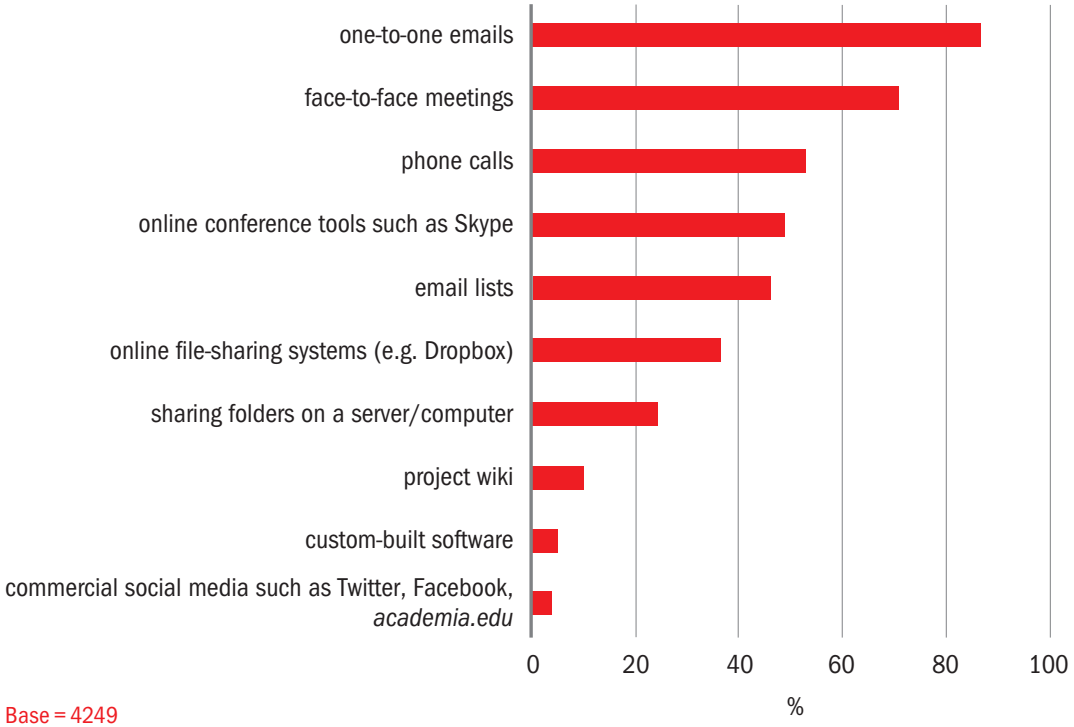


Base = 4239

more concern around sharing software and code and, to a lesser extent, databases than other types of output (See Table 15).

There are some apparent contradictions in the responses to this question, with groups of respondents ticking one of the boxes to say they would share their outputs with 'anyone', but not ticking the box to say they would share it with their own collaborators. This is surprising, because we would expect researchers to be more comfortable sharing outputs with their collaborators on a project than with the world in general. It may be that respondents simply selected the highest level of openness that they would permit for each type of output, considering collaborators to be implicit within the 'anyone' categories. If true, this would slightly raise the proportion of respondents who would be comfortable sharing outputs with their collaborators.

Figure 14: Communication methods within a formal collaboration



Base = 4249

Table 15: Willingness to share research outputs

	My collaborators	Anyone who requests it directly from me	Anyone, via a public website or repository	Wouldn't share this output	Base (respondents who create this output)
Data from simulations	76%	39%	9%	3%	4197
Data from lab experiments	76%	34%	8%	4%	3850
Databases	63%	35%	16%	7%	3007
Images	64%	48%	17%	3%	4399
Code	64%	36%	11%	12%	3595
Software	63%	37%	13%	9%	3301
Hardware	69%	26%	5%	11%	2418

5

Data is a common output but not necessarily prioritised as a formal output by researchers

The types of data produced varied by discipline

Respondents undertaking all or most of their research in computational science were particularly likely to produce data from simulations, while those working in astronomy or mathematics were less likely to produce data from lab experiments. Again, this reflects the way that respondents in different disciplines are able to undertake their research: it is difficult to imagine how you might put the universe in a laboratory! (See Table 16)

Respondents are happy to share data, but do not see a particular need to publish it alongside journal articles

Of the respondents who create data, the vast majority were happy to share it with collaborators. Many would also share it with another researcher who approached them directly, and some were prepared to share it via public websites or repositories (See Table 17).

But the majority did not consider being able to publish data or other supplementary materials an important factor in their choice of journal for research publication. This suggests that, while most are happy to

Table 16: Respondents who produce data outputs, by discipline

	Data from simulations	Data from lab experiments	Databases	Base
Applied physics	78%	83%	58%	1344
Atomic, molecular and optical physics	82%	70%	52%	695
Astronomy and astrophysics	72%	44%	65%	627
Chemical physics	76%	77%	53%	447
Computational science	89%	58%	63%	700
Condensed matter and materials science	72%	76%	48%	1385
Earth systems and environmental science	75%	69%	71%	337
Engineering	79%	83%	60%	1120
General physics	75%	70%	59%	393
High-energy and nuclear physics	75%	60%	55%	524
Mathematics, applied mathematics and mathematical physics	70%	40%	45%	730
Measurement science and sensors	80%	90%	64%	583
Medical and biological sciences	72%	82%	63%	734
Plasma physics	75%	72%	58%	370

share their data, they are not particularly concerned about publishing it formally at present (See Table 18).

Most respondents don't consider data a priority for the future, though astronomers and astrophysicists find it more important than most

When asked to select three factors that would drive developments in their main discipline in the next ten years, only 16% of respondents chose managing and sharing data as one of their three options. But among those who considered most or all of their research to fall under astronomy and astrophysics, 37% of respondents selected managing and sharing data (See Figure 19).

