Effective Science Communication

A practical guide to surviving as a scientist

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For Becky and Ian, whose love and support enable us to do the jobs that we love.

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Preface

This book was conceived as a result of discussions between the two authors and young scientists we met at conferences about what it meant to be an effective communicator, and how daunting it can be to establish oneself in the challenging world of academia. Good communication is a core skill of any academic, especially for the fast-paced, modern-day scientist. The book that you are now reading is the culmination of these discussions, and has been created from the varied experience that both of us have amassed during our time as scientists, especially during our formative years as postdoctoral researchers and junior academics. As senior academics in respected universities we have had the opportunity and honour to conduct scientific research, prepare successful funding proposals, teach undergraduate and postgraduate students, and communicate our expertise to a variety of non-specialist audiences, from five-year-old schoolchildren to Members of Parliament. We have published papers, received grants, and appeared on television and radio. We have also had papers rejected, grant applications dismissed, and faced difficult questions from the media. As with all of life, academia is about taking the rough with the smooth, learning as we go, and doing the best that we can. We have drawn on all of these successes and failures to create this book, and we are confident that it gives a good overview of what it takes to be an effective communicator, and with it an accomplished scientist.

Both of us have a background in atmospheric physics, but like most modern scientists we also have experience in other research fields, from astrophysics and microbiology to pedagogy and social science. As such, whilst some of the examples that are given in this book are based on our more recent environmental science experience, we have framed these examples such that they are useful lessons for any scientist, no matter what their discipline. Being a scientist is not easy, and as you can see from the breadth of topics that are covered in this book, there are many skills other than research prowess that you must be accomplished at if you wish to thrive in this environment.

We hope that you enjoy reading this book, and that it can be a guide and companion to you as you set out, or continue, on your own journey as a scientist.

Acknowledgments

This book is the result of two years of hard work between the two of us, but there are many people who have contributed directly or indirectly through discussions and the experiences they have offered to us. We would like to thank everyone that has ever sat through one of our lectures, listened to one of our talks or put up with one of our rants. Thank you to our scientific colleagues for the innovation, inspiration, and at times perspiration that was necessary for us to shape our ideas.

Thank you also to our students and those we have met at the European Geosciences Union conferences for providing us with feedback and insight during the developmental phase of this book. We would especially like to thank Farrukh Mehmood Shahid, Alexander Garrow, and Jack Richard Varley for their help.

We would also like to thank Leigh Jenkins and the team at IOP Publishing for their help in preparing this book for publication. A big thanks also to Paul Dickens for the wonderful cartoons that appear throughout the book; we really think they help to illustrate some of points that we make and the issues that we raise. Special thanks must also be given to the two anonymous reviewers, whose comments and constructive criticisms helped to mould this book, ensuring that it was consistent and effective in its message.

Author biographies

Sam Illingworth

Sam Illingworth is a Senior Lecturer in Science Communication at Manchester Metropolitan University, where his current research involves looking at ways in which science can be used to empower society. After his PhD in Atmospheric Physics at the University of Leicester (following an MPhys in Physics with Space Science and Technology at the same institute), Sam spent two years in Japan as a Scholar of the Daiwa Anglo-Japanese Foundation, where he taught Effective Communication at the Tokyo Institute of Technology. Following his stint in Japan, Sam took up a postdoc position in the Centre for Atmospheric Science at the University of Manchester, where he used satellites, aircraft and drones to infer information about greenhouse gases in the Earth's atmosphere. In his current position he is the Programme Leader for the new MSc in Science Communication at Manchester Metropolitan, where he also investigates the relationship between science and poetry. You can find out more about him, and read some of his own poetry, at his website: www.samillingworth.com.

Grant Allen

Grant Allen is a Reader in Atmospheric Science at the University of Manchester. His research interests surround trace gas measurement methods and remote sensing, especially from aircraft. After graduating with a PhD on the subject of satellite remote sensing at Leicester University in 2005, Grant was a postdoctoral research associate at the University of Manchester working on projects investigating tropical convection and pollution transport. At the time of publication, Grant has received over £1M in funding from the Natural Environment Research Council on topics related to these themes. He has submitted over 30 grant proposals, with over 50 peer-reviewed publications in high-impact journals, and delivered over 70 academic conference presentations and public lectures. In 2012, he was awarded a Royal Society Westminster Pairing Fellowship to shadow a Member of Parliament to understand the science–policy interface. This was followed by invitations to review government reports on the environmental policy impacts of hydraulic fracturing and the deposition of evidence to parliamentary and local authority enquiries. Grant has also featured in several science documentaries—aired internationally—on atmospheric phenomena and has been interviewed several times live on BBC and Sky News channels discussing topics from volcanic eruptions to flooding. He has also taken part in over 40 radio interviews and provided comment for hundreds of newspaper articles.

