Chapter 9

Other essential research skills

People from different backgrounds approach a subject in different ways and ask different questions.

—Jocelyn Bell Burnell

9.1 Introduction

There is much more to science, and being a scientist, than writing grant proposals, performing experiments, and presenting your findings. A successful research scientist also develops and uses a range of more general skills. Some of these skills are implicitly developed through undergraduate and postgraduate learning and experience, while others are honed lifelong through continuous practice and occasional formalised training. These often invisible but highly important skills include aspects such as time management, networking, academic integrity, and self-reflection. The career pathway of the modern scientist often involves multi-tasking and dynamic adaptation to workload; this is often a source of stress and anxiety, and the best response to this can be a very personal experience. Here, we offer some top tips on how to manage your professional life based on our own experience and those of others. This chapter is by no means exhaustive but we will outline some of these important skills, and discuss why they are important for you to consider in both your current and future career.

The Royal Society's 2010 policy document 'The scientific century: securing our future prosperity' [1] concluded that the majority of people who undertake a PhD will end up pursuing a career outside of academia. It is therefore necessary to consider and develop skills that will help you to succeed in these transferable environments. Pursuing a career outside of academia does not mean that you have 'failed' or 'turned your back on science'. Rather, there are many careers outside of academia that are still connected to science, and which may well be better paid, or have more favourable working conditions suited to your preferred professional lifestyle. In our experience, it is very common that postgraduates and early career

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researchers become blinkered to the opportunities that exist beyond academia. They may often become laser-focussed on their niche research field, and forget that the transferable skills and qualifications gained earlier in their career are still as valued as ever by alternative employers and industry, and that such training opens many doors.

Being a scientist means that you have a number of key transferable skills that make you a genuine asset as a potential employee, or as a self-employed practitioner. However, you must learn how to recognise and advertise these skills effectively, taking advantage of any opportunities to develop them further. This can include keeping track of any events, activities, and training programmes that you participate in, as these will serve as useful exemplars when regularly updating your CV, conducting personal development reviews, or making a case for promotion, for example. Digital tools such as Vitae's 'Research Development Framework' planner [2] offer a convenient way of storing all of this information in one place, and also for identifying areas in which further skills development may be required.

In addition to developing skills that make us more effective scientists, we should also consider how we can become more ethical and apply high standards of academic rigour and integrity. We are part of a long line of practitioners, and as such we have an obligation to respect our scientific heritage, recognise and correct our mistakes, and create an inclusive environment for others. This chapter also contains advice for how we might best achieve this.

9.2 Time management

Procrastination and prioritisation are some of the biggest hindrances that we face as scientists, whether via the obvious and immediate temptations of social media, or the subtler distractions of spending too much time pursuing a project that may be of no long-term benefit. However, there are a number of basic actions that you can take in order to maximise your time efficiently:

1. **Know *when* you work best.** Every person is unique, and research has shown that different people work best at different times of day, and with variable concentration spans [3]. Determine when in the day you are at your most effective, and choose this time to focus on your most urgent and important tasks (see figure 9.2). For example, if you know that you are at your most productive at the start of your working day, then ignore the temptation to check and respond to every email and instead finish your journal article that has a looming deadline. Equally, making effective use of break times can help to reset your concentration and ultimately lead to a more productive day. When it comes to productivity, quality of time spent working is often more valuable than the quantity of time spent.
2. **Know *where* you work best.** Select the correct environment for the task that you are doing. For example, if you work in a busy or shared office, then this environment might be extremely conducive for discussing ideas for a future research project. However, reading journal articles might be better suited to a quieter room, such as at home or in a library.
3. **Avoid unnecessary meetings.** The modern workplace places many demands on people's time. Make sure that any meetings that you organise are absolutely essential, and that they are planned effectively. Only invite those people that are needed and consider structuring meetings for people to be able to attend in part (i.e. only for the parts that are relevant for them). For potentially unavoidable meetings that clash with other commitments, try to obtain the agenda beforehand and accomplish the tasks that are being discussed. Doing so will help to justify why you might not be needed at the meeting, and will help you to prioritise.
4. **Learn to say no.** If you take on too many things, then you run the risk of doing all of them badly, or you may create stress and anxiety for yourself and those that may rely on you. It is perfectly ok to say no to people, or to negotiate the best way to manage activities, and sometimes it is necessary for you to be a little selfish, to know your value, and to ask yourself if it is really worth it. If you do turn down an invitation then make it clear that you are available for future consideration (but again, only if it will be of benefit). Regularly discussing and reviewing your workload with your line manager and mentors (see section 9.6) can be important to ensure that you do not take on too much, and that those who can help you prioritise your workload know what you are doing and what is being asked of you.
5. **Manage your calendar.** Try to include daily tasks and deadlines in your calendar, including dates for follow-up and evaluation where necessary. Blocking out specific days for research or development activities can also help to avoid them being taken up by too many meetings.
6. **Manage your email.** Emails remain a widely-used default method of communication in professional workplaces to convey important (and far less important) information. Many people become anxious about achieving 'inbox