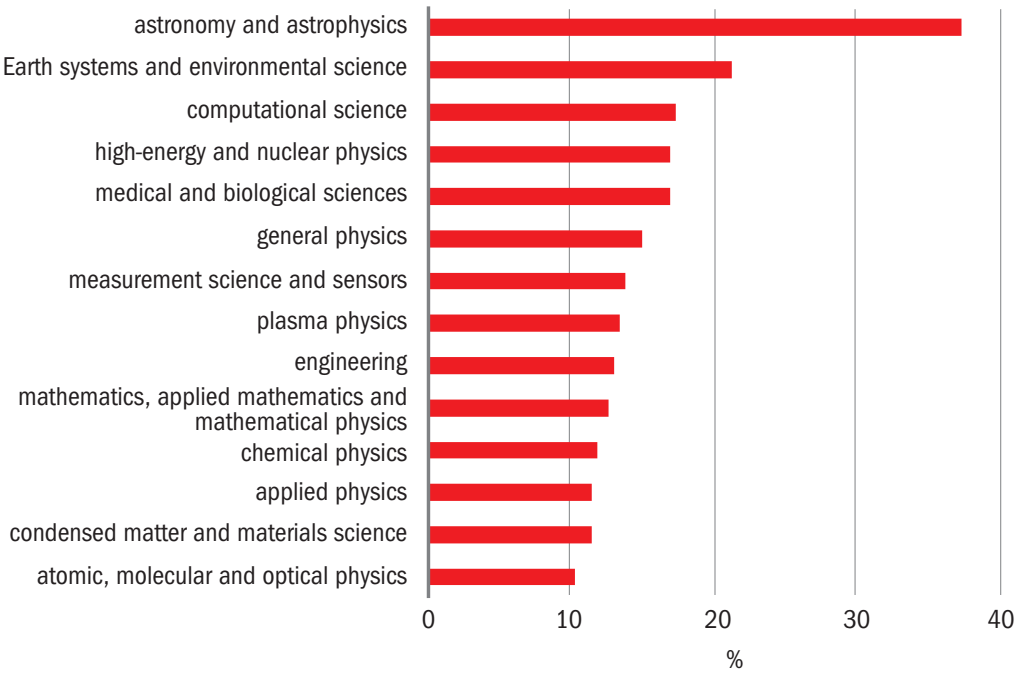
Table 17: Respondents who produce data, by who that data is commonly shared with

	My collaborators	Anyone who requests it directly from me	Anyone, via a public website or repository	Wouldn't share this output	Base
Data from simulations	76%	39%	9%	3%	4197
Data from lab experiments	76%	34%	8%	4%	3850
Databases	63%	35%	16%	7%	3007

Table 18: Importance of supplementary materials publication in journal choice, by type of data created

	Very important	Important	Unimportant	Base
Data from simulations	8%	37%	54%	3390
Data from lab experiments	10%	39%	52%	3037
Databases	11%	41%	49%	2371

Figure 19: Data sharing as a future strategic driver, by discipline



6

Researchers use a range of traditional and non-traditional methods to share and find information

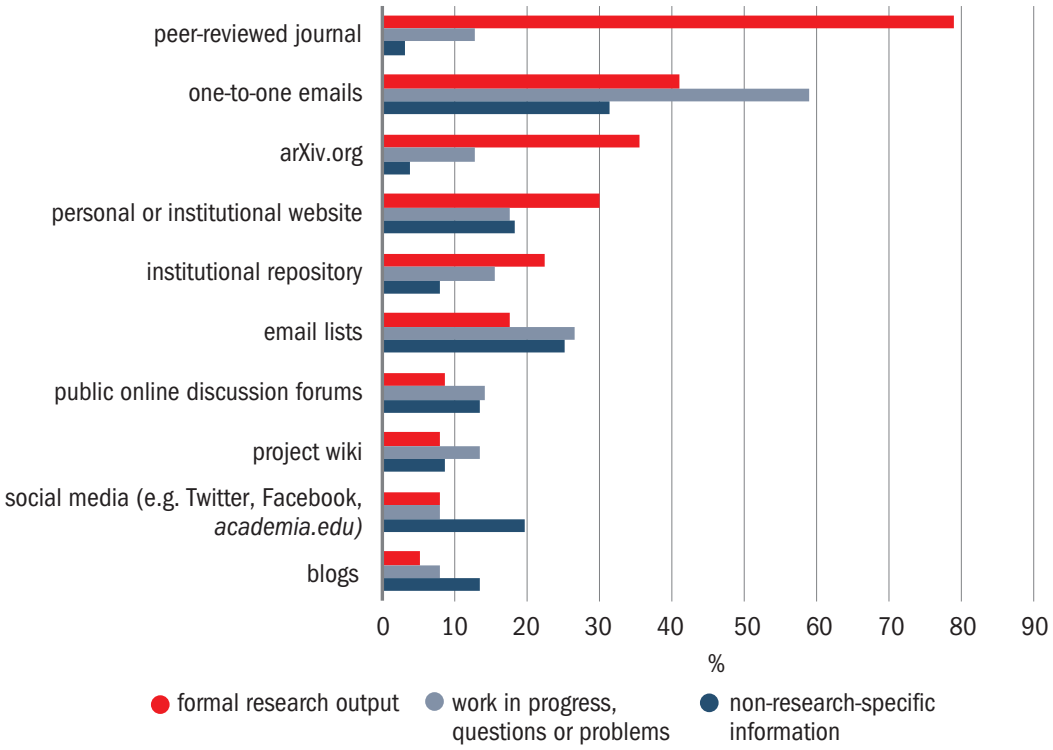
Researchers use a range of platforms to share different types of information

Peer-reviewed journals remain the gold standard for sharing formal research outputs, and 79% of respondents commonly share outputs such as findings, data or code through these mechanisms. No other platform is as popular for sharing formal outputs; one-to-one emails were selected by 41% of respondents and personal or institutional websites by 30% of respondents, but it seems likely that these were chosen as ways to raise awareness of formal findings that were published in journals, rather than places for actually publishing them.

One-to-one emails were, by some distance, the most popular way to share work in progress, questions or problems, with 59% of respondents selecting this option. They were also the most popular way of sharing non-research-specific information, with 31% of respondents selecting this option. Social media were not widely used for formal findings or work in progress, but were relatively popular for non-research-specific information, with 20% of researchers selecting this option.

Overall, respondents were much less likely to share non-research-specific information than information which relates to their work (See Figure 20).