Chapter 1

Introduction

As scientists, our task is to communicate experience and ideas to others.
– Niehls Bohr

1.1 Introduction

As scientists we are taught the skills and techniques which enable us to perform a range of extremely complex tasks, ranging from detecting tachyons, to plotting a map of the human genome. Despite this, very few of us are ever taught how to effectively communicate our research, or even why doing so is important. We live in a world, the scientific community, where we are taught that we must 'publish or perish'. Yet conversely, some scientists still see presenting their research in front of colleagues as a necessary evil, whilst others view communicating with the general public as something akin to root canal surgery without an anaesthetic. The reality is that in order to be a successful scientist, we must be able to communicate effectively to a wide variety of audiences, using a range of different media.

But why? Why should we bother trying to communicate our research with a variety of different audiences? Why can we not just be left alone to get on with our research in peace? The answer to these questions is threefold; we communicate our research because we should do, because we want to, and because we have to.

Scientists no longer exist in a bubble, the research that they do is very often made public by a range of different factors, and at the basest level scientists are accountable to the people who provide the funds that enable them to conduct the research in the first instance. Very often these funds will come from large government organisations, who in turn get their money from the general public in the form of taxes. Whilst it is a somewhat clichéd argument that scientists should be better at communicating their research to the rest of the society that funds it, it is still an argument that is true. More than that though, with grant applications and funding bodies ever more inundated with requests for money, there needs to be a clear and concise thought process given

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over to how the science that is being funded by society is ultimately going to have an impact on it. Communicating science, be it to grant panels, members of the public or journalists who take an interest in your research, is simply part of the job description of being a scientist. We communicate our science because we have to.

Aside from the fact that we have a professional obligation to communicate our research, there is the more altruistic argument that we as scientists should communicate our research because we have a moral obligation to contribute to the society of which we are very much a part. Science can be a greatly empowering force that many people, for whatever reason, have had denied to them. We are incredibly privileged to be able to conduct research and find out more about the world in which we live, and as such we have an ethical responsibility to pass on not only that knowledge, but also the very process of understanding to those less fortunate than ourselves. Science is ultimately about asking questions, and if we can help others around us to effectively question the world in which they live, then we will be better equipping them to be able to deal with the many injustices and inequalities that surround us. We communicate our science because we should do.

And finally, we communicate our science because we want to. There is not a scientist out there who cannot admit to getting a pang of excitement as they make a new scientific discovery, or find that the experiment that they have been working on for months is finally starting to work. Keeping that knowledge and that discovery to ourselves would be very lonesome indeed, and sometimes it is only by telling other people that we are able to truly understand the magnitude of what we have achieved. Communicating science is an essential part of being a twenty-first-century scientist, but it is absolutely something that can and should be enjoyed in the process.

Exercise: what do you want to improve?

Make a simple list of the three ways in which you want to be a more effective communicator. These aims should be SMART, i.e. Specific, Measurable, Achievable, Relevant, and Time-Bound. For example, 'Write more papers' is not a SMART target, whereas 'Author or co-author two papers by the end of this calendar year, in journals with a high impact rating' is.

Now go and look up the relevant chapter and section for each of these targets, work your way through them and then reassess your goals so that they are more realistic. Alternatively, if you are one of those people that absolutely have to work through a book in page order, then make a note of these three targets now, and keep coming back to them, re-evaluating them as you go. Also, maybe think about breaking away from convention, just this once…

1.2 Communicating knowledge: from Ancient Greece to modern days

This book aims to be a practical guide to communicating effectively as a scientist, and as such it is not focussed on the field of science communication as a discipline. However, it is worth spending a few paragraphs investigating the historical significance of the term 'science communication', and how it has developed over the preceding decades.

The word 'science' itself derives from the Latin word *scientia*, meaning knowledge. So to communicate science is effectively to communicate knowledge, and at its most basic level science communication can thus be thought of as those in the know informing those that are not. In ancient Greece this imparting of knowledge took place in public debates, where understanding and thought were deliberated by the masses. This democratisation of knowledge and inquiry ultimately led to the dawn of experimentation, and with it the advancement of philosophy and science.