zero' and struggle to switch off until they have read and responded to every message someone else has chosen to send them. Some may find themselves interrupted from other tasks hundreds of times a day to achieve this. A simple strategy may be to only monitor emails at key points in the day; for example, at the start and end of each day (and perhaps during lunchtime). And while many value the flexibility of being able to send and receive emails outside of working hours, reflect on whether this is useful for you personally and balance this with any impact on your wellbeing (positive or negative). Equally, think carefully about the efficiency of the emails you send and think about whether email is the best medium to convey the information you might need to communicate. For example, would picking up a phone be a more efficient way to get to the bottom of a complex discussion?

The STING acronym (figure 9.1) provides a useful aide when thinking about how to manage your time effectively. Begin by selecting an appropriate task, and plan the amount of time you will need to complete it; for example: 'In the next two hours I am going to write 500 words of the introduction to this journal article.' While you are doing this task, ignore everything else (put your phone on silent and deactivate your email if necessary), allowing yourself only comfort breaks until it is finished. Once the selected task is finished, consider giving yourself a reward. This can be anything you like, from a slice of cake to allowing yourself to check your emails. When selecting the task itself, choose something that is substantial, yet ultimately achievable within a sensible timeframe.

An alternative time management strategy is the Pomodoro Technique®. This is a time management system that breaks the working day into 25 min intervals, separated by 5 min breaks. Each of these intervals are referred to as a Pomodoro, and after four such intervals, a longer break of about 15–20 min is taken. This technique has been shown to instil in the user a sense of urgency, with forced breaks helping to avoid feelings of burnout [4]. You can keep track of these intervals by using a stopwatch, or by downloading a dedicated application for your computer or smartphone.

One final time management technique is the use of an importance-urgency matrix, such as that shown in figure 9.2. If you have a number of important tasks to accomplish, then determine where they lie on this matrix. Those in Q1 need to be dealt with

Select a task

Time yourself

Ignore everything else

No breaks

Give yourself a reward

Figure 9.1. The STING acronym for time management. This provides one useful methodology for managing your work effectively.

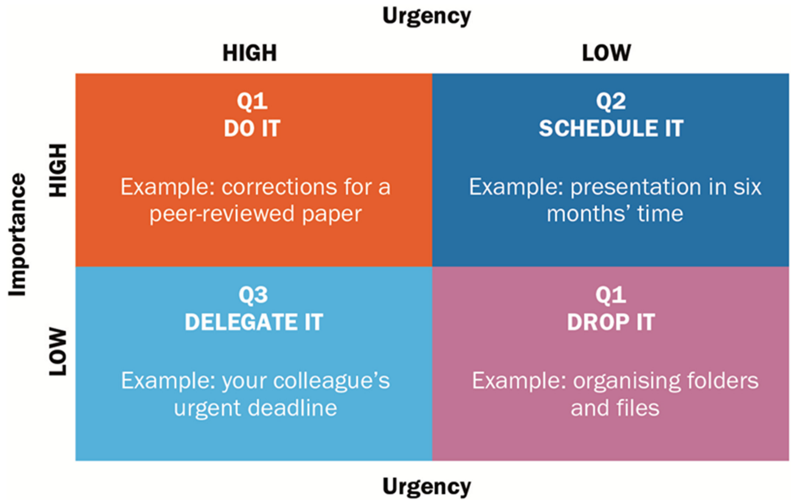

Figure 9.2. The importance-urgency matrix. This can be used to help prioritise which tasks need doing quickly, which can be postponed or delegated, and which can be dropped altogether.

immediately, followed by those in Q2, while those in Q3 might either be delegated or pushed back, and those in Q4 can probably be dropped or ignored altogether.