Figure 20: Types of information respondents expect to share on different platforms



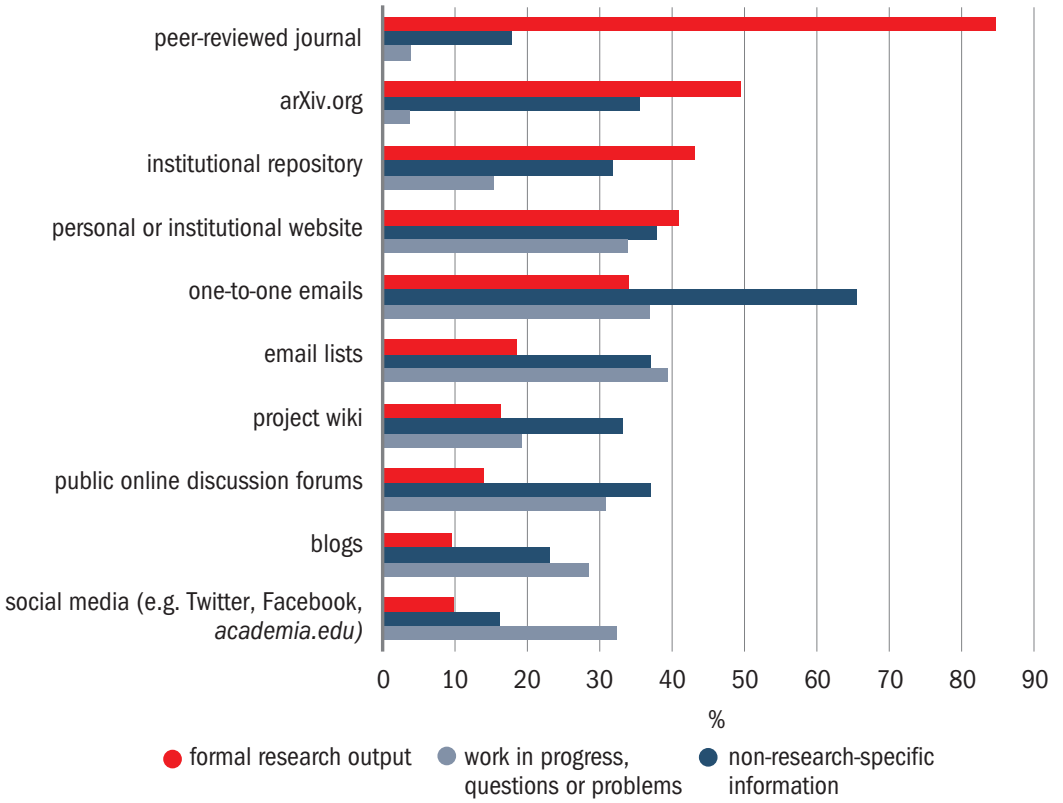
Base = 5939

They also expect to find information on a range of platforms

Again, peer-reviewed journals dominate as a place for finding formal research outputs; 85% of respondents selected this option. arXiv was, relatively speaking, more important as a place to find research outputs (49%) than as a place to share them (36%).

Websites and social media were also much more important as a place to find information than as a place to share it, suggesting that respondents are likely to be users of social media more than they are contributors to it (See Figure 21).

Figure 21: Types of information respondents expect to find on various platforms



Base = 5939

7

Researchers build personal libraries of articles

Most respondents stored the last article they read, and used electronic means to do so

Only 8% of respondents did not store the last article they read, and only 5% stored it using only paper (although 29% of respondents stored a paper copy of the last article they read – the majority choosing to store an electronic version as well). 87% of respondents stored the last article they read using electronic devices or services. The most popular method, by some distance, was storage on a computer or laptop.

Of those respondents who did store articles, 46% stored articles using more than one method, suggesting that respondents are cautious and use several storage methods to ensure their articles are secure and available to them in the long term (See Figure 22).

Storage methods vary somewhat by territory and career stage

Respondents based in the US were more likely than those in any other territory not to have stored the last article they read. When they did store articles, they were again less likely to use a computer or laptop than respondents based in any other territory.

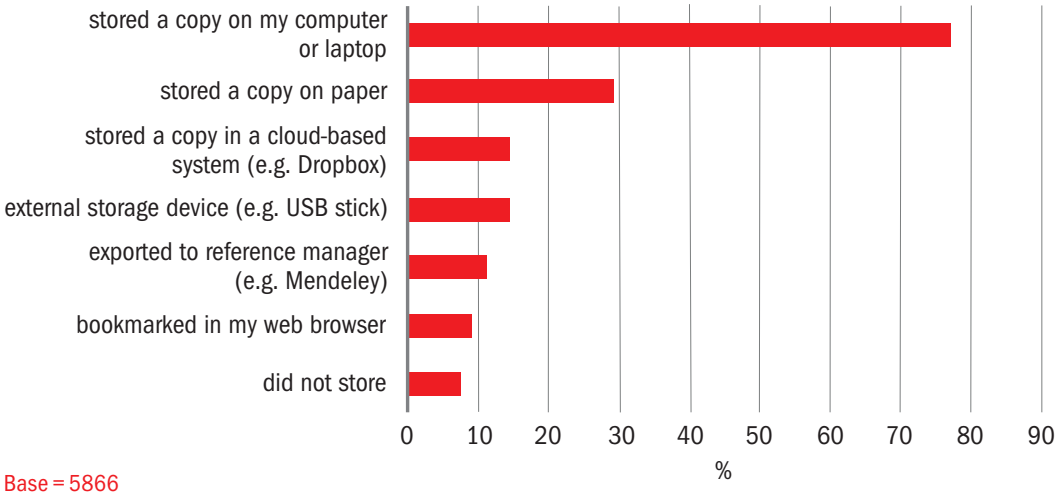
Respondents from Asia and the rest of the world were more likely than those in Europe or the US to use external storage such as USB sticks to store the last article that they read (See Table 23).

In terms of career stage, PhD candidates were more likely than any other group to use web-based storage options such as browser bookmarks, cloud-based storage like Dropbox or reference managers such as Mendeley. The differences are not huge, but in each case PhD candidates are the biggest users (See Table 24).

Respondents like to read articles in print, even if they store them electronically

Thinking about the last article that they read, most respondents read it online in a web browser, closely followed by printing their own copy and reading a previously downloaded copy. Of the respondents who stored the last article they read electronically, 56% read a print copy – either the original journal article, a photocopy of the article, or a self-printed

Figure 22: Storage methods for last article read



Base = 5866

copy of an electronic version of the article. This suggests that although researchers prefer to use electronic means to build their libraries, they still prefer print as a way to read such content (See Figure 25).