Sadly, in Western Europe the dark ages quickly put an end to this period of scientific enlightenment, with knowledge now transferred via the written word, and often hoarded by the privileged few. The masses were now either unable to process any knowledge because of their illiteracy, or else the vast expense associated with hand-copied books and manuscripts prevented them from learning anything of scientific merit.

Thankfully, the invention of the printing press by Johannes Gutenberg in 1456 eventually made the printed word more accessible, meaning that knowledge could now be much more easily spread. Yet, despite the ensuing scientific revolution that the printing press sparked, it wasn't until much later on that scientists began to consider their responsibility to communicate knowledge to the general public.

The British Science Association (BSA) [1] was set up at the beginning of the nineteenth century, mainly to address the fact that science in the UK was in a somewhat laconic state. The first meeting was held in York on 26 September 1831, where one of the aims of the society was declared to be: ‘to obtain a greater degree of national attention to the objects of science’. The association also inspired the formation of similar associations for the advancement of science in other countries, and has continued to host annual meetings ever since. Perhaps the best remembered of all these meetings was at Oxford in 1860, where the English biologist Thomas Huxley debated Darwinism with the then Bishop of Oxford, Samuel Wilberforce. Huxley’s speech ended with him stating that he was not ashamed to have a monkey for his ancestor, but that he would be ashamed to be connected with a man who used great gifts to obscure the truth; a reference to the oratorical skill, yet perhaps clouded judgement, of his religious opponent.

In more recent times, science communication in the UK can essentially be thought of as having gone through three stages of development. The first generation of science communication centred on a deficit approach, which aimed to fill in the gaps in the knowledge of the general public. The second-generation approach favoured a more two-way dialogue, in which the scientists engaged with the general public, and in which the general public began to have an influence on informing scientific practice and policy. Currently the third-generation approach aims to continue this two-way dialogue, but also transfers greater ownership to the general public, by recognising that they have knowledge that might also be useful in the development of science.

1.3 How to use this book

Following this introductory chapter, this book is split into a further eight different chapters, each of which outlines a particular skill set that is necessary in order to be a more effective science communicator, and with it a more well-rounded scientist. Each chapter presents an overview of the topic, and gives plenty of practical advice about how to improve this aspect of your skill set. There are a number of exercises for you to work though, as well as some further study and suggested reading to further improve your knowledge and understanding of the subject.

The book has been designed so that you can either work your way through it from the start to the finish, or else dip in and out, choosing to focus on specific chapters that you think you might find more relevant to your current situation. Whether you are an undergraduate scientist embarking on your first steps into the exciting world of scientific research, or a professor with dozens of years of experience, there will be something for you here. Being a scientist is an incredibly rewarding and enjoyable experience, but there is no doubting the fact that it can also be a testing and difficult one as well. We hope that this book acts as a handbook for improving your ability to communicate effectively, and that in doing so it is also a practical guide to surviving as a scientist.

1.4 Summary

As scientists we have a responsibility not only to communicate our research to a wider audience, but also to find out what subjects our communities actually want to find out about. By reading this book, working through the exercises, and following the recommendations for further study you will become a more effective science communicator, and with it almost certainly a better and more capable scientist. That being said, this is very much a practical book, and the more that you put into it, the more you will get out of it. In the words of Winston Churchill, 'Continuous effort—not strength or intelligence—is the key to unlocking our potential'.

1.5 Further study

The Further study sections at the end of each chapter in this book are an opportunity for you to reflect on what you have learnt, and to develop some of these ideas through further reading and practice.

The further study in this chapter is designed to get you thinking more about why it is important to be an effective science communicator, and the importance that this can have on the rest of society:

1. **Check the newspapers:** go and pick up a copy of a tabloid and a broadsheet newspaper (or visit their respective websites). How much space do they give over to scientific stories? Is what they are reporting on entirely factual, and if not would somebody without your training be able to come to the same conclusions?
2. **See what science means to a non-scientist:** find a family member or a friend that is a non-scientist and ask them what they think science is. Can they define it? Can you define it? Do they think that scientists are good communicators? And if not, why not?
3. **Check out some science being communicated:** go to the BSA's Events Page [2] and find a couple of events that are going on in your local area. If they are nearby then go along and see what you think. Watching other scientists communicate is an extremely effective way of developing your own style and technique.

Suggested reading

For a good introduction to communication theory check out *The Communication Theory Reader* [3]; whilst those wishing to find out more about the scientific revolution should read *The Scientific Revolution: A Very Short Introduction* [4]. For further reading in the field of science communication as an academic discipline, there is the excellent *Science Communication: a Practical Guide for Scientists* [5]; there are also many journals that explore this subject in more detail, but two of the most renowned are *Science Communication* [6] by SAGE Journals and the *Journal of Science Communication* [7] by SISSA Medialab.