9.3 Networking

Networking is a skill that for many of us does not come easily. Very few would call themselves an expert networker, and some may never find it comfortable, choosing to instead develop alternative approaches to engaging with other professionals. However, as with presenting and writing, effective networking can be developed with time and practice. As a scientific researcher there are typically plenty of opportunities to network, be it either informally during coffee breaks at conferences, or in a more formal setting such as an organised dinner or dedicated networking session. In almost all of these circumstances, the biggest barrier to overcome is the initial nervousness associated in approaching a stranger and starting a conversation. The following advice should help you to overcome these nerves, and to build your confidence when a networking opportunity presents itself:

1. **Don't be afraid.** Many early career researchers struggle to engage with more senior scientists, afraid that they are too 'important' for them to talk to. However, all eminent scientists were once early career researchers themselves, and most of them will welcome the opportunity to speak to other eager and passionate researchers.
2. **Be yourself.** All of us get nervous at times, and this is even more pronounced when we are trying to be someone, or something, that we may feel that we are not. Imposter syndrome (a feeling of inadequacy) is especially prevalent in the academic community, for people of all ages and backgrounds [5]; even the most successful scientists often question their authenticity. Recognising and accepting this are the first steps in mitigating its more negative impacts.

Maintain your integrity and be safe in the knowledge that you are no doubt a very interesting person, who is an expert in their respective field(s). There may be more experienced scientists present, but this does not make your own research or opinions any less valid.

3. **Don't hog conversations.** Oftentimes, well-known scientists may have a queue of people waiting to talk to them in busy social environments such as conferences. If this happens to you, then go and talk to someone else and come back to others later. Similarly, if you are talking to someone and other people may appear to want to talk to you, then you could attempt to bring them into the conversation to allow things to move along in a natural way.
4. **Just stand there.** If you find it difficult to start a conversation then look for a group of people who are engaged in conversation and stand next to them, joining the group. Eventually someone will either start speaking to you, or an opportunity will present itself in which you can introduce yourself. Of course, this may not always be entirely appropriate and may feel very awkward, but if the group you approach are clearly discussing a private matter, they will be sure to tell you politely.
5. **Try not to be too blunt.** Networking sessions can be an excellent opportunity for seeking out potential employment for early career scientists. However, a slightly tactful approach in which you demonstrate your skill set and expertise, before causally mentioning that your contract is coming up for renewal, can be preferable to asking someone if they can employ you before you have even been properly introduced.
6. **Always carry business cards.** Doing so will enable you to continue any conversations at a later date, and will mean that your details can also be passed on to other colleagues.

If you find yourself overwhelmed at a networking event, then ask someone for an introduction. For example, if you are joining a new team or working group, or want to speak to someone in particular, then try asking one of your colleagues or even your supervisor for an introduction. This can help to remove some of the nervous apprehension from networking. Similarly, on occasions when you know that two people's work and interests would be well aligned, take it upon yourself to make the relevant introductions.

If you tend not to feel comfortable in large, social settings, you could hone your networking skills in small-group or informal networking events first. It may also help to start by going to events where you are more likely to find like-minded people (e.g. a meeting of cat-loving particle physicists), or to go to events with colleagues you feel at ease with. However, if you do end up attending a networking event with some friends or colleagues, try to avoid talking only to them, as that somewhat defeats the purpose of attending such an event in the first instance.

9.4 Teamwork

Working in a team, whether as part of a large international consortium or as a member of a small local group, is often a part of any scientific researcher's day-to-day activities. Effective teamwork requires a variety of roles to be filled by different members of the team, with each role and team member to be treated with unbiased and non-prejudiced respect. Despite the claims of several behavioural and personality tests, the best way to determine which role you are most effective in (and which you enjoy the most) is through trial and error. It might be that you are the kind of person who likes to organise, but who struggles to come up with innovative ideas. Similarly, you might be the kind of person who is excellent at seeing the bigger picture, but who sometimes has difficulty in recording those ideas in an accessible and informative manner that is essential for grant applications, etc. Your favoured or most effective role might also change depending on the project or team; don't be afraid to try new roles in new situations.

Whatever your role in the various teams you are a part of, it is typically impossible for you to be able to do everything by yourself and to a high standard, while also maintaining a healthy work-life balance. Furthermore, the days when review panels looked more favourably on solo-authored publications and lone grant applications are now thankfully behind us. Instead, internationalisation and collaboration are viewed as the key to being a successful scientific researcher. In addition to developing such collaborations you should also learn how to contribute to them in an inclusive and considerate manner.