It is worth noting that print articles in original print journals are still more popular than mobile devices, e-readers and tablets as a way of reading articles.

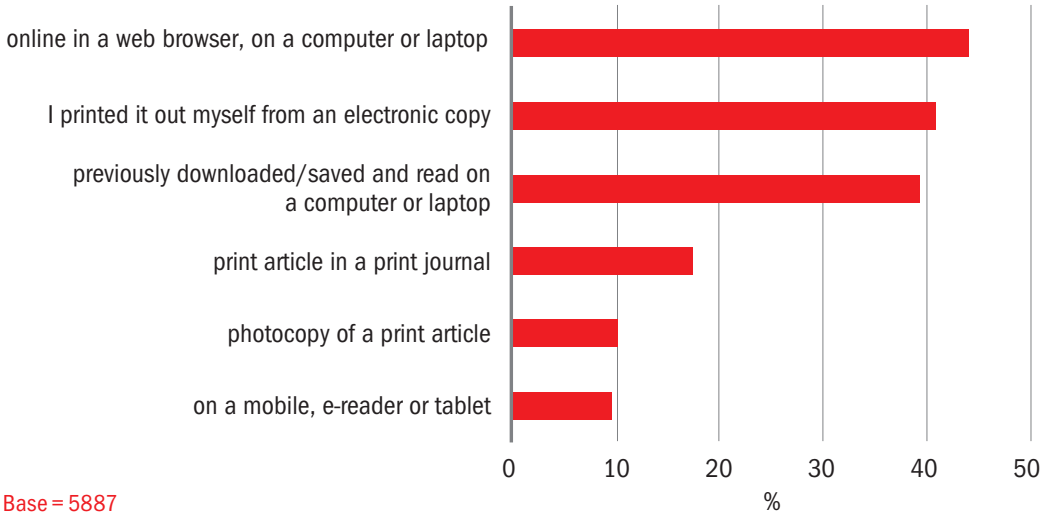
Table 23: Storage methods for last article read, by territory

	Europe (inc UK)	North America	Asia	Rest of world
Did not store	7%	13%	5%	6%
Bookmarked in my web browser	7%	9%	13%	8%
Stored a copy on my computer or laptop	77%	69%	83%	81%
Stored a copy in a cloud-based system (e.g. Dropbox)	14%	17%	13%	15%
Exported to a reference manager (e.g. Mendeley)	14%	12%	8%	9%
External storage device (e.g. USB stick)	12%	9%	21%	19%
On paper	32%	27%	27%	30%
Base	2494	1249	1358	765

Table 24: Storage methods for last article read, by career stage

	PhD candidate	Post-doctoral researcher	Early-career researcher	Mid-career researcher	Senior researcher
Did not store	6%	8%	8%	8%	6%
Bookmarked in my web browser	10%	7%	10%	7%	8%
Stored a copy on my computer or laptop	76%	77%	76%	80%	81%
Stored a copy in a cloud-based system (e.g. Dropbox)	20%	13%	17%	12%	11%
Exported to a reference manager (e.g. Mendeley)	18%	15%	11%	10%	5%
External storage device (e.g. USB stick)	15%	11%	12%	13%	16%
On paper	31%	28%	28%	26%	31%
Base	1383	1016	837	880	1143

Figure 25: Reading methods for last article read



Base = 5887

8

Physical science researchers read books, and prefer print

Books are important in all disciplines, territories and career stages

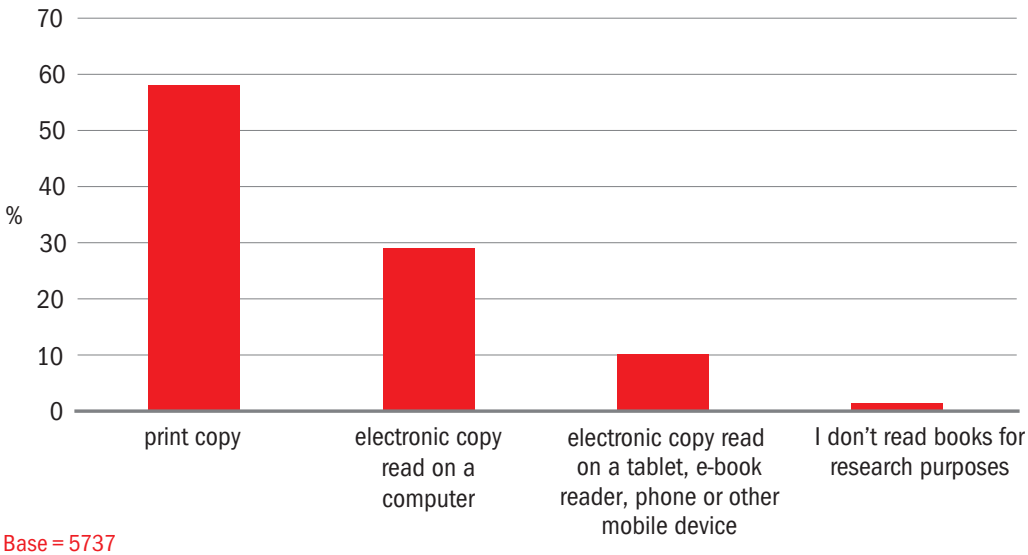
Only 2% of respondents said they did not read books to support their research activity. 58% prefer to read the books they use in print, while 40% preferred an electronic method, with the majority preferring a computer to a tablet, e-book reader or other mobile device (See Figure 26).

The importance of books, and researchers' preference for print, hardly varied at all by discipline or career stage. There were, however, some subtle geographic differences. Respondents from Asia and the rest of the world had a less marked preference for books compared to their colleagues in Europe and the US, and US-based respondents were slightly more likely to say that they did not read books for research purposes at all (See Figure 27).

Unsurprisingly, there was some correlation between respondents' preferred book-reading format and the format in which they had read the last article used, although the correlation was not perfect. Of respondents who had read the last article in print only, 81% preferred print books. Of respondents who had read the last article in electronic format only, 56% preferred books in some electronic format (with reading on a computer more popular than reading on a mobile device). Of those who read their last article in both print and electronic format, 60% preferred print books and 39% preferred an electronic format.

There are two possible conclusions here. First, that respondents have different preferences for reading books and articles. Second, that respondents are pragmatic and, even if they prefer to read in one format, will read in another if that is more convenient at the time (See Figure 28).