References

[1] The British Science Association www.britishscienceassociation.org/, accessed 8 July 2016
[2] The British Science Association's events page: www.britishscienceassociation.org/Pages/Events/, accessed 8 July 2016
[3] Cobley Paul 1996 *The Communication Theory Reader* (London: Psychology Press)

[4] Principe L 2011 *The Scientific Revolution: A Very Short Introduction* (Oxford: Oxford University Press)
[5] Bowater L and Kay Y 2012 *Science Communication: a Practical Guide for Scientists* (Oxford: Wiley-Blackwell)
[6] Sage Journals *Science Communication* http://scx.sagepub.com/, accessed 8 July 2016
[7] SISSA Medialab *Journal of Science Communication* http://jcom.sissa.it/, accessed 8 July 2016

Chapter 2

Publishing work in academic journals

If I have seen further it is by standing on the shoulders of giants.

– Isaac Newton

2.1 Introduction

This chapter offers some advice on how to publish a peer-reviewed scientific paper, laying out a framework from conception to publication. Based on personal experience as an Associate Editor, a reviewer, and an author, this chapter will provide practical advice and guide you through the process of publication in a typical modern scientific journal. We shall track a paper's journey—from deciding on when you have something to offer to science, to identifying an appropriate journal to publish in; and then how to navigate the peer review process and ensure your published paper reaches its audience. The advice in this chapter is especially relevant to those embarking on preparing their first scientific paper, but it may also offer some helpful insight to maximise a paper's academic impact and reach for those with some existing experience.

Writing and publishing peer-reviewed academic journal articles remains the principal way that scientists and engineers communicate their research widely among other researchers. Unlike other scientific communication methods, which may have a greater value in reaching wider audiences, peer-reviewed journal publications in reputable journals represent a time-honoured gold standard in academic rigour, and provide a permanent record of contributions to humanity's body of scientific knowledge. This is because the checks and balances of the peer review and editorial process serve as an important quality control on the accuracy and rigour of the work presented to a journal, and serve to keep science honest in the face of constructive criticism and independent oversight. On final publication, science can be reassured that an individual's or team's work has been carefully and reasonably vetted by independent experts familiar with a particular field, and that a published article has addressed any reasonable concerns. That said, peer

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review (like any human endeavour) is not perfect (as we shall discuss later), but it does represent the best system we know of in science to ensure accountability and scrutiny. First and foremost, peer review is intended as a constructive process, and should be approached in this manner by both reviewer and author; though that may not lessen the sense of anxiety some may feel when they receive reviews relating to their latest paper submission!

Bringing a paper to publication can be a daunting but also very enjoyable and rewarding experience. It is our duty as scientists to publish our work and bring it to the attention of others who may learn from it. The quotation at the head of this chapter encapsulates the engine of scientific progress—all of our current knowledge and teaching emanates from those that have previously published their findings for us to learn from. We build on each other's work and move our own forward incrementally. The record that is our academic literature ensures that our work is forever open to scrutiny such that it may be refined, disputed or reinforced with time, future understanding and effort. In the modern scientific world, the number of journals (and the number of scientists) has been growing exponentially. This has much strength and some weaknesses, as we shall discuss later. But the process and the end result remains the same as ever—to record knowledge and take it further. Let's now explore how you can make the most of this process for your work.

2.2 Scoping your deliverables

The word 'deliverables' is well-used in academia these days, implicitly commercialising science by virtue of it being a term borrowed from the world of business. However, it serves its descriptive purpose. A journal article or paper is an academic output that contains a deliverable or deliverables. Those deliverables are the key conclusions of the paper that represent new pieces of information not previously known to science. They could represent enormous leaps forward in fundamental knowledge, or they could represent incremental advances or facts about the Universe (or anything in it). The relative importance and the scientific field of those advances may dictate the journal you choose to submit to (see section 2.3), but the fact remains that any paper must contain some new contribution to knowledge, no matter how large or small. This simple requirement is one of the first aspects that an editor or reviewer will look for and be asked to comment on concerning any submitted paper. Therefore, the first step in writing a paper is to recognise when you have something useful to say. All that follows from that point concerns framing that deliverable(s) to provide clear evidence and explanation, so that others can be confident in your conclusions.