The key to successful teamwork is in appreciating that everyone is different. This might seem like an extremely obvious statement, but the majority of disagreements in teams occur because people either assume that everyone will behave in the same manner as themselves, or else they expect them to do so. Each team member will have a different set of strengths and weaknesses in different contexts, and what may work for one person might not work for someone else. For example, if you are the kind of person who leaves everything to the last minute, but always gets it done, be sensitive to the fact that other members of your team may have prepared their contributions weeks, or possibly months, in advance and may find deadlines stressful. Equally, if you work towards completing deadlines as quickly as possible then you have to accept that other people might not be able or willing to do this, so don't harass them because they are not working to your timescale. To manage and mitigate this in complex projects, effective planning, regular review, and flexibility should be built-in to project management and design from the beginning of any project to its end. As with any relationship, working as part of a team is all about compromise and respect, and if you remain professional, committed, and polite then you will find working as part of a team to be a more enjoyable and rewarding experience.

A final, critical, component to working as part of an effective team is diversity.

Diversity is, however, not just a box to be ticked; several studies have shown that an increase in diversity leads to an increase in productivity, innovation, and impact [6–10]. Ensuring that teams are made up of a diverse collection of people with different approaches and backgrounds will mean that there is a diverse range of opinions, needs, experiences, and solutions. If your current or future collaboration is missing this diversity then ask yourself why, and then address it. If you find yourself in a position where you cannot enact change then find someone who can and raise it with them. Part of our responsibility as ethical scientists is in helping to ensure that science is for everybody, and a vital step in achieving this is in re-normalising who a scientist is and what they look like.

9.5 Objective reflection

Reflection is a fundamental part of the learning cycle—a necessary step in the development and reinforcement of knowledge and a check and balance on the accuracy of what we ultimately communicate in the form of scientific outputs. As scientists we are constantly taught to reflect upon our scientific work. For example, we may perform and repeat an experiment and then adjust certain variables based on the initial results. This reflection is a critical part of the scientific process, yet how often do we take the time to formally reflect on our scientific careers more generally?

The value of reflective learning extends far beyond analysing the results of your latest experiment; it is a practice that will help shape your research and evaluate your career path. For example, reflecting on a recent success will increase the likelihood of it being more than a one-off, while reflecting on a failure will enable you to better understand what happened and to avoid repeating similar mistakes in the future.

There are several models that can be used to help guide and structure a useful reflection; one of these, Gibbs' Reflective Cycle [11], is shown in Figure 9.3. Gibbs' Reflective Cycle is centred around the concept that reflection takes place after an experience; it provides a framework of cue questions, offering a checklist for learners as they progress through the cycle. This reflective cycle focuses on learning from experiences by involving feelings, thoughts, and recommendations for future actions. For scientists who have often been taught to ignore their emotions (see chapter 4) this can be difficult, but doing so will facilitate the creation of more

Figure 9.3. Gibbs' Reflective Cycle. This cycle features a series of questions that help to guide the user through a process of meaningful reflection.

effective future plans. If you find that Gibbs' Reflective Cycle does not work for you, then there are several other models, such as Johns' Model of Structured Reflection [12] and Jay and Johnson's Typology of Reflective Practice [13], that you can investigate; experiment with several of them until you find the one that is most suitable for you.

9.6 Mentoring

Working with a mentor will provide you with valuable advice from a more experienced person, improving your knowledge and skills, and building your professional network in the process. Many research institutes offer formal mentoring schemes, especially to early career researchers and new members of staff; such schemes can also lead to a better understanding of your organisation and its various bureaucracies. However, with more formal mentoring schemes there remains a risk that you may be paired with an unsuitable mentor, someone with whom you either have very little in common or whose networks and experiences are not necessarily aligned to your future career trajectory. In order to counteract this, and in instances where no formal mentoring scheme exists, it is advisable to establish your own independent network of informal mentors.