Figure 26: Preferred method of reading books for research purposes



Base = 5737

Figure 27: Preferred method of reading books, by territory

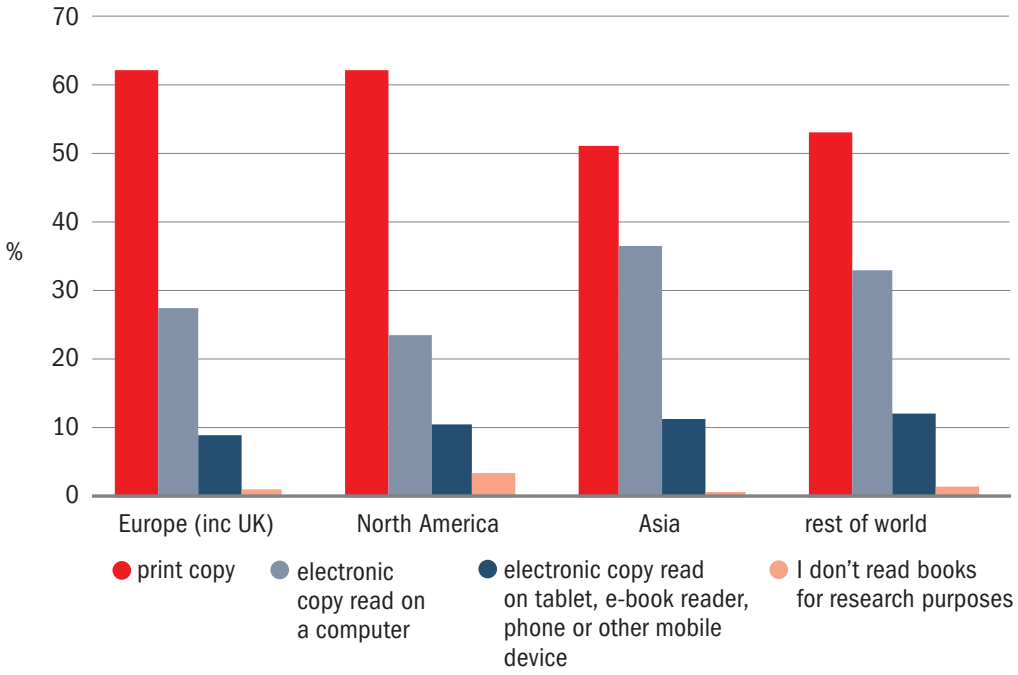
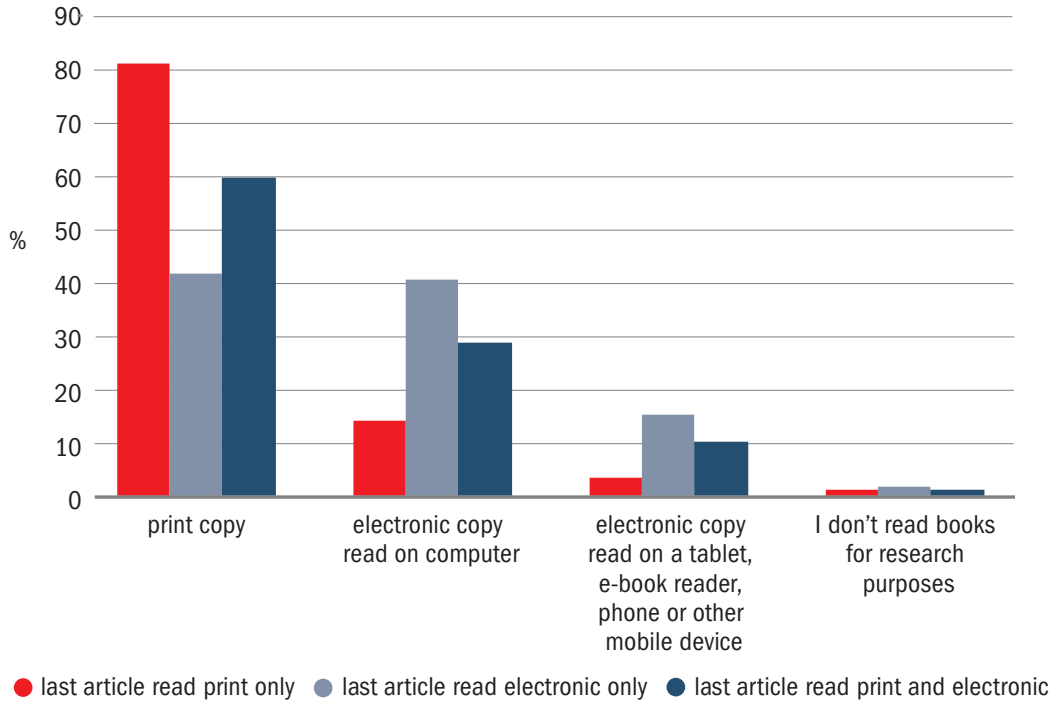


Figure 28: Method of reading last article read, by preferred method of reading books