From experience of supervising students and researchers, and as a former student myself, it is not always easy to recognise when a critical threshold has been reached in the context of having something useful to publish. For some it may be easier than others—for example if the deliverables were planned in advance of some fairly routine work that was carried out. But in some cases (and in my opinion, the best cases), science moves forward by stumbling on some unexpected new advance as a result of working on something else. At this point it is important to take a step back, explore what you have already found and decide on three things before deciding on whether to write a paper:

1. Is what you have found so far a scientific deliverable that others should hear about?
2. If so, does the work so far represent enough information, data or explanation to provide a coherent and substantial narrative from which to inform others on that advance?
3. If so, could that work be written up as a paper now, or could further work provide additional deliverables within the scope of the intended article?

Some of the words in the above list are necessarily subjective or vague. This is because every discipline and every piece of work is different. However, choosing the right point in the course of your work to publish is a skill and an art. The difference between a mediocre paper and a truly groundbreaking one could be as simple as gauging when there is a neat package of work to create a clear and full story, as opposed to publishing as soon as there is anything to say. However, delaying publication while waiting for new results is a risk that involves making educated decisions about the future direction and timescales of the work you might be engaged in. If in doubt, the less risky option may be to publish as soon as possible. Therefore, implicit in point 3 above is knowing where and when to stop, where to draw the line under a body of work and present it to others. Of equal importance to knowing when you have something to say, is to know when not to say too much. This is absolutely not about holding anything back, but it is about knowing how to properly scope an article. It is often just as hard for new researchers to know when to stop (and publish) as it is to know when there is something useful to say. There is always a temptation to keep going. But remember that science is never-ending (or at least we hope so), and it is therefore an important career skill to recognise when to compartmentalise your work and bring it to fruition in the form of a paper. This is not to say that you should abandon a thread of research once you have a good deliverable on a given subject, but a paper should be relatively self-contained and address deliverables in the context of the title of the paper. It may not make sense to produce a paper for every new deliverable where they are variations on a theme for example, but it is important to know where to stop before a paper runs the risk of becoming unwieldy.

Something to avoid is falling into the trap of believing that simply publishing more papers is always better for your career. In a world where the length of a scientist's publication record is a cursory symbol of academic success, it is tempting to add quantity to that list at the expense of quality. In reality, both quality and quantity matter. A long string of papers that have just made it past the post of publication acceptability in a low impact journal with only meagre deliverables may be meaningless if no one has chosen to read the paper or cite it in their own work. Increasingly, academic reach and success is rated in terms of the number of citations a paper may receive (see section 2.7). A high quality paper with important and useful deliverables on a well-scoped theme may attract a higher readership and hence more citations. Such an output is far more important for your publication record and self-esteem, and more importantly, far more useful to science.

In essence, deciding on when and what to publish should be an informed balance between the completeness and complexity of understanding from research already done, and the promise and direct relevance of what may still come from further work. Scoping out your potential scientific deliverables as you go is a useful way to keep this balance in focus.

Exercise: scope out your deliverables

This exercise will help you to think about your own research, and to scope out which aspects may lead to scientific papers now or in the future.

1. If you are currently carrying out a research project, list what aspects of your research (past or future) may represent original contributions to scientific understanding.
2. From your list, group any aspects into specific themes.
3. For each of those themes, think about whether they would be best presented in a stand-alone paper, or whether they could be grouped into sections of one umbrella paper. Remember, more papers is not necessarily better—but good scoping is.
4. For each of those themes, think about what work you may still need to do to fully address them. If more work is required, do you still have important deliverables to publish on the other themes at present?