In choosing your mentors pick people whom you respect, and whose experience and/or networks will help you in your development as a scientist. Such a network need not be made up solely of colleagues from your immediate place of work. They could also be people you can meet up with on an irregular basis (either virtually or in person), and in whose presence you feel comfortable exchanging knowledge and advice. Your prospective mentor(s) should be someone that you get on with, and with whom you share a mutual level of respect and understanding, but they needn't be in a position that is senior to your own. Rather, they should possess a level of expertise in an area that you have identified as lacking in your own skill set. For example, if you find presenting work to a non-scientific audience difficult, then who might you know that excels at this? If you are inexperienced in writing grants then do you know someone who has recently been successful in their own application? Building up this informal network of mentors will also build your self-awareness and confidence, and could potentially lead to future opportunities to collaborate.

As well as being a mentee, you should also seek out opportunities to act as a mentor. This process can be done either formally or informally, and by exchanging knowledge with other scientists you will help to reinforce your own understanding, build networks, and gain new perspectives and fresh ideas. Furthermore, as an ethical scientist you will be helping others to determine the best path forward in their own scientific pursuits.

9.7 Career planning

As mentioned in the introduction to this chapter, the majority of people who undertake PhD study will end up in a career outside of academia. Given the limited availability of government funding, and the increasing numbers of research students who see a PhD as a gateway to employment, this seems to be a trend that will only increase in the years to come. In fact, it is probably more accurate to say that academia is the alternative career path. Pursuing a career outside of academia can be a rich and rewarding experience. However, it is necessary to have a clear plan of what you want to do, why you want to do it, and how you intend to achieve this.

If you enjoy doing scientific research, then there are plenty of careers that you can pursue outside of academia. For example, you could work for a large non-university research institute or government agency such as the UK's Environment Agency, or the Max Planck Society in Germany. Alternatively, you might want to work for one of the global tech giants, or at an instrument manufacturer or manufacturing company. Many of these jobs will allow you to conduct scientific research, publish journal articles, and attend conferences, with the added bonus of a full-time contract and the sense of security that is often absent from many non-tenured positions within academia.

If you find yourself no longer interested in scientific research at any point in your career, then there are always plenty of options for you to pursue. However, you need to think carefully about how best to market your unique skill set to a non-scientific audience. For example, writing a thesis demonstrates that you have excellent written communication and time management skills, while analysing data and setting up experiments exemplifies your problem solving skills. Presenting your research at a conference typifies your outstanding oral communication skills, while supervising undergraduates expresses your aptitude for teamwork and leadership, and doing all of the above is testament to multitasking capabilities. Recognising your experiences as evidence of the skills others may be seeking is key to developing an engaging and effective CV.

There are many jobs outside of scientific research that would benefit greatly from your transferable skills. It is just a question of finding them and not being too narrow-minded and blinkered by the minutiae of what you may have worked on in the past. A good place to start is The Versatile PhD website [14], which provides a list of non-academic careers and the potential routes into them. If you have an aptitude for communicating your research to a varied audience, then you could consider a career in teaching. In the UK (and many other parts of the world), there is a large shortage of qualified science teachers, particularly those with expertise in physics, maths, chemistry, and computing. In order to address this shortage, schemes such as that set up by the UK Government's Department for Education offer bursaries and financial support for teacher training.

If you do decide to pursue a career in academia as a research-focussed academic, then you may need to be realistic. In most countries the number of PhD students is increasing at a rate that is greater than the increase in government spending on research, or the rate at which undergraduate numbers may grow demand for teaching. This means that there are simply not enough permanent academic positions for every PhD graduate, and many excellent researchers are forced to find employment via a series of fixed-term contracts that may offer less job security and might involve relocating over long distances. To give yourself the best opportunity of achieving tenure you need to have a CV and expertise that demonstrates leadership and independence. Applying for fellowships, such as those described and discussed in chapter 3 are often a springboard into academic tenure. You also need to be open to a variety of possibilities (including moving abroad), resilient, and reflective in your approach (see section 9.5). Getting a tenured position in academia is not impossible, but it is certainly more difficult than it has ever been.

When considering your next career move, be aware that leaving academia does not permanently close the door to a future return. If an opportunity away from academia presents itself then don't dismiss it without reflection; many successful academics have spent time away from academia, and their careers have improved significantly because of this.

Exercise: write a five-year plan

Having a five-year plan will help you to focus your future career objectives. Taking the time now to plan out what you want to achieve over the next five years will also help to ensure that you maximise your opportunities, and will reveal which skills you need to develop further and where best to focus your time and energy. Think about what grants or fellowships you wish to apply for, how many publications you aim to produce, and any awards or accolades that you would like to receive.