9

Libraries are not a crucial part of respondents' working lives

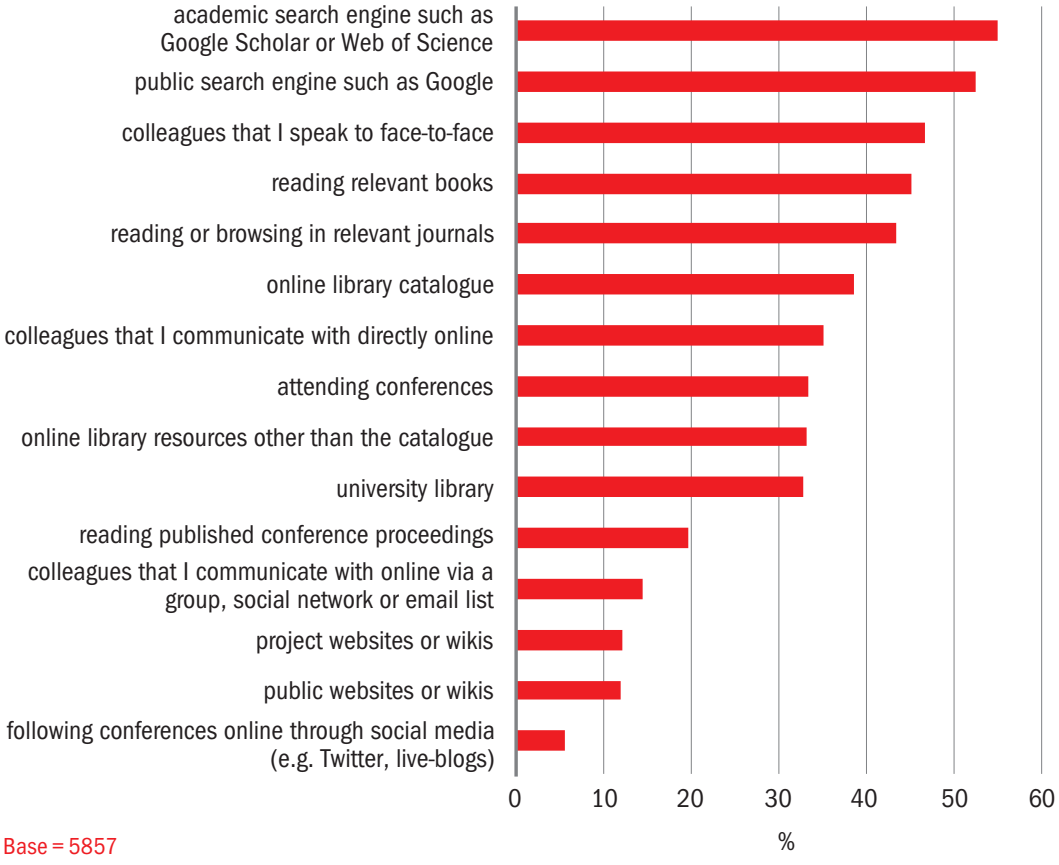
Library tools are more important in unfamiliar areas, but overall not essential ways of finding information

Only 13% of respondents considered keyword searches in the library catalogue 'essential' to find new, relevant research in their core research areas. When seeking information in a new or unfamiliar field, respondents were more likely to use library tools, with 33% rating the university library 'essential', 39% rating the online library catalogue 'essential', and 33% rating online library resources other than the catalogue 'essential' (See Figure 29).

There are some interesting variations by career stage. PhD students and early-career researchers – but not post-doctoral researchers – are more likely than other groups to consider all three library services 'essential' for finding information in new areas. This was also evident (although to a lesser extent) in the importance placed on keyword searches in the catalogue for finding material in core research areas (See Table 30).

Territory, too, shows interesting variation. Respondents in the US and the rest of the world categories were most likely to find the library and its services essential when seeking information in a new subject area. Respondents from Asia seemed to find the library essential, but its online resources less so, and respondents from Europe were the least likely (by some distance) to consider

Figure 29: 'Essential' tools for seeking information in a new or unfamiliar field



Base = 5857

the library and its services essential when seeking information in new areas. Again, when seeking information in a core research area, the library catalogue was considered 'essential' by fewer European respondents than those in any other group. Differences between disciplines were very small (See Table 31).

Librarians are not seen as an important source of wider information

We asked respondents which of certain defined groups were most important to them as sources of information or guidance on specific issues. In most cases, peers were seen as the most important source of information, and the library was not rated as important by researchers in most areas. A relatively large group of respondents considered the library important for support on information search and management, but even there more respondents considered their peers or their employing institution to be important (See Table 32).

Because the overall numbers of respondents are so small in most cases, it is difficult to observe any differences by career stage or territory. However, respondents from Asia were particularly unlikely to find librarians important for information search and management, as were post-doctoral researchers.

Table 30: 'Essential' tools for seeking information in a new or unfamiliar field, by career stage

	PhD candidate	Post-doctoral researcher	Early-career researcher	Mid-career researcher	Senior researcher
University library	39%	27%	36%	28%	30%
Online library catalogue	43%	35%	42%	37%	35%
Online library resources other than the catalogue	38%	29%	36%	32%	27%
Base	1383	1016	835	875	1145

Table 31: 'Essential' tools for seeking information in a new or unfamiliar field, by territory

	Europe (inc UK)	North America	Asia	Rest of world
University library	26%	37%	39%	38%
Online library catalogue	34%	44%	39%	43%
Online library resources other than the catalogue	29%	38%	34%	39%
Base	2491	1243	1357	750

Table 32: Most important group for information on specific topics

	Peers	Institution/ employer	Funders	Specialist librarians	None of these are important for this issue
Personnel and project management	34%	43%	5%	1%	9%
Funding and grant applications	20%	32%	35%	1%	5%
Giving talks or conference presentations	55%	23%	5%	1%	7%
Choosing where to publish	58%	18%	3%	3%	11%
Finding jobs	36%	27%	5%	2%	19%
Patents and intellectual property	12%	44%	6%	7%	18%
Information search and management	28%	22%	3%	18%	15%
Social media and online self-promotion	23%	14%	3%	3%	40%
Open access	28%	20%	6%	10%	23%

Base = 5665

Conclusions

Researchers in the physical sciences and related disciplines are highly interdisciplinary and collaborative

70% of respondents classified at least some of the research that they do as falling under more than one discipline, and 71% of respondents had collaborated formally with researchers outside their own department in the last five years, with a further 16% collaborating informally. Many researchers also see this as one of the top three priorities driving developments in their discipline over the next ten years. The picture is one of flexible researchers, collaborating and moving outside formally defined boundaries in order to meet the needs of a specific project, or to follow the investigation of a research question as far as they can, even when it takes them beyond the boundaries of their own expertise.

Respondents are not particularly concerned about open access or data publishing, even though these issues are important to policymakers

Open access is important to 65% of researchers when they think about where to publish an article, but once their articles are published relatively few are making use of repositories. Similarly, although data is a fairly common output for researchers, most share it through informal networks and don't prioritise organisations which offer formal publication of data outputs. Discipline plays a very important role in both these issues, with pockets of intense interest in subject areas where open access or data publishing are common. But it does not seem to be a widespread preoccupation.

Respondents were surprisingly traditional in many of their information behaviours

Journal articles and personal emails remain the most important ways of sharing information emerging from research projects, and (along with personal or institutional websites) are the primary places that researchers expect to find information. There is more use of social media when it comes to finding and sharing non-research-specific information, but for research itself traditional platforms are crucial. Similarly, a large proportion of researchers continue to read journal articles in print, even though in many cases they are printing their own copy of an electronic version, and most prefer to read books in print. That said, most chose to store the articles they read in an electronic format.