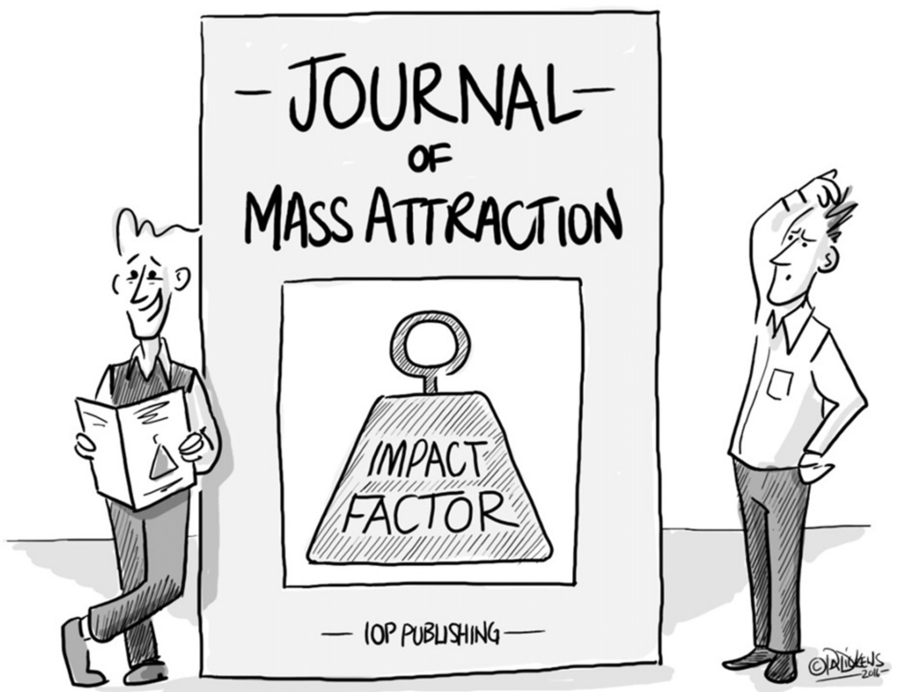
2.3 Choosing a journal

Once you have decided you have something useful to say, the next task is to decide which scientific journal will best speak for you. A journal is the medium through which we permanently record and communicate our research in its most complete form. Choosing a journal is analogous to deciding whether to present work at a large but general, or small but specialist conference—each has relative strengths and weaknesses depending on the scope of the work.

The scientific journal landscape is vast, and growing. Virtually all scientists (and many non-scientists) will have heard of and read publications such as *Nature* or *Science*. But only a small cadre of specialist researchers may regularly read the *Journal of Waste Management*, for example. The relative reach and specialism of different journals reflects the scope and wider import of the articles each publishes. For example, *Nature*'s readership may well not be too interested in the finer details of anaerobic digestion of organic waste in landfills, whereas the *Journal of Waste Management*'s readership may be surprised to read an article about new predictions of global climate catastrophe due to greenhouse gas emissions from landfill. But each article has its rightful place, and its attentive audience. Therefore, a key aspect when choosing a journal is to think about the scope of your conclusions and which group of people will be best served by hearing them. The journal you choose should then be analogous to selecting the loudest microphone positioned in the right room of people.

One of the metrics of a journal's reach is its Impact Factor (IF). This is defined as the ratio of total citations for the journal in some time period (usually two years) to the number of articles published in the same time period. For example, if a journal had an IF of 5 in 2016, then that would mean that the papers published in this journal between 2014 and 2015 received on average 5 citations each in the year 2016. These are routinely published by academic journals (usually on the homepage of their website), and in league tables produced by various organisations that can be found easily in any internet search. The higher a journal's IF, the more impact that journal's articles can be assumed to have, by virtue of the fact that others are referring to work published there. So generally, the IF is a proxy for the relative importance of the journal within its field. In reality, this IF ratio reflects both the magnitude of the journal's readership and the quality (and scope) of the articles it chooses to publish. Thus, many of the highest IF journals such as *Nature* and *Science* publish only the highest quality articles with broad and societally important themes that carry interest to a wide (and even non-scientific) audience. Such wide-ranging articles are naturally positioned to be more readily cited by others, whereas more specialist and technical articles in specialist journals may be less obviously cited. Put simply, it is important to attempt to publish in high IF journals where possible to maximise reach and impact. But your choice of journal may be limited by the scope and import of the subject matter and its conclusions. In all cases, your choice should be about reaching the attention of an appropriate audience for your work.

As briefly discussed above, one of the metrics of success for academic outputs concerns the IF of the journals we publish in, and how often our individual articles are cited. However, not all articles are suitable for the highest IF journals.



A specialist technical article may be best suited to a specialist journal with a smaller readership and a lower IF. In other words, the choice of journal should reflect both the IF and its scope, and it is always important to target a journal with a high IF for the specific field of interest.