After writing your five-year plan, ask one of your mentors to review your initial thoughts, and to see if you are being realistic. After another iteration, start to break down your plan into milestones and achievable tasks, and then use this as a guide to help focus your work into achieving your aims. Reflect on the five-year plan during regular intervals (e.g. every six months), updating it with every major achievement, accomplishment, and setback, and what you have learnt from these experiences.

9.8 Open access

Access to knowledge is a basic human right. Yet sadly as scientists we are often forced to operate in a framework in which this is not facilitated as easily as we might wish. If you are reading this as a scientist at the outset of their scientific career, then you may be surprised to find out that it can cost (often very large sums of) money for others (especially non-scientists) to access and read the latest scientific research. Even if these fees are not being charged to you personally, the chances are that it is costing your research institution or library tens of thousands of pounds/euros/dollars that could otherwise be spent on research, resources, staff, or infrastructure.

From a European perspective, the '2019 Big Deals Survey Report' [15] provides a mapping of major scholarly publishing contracts in Europe. By gathering data from 31 consortia with five major publishers (Elsevier, Springer Nature, Taylor & Francis, Wiley, and the American Chemical Society) this report found that the total costs of the participating consortia exceed €1 billion for periodicals, databases, e-books, and other resources, almost all of which led to significant profits for these large commercial scholarly publishers.

Over the last 30 years, traditional journal prices have increased at a much faster rate than inflation, often resulting in significant profits for publishers [16, 17]. In the past, scientific journals existed for two reasons: as an affordable option for scientists to publish their work (as opposed to the more expensive option of personally-published books), and as a place where both scientists and non-scientists could find out about advances in science. Sadly, in recent times many journals seem to have lost sight of their role in providing a service to the scientific and non-scientific publics, hence the current drive for open access (OA). Open access represents a model where published research is free at the point of use for public readership, but where publication fees might be paid by the author's research institute or other funding body. We describe the different and emerging OA routes below.

The beginning of the modern OA movement can be traced back to the 4th July 1971, when Michael Hart launched Project Gutenberg [18], a volunteer-led effort to digitize and archive cultural works for free. However, it wasn't until 1989 (and with the advent of the Internet) that the first digital-only, free journals were launched; amongst them *Psycoloquy*, edited by Stevan Harnad and *The Public-Access Computer Systems Review*, edited by Charles W. Bailey Jr. Since then, the OA movement has grown considerably, although publishing articles so that they are free to access is itself not without expense. Despite the lack of print and mailing costs for fully online journals, there are still large infrastructure and staffing overheads that need to be taken into consideration, and so rather than make the reader pay, alternatives have had to be found.

One alternative, known as the 'Gold Route' to OA, is to make the author(s) of an article pay for the right to have their research accessible and free to all readers. Many journals already require an article processing charge (APC) to be paid before publication. Fully OA journals build this cost into their APC, while other journals introduce an additional charge if the author wants to make their publication free to read.

The other main alternative is the 'Green Route' to OA, which involves the author placing their journal in a central repository that is free to access. The journal in which the article was originally published will usually enforce an embargo period of a number of months or years that must pass before the published articles can be placed in these repositories, although this can often be circumvented by uploading final 'accepted for publication' drafts of the journal article to public repositories. Most research institutes will have their own repositories in which such articles can be stored, and their data management team will be able to advise you with regard to the legalities of storing and hosting your publications (i.e. what version to use, how long to wait following publication, etc).

Both of these approaches to OA have their respective advantages and disadvantages, and normally research institutions and/or funding bodies guide the route that researchers choose. For example, the United Kingdom Research and Innovation (UKRI), has a policy that supports both the Gold and the Green routes to OA, though it has a preference for immediate and no-cost public access with the maximum opportunity for reuse. Another key aim of the OA movement is that published research is free to reuse in future studies. This might seem like a fairly trivial point, but for most articles published in closed access journals, express permission is technically needed from the publishers if the results are to be used in any future studies.

The major barrier that still needs to be overcome with regards to OA is determining who pays for the rights to free access. Many governments and/or funding bodies have a centralised amount of funding, which they allocate to research institutes. However, issues arise when one considers the limitations that this imposes on poorer countries, institutes, research disciplines, and independent researchers. It is for these reasons that many organisations and individuals are investigating and developing 'OA 2.0', an initiative in which articles are: free to read, free to download, and free to publish. However, such an approach will require a major change in the funding model of almost all publishing companies, and must be cautious to retain rigorous processes in peer review, impartial editorial decision making, and legacy archiving.