Personal connections and collections are very important to researchers, and they make less use of targeted services provided by third parties

The large proportion of researchers who stored a copy of the last article they read on their laptop, paper, generic cloud-based storage system or external storage device shows that they are keen to build collections. But few make use of services such as Mendeley which are designed specifically for this purpose (although PhD candidates are slightly more likely to use these services, suggesting that there may be a generational change to come). In a similar vein, researchers rely on independent search via generic search engines and recommendations from peers to find new information, rather than going to the library catalogue. For most topics where they might want support, researchers go to their peers rather than their employer, funder or librarians.

The qualitative and quantitative studies have shown similar findings

Many of the findings from the previous qualitative case studies of information practices in the physical sciences are echoed in this quantitative survey. There are some new areas of interest – the importance of building personal libraries; the continued importance of print, particularly in relation to books – but in general the survey results echo the overall conclusions from the case studies. The message from both studies that researcher behaviour in the physical sciences needs to be understood at the sub-disciplinary level is particularly clear and important.

Recommendations

Recognise and understand diverse researcher practices

- The survey suggests that researchers create their own working practices to match the needs and norms within their discipline. Anybody seeking to work with researchers needs to understand these practices, and where they have come from, if they want to develop services that will be used by researchers.
- Most researchers feel that their work falls into more than one discipline. Their preferences and behaviours are likely to be shaped by coming into contact with people from different backgrounds and training, especially when working in newer interdisciplinary areas. Anybody working with researchers needs to understand that even within a discipline or sub-discipline different preferences and working methods may prevail, and services need to be flexible enough to accommodate this.
- The first study found that physical science researchers are adept at creating their own tools and systems to conduct their research. This study suggests that they are similarly adept at adapting existing tools and services to meet their information needs. When creating their own electronic libraries, they seem to prefer generic and broadly specified tools to those which are targeted specifically at researchers and, in some respects, they are quite old-fashioned. Anybody working with researchers should bear this in mind when considering the services that they develop.

Research councils and funders

- Open access and data sharing, although major priorities for research funders, are not yet significant priorities for researchers themselves. More work could be done to understand why this is the case – whether the messages about the importance of open access and good data management and sharing are not framed in a way that is meaningful to researchers, or whether other barriers (such as lack of time or funding) mean that researchers cannot do these things routinely.
- Funding pressures are the number one priority for respondents to the survey: most think that this will be one of the top three factors to drive developments in their main discipline in the next ten years. Funders should continue to engage with researchers to understand how best to minimise the negative effects of funding pressures on research activity.

Publishers

- Journal quality remains the first priority for most researchers when selecting their publication outlet, and they do not believe that impact factor is the only way to assess journal quality. Publishers could do more work to understand exactly what constitutes a 'high quality' journal in different disciplines, in order to ensure their offers are meeting researcher needs.
- Most researchers are working across or between disciplines, and in a number of collaborations. Publishers need to provide journals that make it easy for researchers to share the content that they create, and find the content that they need. To do this, they need to stay on top of developments and trends in the research community – to understand emerging research areas and ensure that they can respond rapidly with platforms that allow researchers to share findings in a way that suits the research itself.
- Researchers like to build personal libraries of articles, storing them on their own computers, hard drives or cloud-based services. Publishers need to make it easy for researchers to do this by offering flexible formats, and making it easy for researchers to download and store content wherever they want to. They may also want to consider how these personal libraries

might affect article usage statistics or repeat views of content on the publisher's own website.

Libraries, institutions and repositories

- Institutional repositories are not widely used by respondents to this survey, even in disciplines where sharing content through subject-based repositories is relatively common. Depending on the institution's priorities, either researchers need support, encouragement or sanctions to promote use of the institutional repository, or the repository needs to scrape subject-based repositories to ensure content deposited there is displayed in the institutional collection.
- Researchers do not see libraries as particularly important. Even though most of them access journal articles electronically, in many cases using library-provided subscriptions, they do not consider the library or librarians an important resource for search, discovery or wider information. Most respondents rely heavily on their peers for advice on what to read, where to publish and even information search and management – librarians need to work to be seen as part of this group, and not as an external service with limited knowledge of an individual's research area or practices. In particular, librarians might be able to help researchers organise the personal electronic libraries that many of them are building up.
- Career stage is a more important factor than discipline or territory when researchers are making a decision about where to publish. More established researchers have wider networks to draw on that will help them to make an informed decision about where to publish – younger colleagues rely more upon their immediate collaborators or supervisors. Early-career researchers may benefit from more targeted support on how to select the most appropriate outlet for their journal articles, particularly as they seek to further their careers.

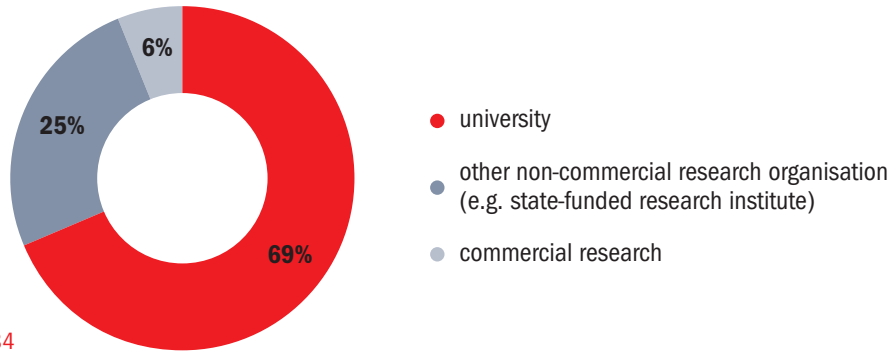
Learned societies and professional bodies

- When researchers have a question or concern about their research or their wider career, most of them turn first to their peers. If learned societies and professional bodies wish to support researchers' professional development, they should consider providing targeted support to institutions or, even better, a network of individual researchers, with expertise on specific issues.