A recent proliferation of academic journals has accompanied the growth of science in the developing world, and the profits that publishing companies may stand to make from publication fees from a growing population of scientists. The era of digital online publishing has also removed much of the cost barrier in starting up new publishing enterprises that typically accompanied the print media of the past. My email inbox is littered with spam from such journals asking me to publish with them. Some of these new journals have become highly successful and respected and their IF has grown dramatically. But beware. Recent research has shown that this system is ripe for abuse (and is being abused widely) [1, 2]. Some of the most unscrupulous of these 'predatory' journals pay lip service to the peer review process (or bypass it altogether) [3], taking publication fees for profit and greed at the expense of academic quality and rigour. Unfortunately, some unscrupulous and career-hungry scientists, jaded by rejection or heavy revision as part of the peer review process in more prestigious journals, have elected to feed the growth of these predatory journals to add bulk to their publication record. A growing awareness of these predatory journals and regularly updated blacklists (e.g. [1]) does mean that this problem is slowly being dealt with within the academic community. But for the uninitiated (e.g. employers in non-academic career paths), an unvetted publication record can still, unfortunately, be taken at face value. Here, the advice is simple—do not publish in such journals and always check that a journal that you are considering is not included on any blacklist. The easy ride they may appear to offer is at the expense of the quality of your published work, and represents a blemish on any academic record. Publishing in these journals is akin to buying a bogus qualification, and is considered by most to be a crime against academia. An updated list of potential, possible, or probable predatory scholarly open-access journals can be found on the Scholarly Open Access website [4].

To find a genuine and appropriate journal for your article, a good place to start is to read recent issues of journals that others in your field have published in, to get a sense of their scope and quality. When conducting any literature review you may perform prior to embarking on a research project, or when writing the introductory and discussion sections for your own paper, you should naturally become familiar with a range of appropriate journals relevant to the context of your work. When you have compiled such a list, visit the journals' websites to investigate their IF and read about their aims and scope. Your choice of journal should then be determined according to which one will give you the greatest reach based on its IF, the journal's scope, and the journal's likely audience.

A further consideration also concerns whether the journal has an open access model. Open access (OA) refers to a funding model under which published articles are freely available to anyone who has access to the internet; as opposed to previous closed access models, where individuals or institutions (or libraries) may have had to pay a regular subscription or per-article access charge [6]. This funding model relies on the payment of publication charges by the author at the time of publication and/or on contributions from institutions or other funding agencies. A recent trend in enhancing the visibility of research and its accessibility to wider, non-fee-paying audiences means that the popularity of OA journals has grown markedly. Furthermore, in many countries where research has been commissioned with public money, it has become a requirement of funding to publish in OA journals such that the public has free access to the results of the work. Given this trend, and the natural enhanced visibility that OA offers, it would be advisable to explore OA journals when making your choice. A further discussion of the OA model, and why it should be supported is given in chapter 9.

2.4 Writing and manuscript preparation

In this section, we discuss some tips for journal publication preparation. However, in this book we do not offer detailed advice on scientific writing style, suffice it to say that the best way to learn in this author's experience is to read widely around your subject, to learn from the best practice of others, and then to put pen to paper yourself (or rather finger to keyboard) and be prepared to iterate tirelessly. Other published material offers some excellent and detailed advice on scientific writing style (e.g. [7]).

But before moving on to discuss preparing manuscripts for publication, one piece of advice on style and writing I would offer is to thoroughly check your manuscript prior to submission for typographical and grammatical errors, and to get your work proofread by a technical writer or proofreader if you have this resource available to you. A well-prepared and clear text will go far with any reviewer. Nothing gets reviewers worked up more than having to write out a long list of technical errors such as grammatical and typographical mistakes. If you put your reviewers in a bad frame of mind over this avoidable aspect, then they may be less objective about your technical presentation, siding with a presumption of sloppiness. Put simply, typographical and grammatical errors reflect laziness and push the burden of correction onto reviewers and editors who simply shouldn't have to take on this role in what is mainly an unpaid duty to science, and which relies on the good will of busy people. And most importantly, remember that papers can, and frequently do, get rejected if the writing style is so poor as to affect the ease of reading—and therefore the clarity—of submitted work. This may seem like common sense, but ignorance of this is unfortunately all too common.

Once you have decided on a journal to submit your paper to, it is useful to thoroughly read through any author guidance material available. This is usually accessible from the journal's homepage under a tab such as 'Guidance to Authors' or similar. This guidance will typically contain rules and advice on how your submitted article should be formatted or prepared, and it may detail how items such as figures and tables should be provided.

Most journals will accept a word-processed document with embedded figures and tables for any initial review phase. But you can save yourself a lot of time later on if you have prepared all material in any required format in advance. This is especially true for any figures, photographs or illustrations, which usually have strict file formats, e.g. encapsulated PostScript for data plots and raster graphic formats for any illustrations. As many scientific analysis software packages have the ability to output graphics in a range of file formats, it could save you hours (if not days) of time to prepare all outputs in the journal-required format at an earlier stage, as journals typically require separate files for each figure during the final stages of copy-editing. Other guidance to look out for includes any word or page limits, as some journals that take letter-style articles usually stipulate strict restrictions. It is also worth considering the graphics and colour schemes that are used in your article, as these can really make a big difference to how well received your article is by both readers and reviewers. An excellent resource for making your images best represent the underlying data is the Climate Lab Book website run by Dr Ed Hawkins [5].