9.9 Integrity and malpractice

In their 2015 report ‘Seven reasons to care about integrity in research’ [19, p 1], Science Europe observed the following:

> ‘Research integrity is intrinsic to research activity and excellence. It is at the core of research itself. It is a basis for researchers to trust each other as well as the research record, and, equally importantly, it is the basis of society’s trust in research evidence and expertise. Research misconduct is not a victimless crime and can damage reputations, careers, patients and the public. It is also a waste of public investment in research and is costly to remediate.’

Without integrity there is no meaningful research, and thus there is no science. Even with the checks and balances of peer-review systems, ethics boards, and academic scrutiny, so much of our research remains reliant upon science being conducted in a fair, honest, and transparent manner.

At this point, it is important to differentiate between ‘integrity’ and ‘malpractice’.

Integrity represents both the ethics and the quality of academic rigour and best practice in the presentation and approach of science. This can include best practice in the conduct of experiments and experimental techniques, as well as the proper use of statistical and analytical approaches, thorough transparency of methods, and data availability. Integrity can therefore be summarised as representing standards of best practice and convention, which ensure transparency, scrutiny, and analytical repeatability. The checks and balances of science work hard to push up these standards constructively when applied well. Poor standards of integrity can therefore represent sloppy practice and ultimately useless scientific outputs, but not necessarily wilful neglect. It also includes instances of less serious plagiarism, such as careless oversight resulting in a lack of proper citation when discussing other people's work.

On the other hand, malpractice represents wilful neglect, data fabrication, wilful plagiarism, and potentially illegal and wildly unethical approaches. Thankfully instances of malpractice remain extremely rare, but they can have a very high impact and be extremely dangerous to the scientific community and society at large. Some contemporary examples of fields in which malpractice must be carefully guarded against for public good include (but are not limited to): germline gene editing [20] and the application of artificial intelligence [21]. These two examples represent current ethical challenges in scientific research, but other examples of malpractice include the fabrication of data and wilful plagiarism. The temptations for fabricating or copying the perfect results may be great, but the potential damage that this can cause to both reputations and knowledge mean that the negatives vastly outweigh any wrongly perceived positives. As ethical scientists we have a responsibility to be vigilant of ourselves and others, and to be sure that we remain beyond reproach at all times.

Any research that you carry out should stand up to the ethical and integrity guidelines laid out by your research institute, especially if it involves the possible invasion of others' privacy. Most research institutions have such a policy, which sits within a hierarchy of legal and regulatory approaches to mitigate and respond to instances of malpractice. However, such ethical procedures are no longer the sole preserve of medical researchers and anthropologists, and must be taken extremely seriously whenever your research might have a direct influence on the lives of others; for example, by flying a drone near to people or a built-up area, or when using satellite imagery to record high-resolution imagery of privately-owned land.

As ethical scientists we must also act with integrity towards our fellow researchers. Avoiding plagiarism, explicitly seeking permission, and dispensing appropriate acknowledgement are essential ingredients for building a fertile research environment. If you are ever in doubt, then consider how you would feel if your own work had been abused in such a similarly anonymous manner. We owe it to each other, as scientists, to make sure that everyone is given a slice of cake that is proportional to what they have legitimately earned.

With this in mind, we have a duty to challenge and report instances of poor standards or academic integrity and malpractice. To ensure integrity as co-authors, we should challenge our own research teams if poor standards are identified, and work constructively to reach good solutions. As peer reviewers we have the same duty, and as members of the academic community, we should seek to publish a rebuttal of inaccurate work or conclusions. However, true malpractice may require a more formal and serious intervention. This can include reporting concerns such as plagiarism and fabrication to journals (which may lead to retractions for example), or reporting these same concerns to your institution, a funding body, a public or regulatory body, or in extremely rare circumstances, the police. When doing so, it may be useful to first discuss your approach to reporting malpractice with a trusted colleague or line manager, but this should not prevent you from acting on your instincts if you have an objective reason to seriously question a potential case of malpractice. For further reading on this very broad and important topic and its contemporary challenges, see the *Handbook of Academic Integrity* [22].