Appendix

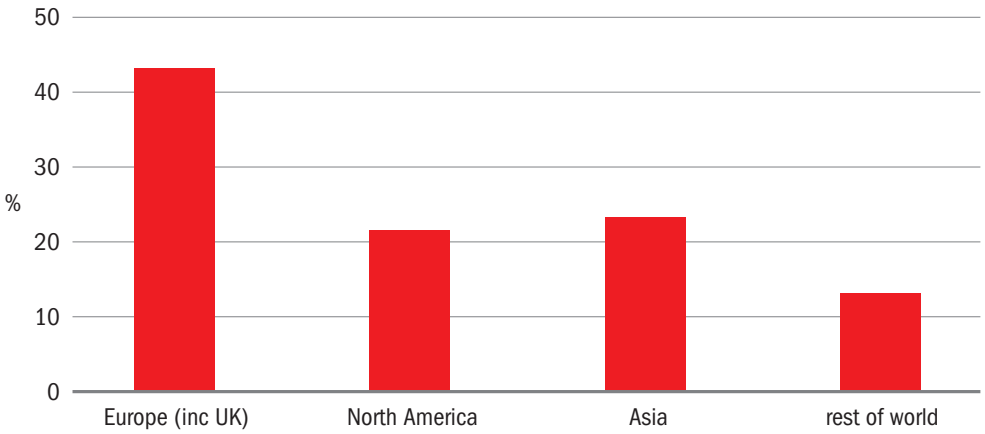
Breakdown of survey respondents by territory, employer, career stage and subdiscipline

Figure 33: What kind of organisation do you work for?



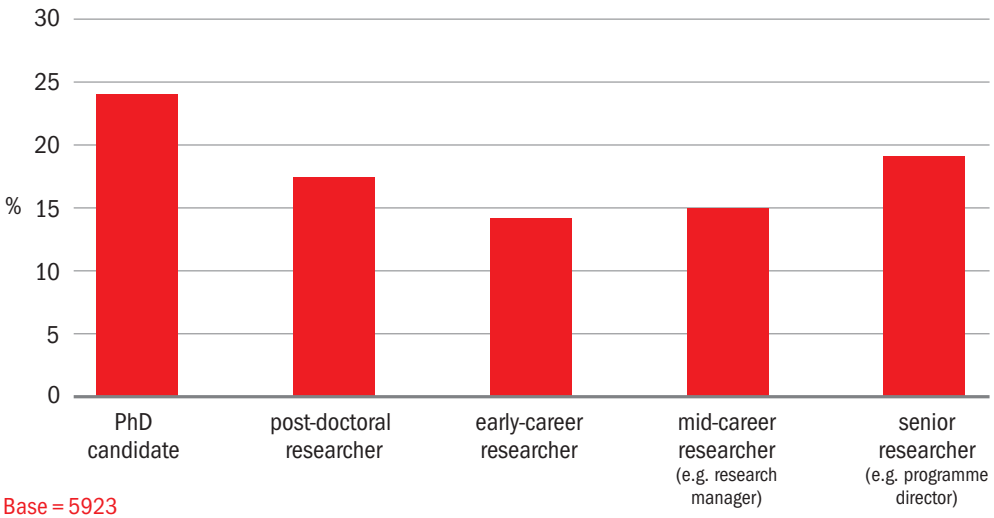
Base = 5884

Figure 34: Where do you do most of your work?



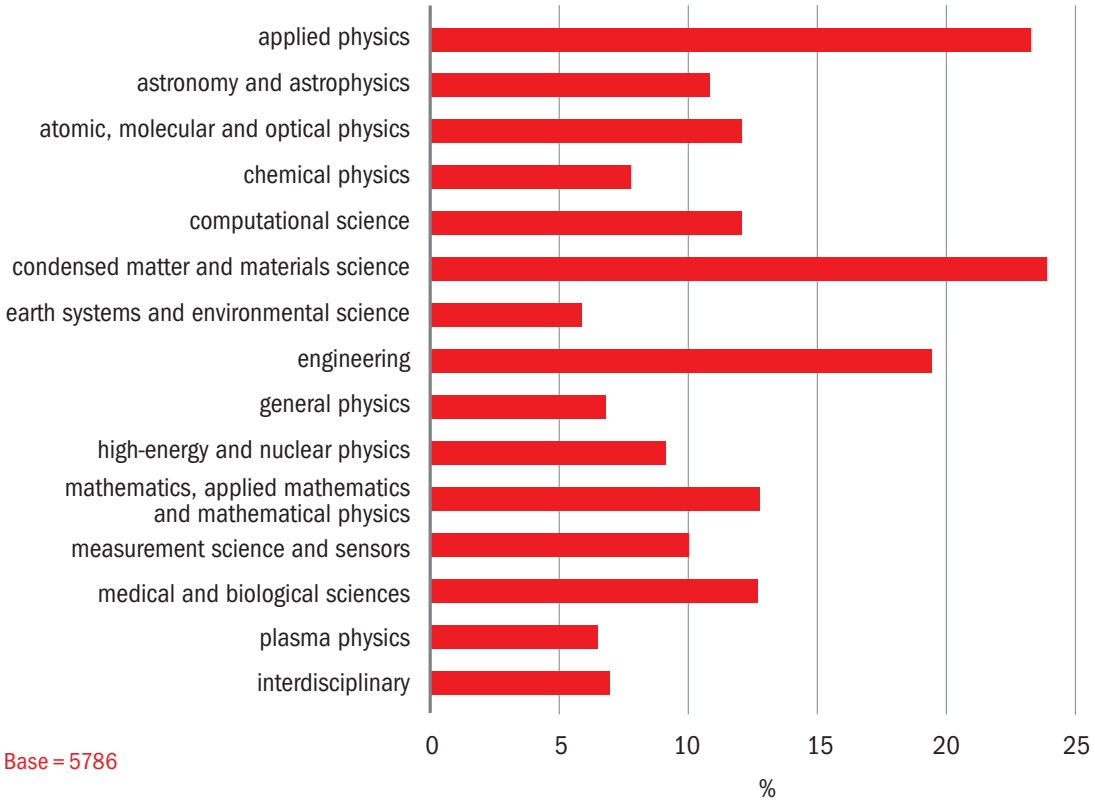
Base = 5915

Table 35: Which of the following categories best describes your career stage?



Base = 5923

Table 36: All or most of my research is in the following area



Base = 5786

Further reading

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Acknowledgements
This report was the result of a collaborative effort between the Research Information Network (RIN) and IOP Publishing. The lead author of the report is Ellen Collins, a senior research consultant at RIN. The IOP Publishing project team comprised Joe McEntee, Margaret Harris, Leanne Mullen and Mark Purvis.

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