9.10 Promoting diversity

Section 9.4 discussed the benefits of building a diverse team, and why this is not just a box to be ticked but rather a useful and effective way to conduct scientific research. However, one of the biggest challenges to achieving this diversity is in overcoming our own prejudices.

Taking the Implicit Association Test (a version of which is available via Harvard University's Project Implicit® website [23]) is a necessary step to highlight any preference that you might have for certain social groups over others. While it may be uncomfortable to admit, very few of us are totally without prejudice, and research has shown that most people have an implicit and unconscious bias against members of disadvantaged groups [24].

Once you are aware of your own prejudices you can actively start to address them, and one of the ways in which this can be done is in helping to proactively promote and enable diversity. There are several steps that individual researchers can take in order to do this, most of which will depend on your personal circumstances, and often the extent to which you are 'privileged' within (and by) the scientific system. For example, as a male researcher you should turn down any invitations to join a 'manel' (i.e. male-only panel) and instead suggest several non-male colleagues to take your place. Strategies also include seeking and providing professional development to empower and equip members of your team to address their own unconscious biases [25].

If you are organising talks, seminars, and conferences, ensure that there is diverse representation. Crucially however, make sure that you are inviting these people to talk about their work and research, not just so that they can give an opinion on what it means to be a non-white-cis-heterosexual-male scientist. Providing a platform for a diverse range of scientists to talk about their research is a powerful way to help re-normalise science, i.e. to make diversity the norm rather than the exception.

9.11 Summary

This chapter has discussed a number of the additional skills and professional practices that are required in order to be a successful and an ethical scientist. Practical advice and activities have been provided that will help you to be more proactive in building a valuable and transferable skill set. Whatever direction your career is headed, you need to plan ahead, identifying areas in your expertise that require strengthening and actively seeking out ways to improve them. This can be done via training opportunities, professional development activities, or formal/informal mentoring. Take the time to build a robust and versatile CV, and use networking opportunities to find and develop contacts who will help you to maximise your true potential.

As scientists we are not just representatives for our research institutes and fields of research, but also for science in general. In conducting our research, we must approach all situations with high standards of integrity and consider the wider ethical implications of our work. Similarly, we have a responsibility to behave as ethical scientists, to acknowledge and address our own conscious and unconscious biases, and to proactively promote and support diversity in science.

9.12 Further study

The further study in this chapter is designed to help you think further about developing your essential research skills:

1. **Find a mentor.** From your five-year plan identify an area of expertise in which you require some assistance, be it either a technical skill or a more general one (e.g. grant writing, presenting, etc). Identify a colleague who has expertise in this skill, and ask them if they could provide you with some developmental advice. Offer to take them out for a coffee to discuss the matter at hand, and gradually start to sound them out for their opinion as you begin to develop your own expertise.
2. **Attend a course.** Your research institute will almost certainly offer a large number of Continuing Professional Development (CPD) opportunities, normally through its HR department. Again, use your five-year plan to identify areas in which you require training, and sign up for the appropriate courses. Where possible, it is always preferable to choose training opportunities that offer external accreditation, as these will be the most useful for future career opportunities.
3. **Get some experience.** If you have decided that a career in academic research is not for you, then identify opportunities to gain some relevant experience elsewhere. For example, if you want to go into teaching then volunteer at a local school. Similarly, if you are thinking about working in industry, then approach an appropriate company and arrange some knowledge exchange visits. In addition to bolstering your CV, gaining this experience will also help you to better decide if this is indeed the correct career path for you.
4. **Investigate open access.** Find out the approach to OA that is adopted by your research institute. If there is an OA group then ask if you can join, and if there isn't then think about setting one up yourself.
5. **Address you bias.** Take a version of the Implicit Association Test in order to better identify any unconscious biases. Then actively work to address these biases and to remove any prejudices in your approach to science.

9.13 Suggested reading

There are many web-based platforms that offer useful career planning tools for scientists and researchers, with the Vitae Researcher Careers website [26] offering a host of resources, which are useful if you want to either pursue an academic career, or use your skills elsewhere. The Institute of Physics also has some very valuable resources, including a hub for early career researchers [27].

If you want to find out more about open access, and the wider open science movement, then there are several recommended journal articles that present an accessible introduction to the subject, including discussions of required changes in research culture [28–30]. Finally, the journalist Angela Saini has written two very important books on addressing sexism (*Inferior* [31]) and racism (*Superior* [32]) in science, both of which are highly recommended and necessary reads.

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