Finally, before submitting an article to a journal, make sure that any co-authors have read and commented on your draft, and ideally pass it to someone uninvolved with the work (perhaps someone in your research group) to provide a fresh pair of eyes and comment on how accessible the narrative is. And perhaps as importantly, if the language of the journal is not your first language, or if you feel that the writing style is not commensurate with that of other journal articles you may have read, consider contracting a proofreader or ask if your organisation can provide this service for you. Such a service is often just a fraction of the cost of publication charges and may save you (and your reviewers) a lot of time in the long run.

2.5 The peer review process

To anyone writing their first paper, submitting your work for scrutiny can be daunting. In this section, we briefly explain the typical review process and approaches to handling it.

In almost all reputable journals, after you have submitted an article (usually online) it will first be assigned to a handling Associate Editor (AE) for the journal, who will typically have a reasonable (but not necessarily always high) level of expertise in the field of research with which your paper is concerned. It is possible to examine or request a list of AEs for your chosen journal, and to make a recommendation based on your reading of their expertise in a covering letter to the journal which accompanies your paper on submission. However, the assignment of an AE is ultimately made by the publishing staff or a senior editor. The AE will preside over the peer review process for your article and they will make any final decision on suitability for publication.

On first receiving an article to handle, the AE may make an initial judgement on whether the subject matter of the article fits the scope of the journal and whether the initial manuscript is suitable to send on to reviewers. It is not uncommon with some journals to receive guidance from the AE prior to further peer review at this stage. Any comments from the AE at this point should be carefully examined and answered to allow your paper to progress further. The AE will then select and invite several expert reviewers to comment on your paper. This phase can sometimes take several weeks while reviewers accept or decline invitations to review, requiring the AE to find suitable alternatives. It is important to remember that peer review for journals is universally a service that other researchers provide for free in their spare time. This can sometimes make it difficult for journals to solicit suitable reviewers quickly. Again, it is possible for you to suggest sensible reviewers to the AE. However, it is important to avoid bias in your choice and only suggest expert reviewers that are not linked to your work or organisation, as an AE will take a dim view of any attempt to undermine or subvert the quality of the peer review process. The AE may then choose to invite one or more of your suggestions, but this is entirely at their discretion.

Once expert reviewers have been assigned (typically two or more), the reviewers may take several weeks to complete their review of the submitted paper. They will be asked to comment on the suitability of the subject matter for the journal, to report on the quality and importance of the work, and to discuss any technical points where there may be cause for question or concern. They may also be asked to comment on the quality of the figures and tables, and to list any technical errors such as typos and grammatical mistakes. Finally, the reviewers will be asked to make a recommendation for publication, and sometimes they may be invited to submit a score against a set of criteria. This score or recommendation may not be directly visible to you, and it is important to remember that any reviewers' comments and recommendations are advisory to the AE and do not represent a decision on publication, which is usually the decision of the AE alone.

After all of the solicited reviews have been received by the AE, they will contact you and provide the reviews along with their decision on publication. Rarely, an article may be accepted outright in its current form, with no further modification

necessary. However, most often reviews will be returned to you with some guidance from the AE on how to proceed in their opinion. This can range from outright rejection, where the article has been deemed to be out of scope with the journal or of insufficient quality to be improvable for publication, to a suggestion for revision based on the comments of the reviewers. Suggestions for revision typically take the form of either a major revision, where significant further technical and presentation work may be required, or a minor revision where further clarity or graphical improvements may be required, for example.

On receiving the AE's decision and guidance, you will then be given several weeks to prepare a response to the reviewers' comments if your paper has not been rejected. In your response, it is always courteous to thank all of the reviewers for their comments and to briefly summarise what you see as the salient points of their collective reviews before continuing to address each review and each reviewer's comments in turn and in order. This logical sequence will make it easier for the AE to follow your response.

I can recall the reviews of my first submission as a PhD student. The many pages of comments and suggestions made me wonder if my original article was of a good standard. Only a few years later did I realise that those comments and suggestions were made by busy people who took the time to help me make the most of my article, and provided a fresh pair of eyes on work that it is not always easy to keep in clear focus from the inside. For the most part, it is a valuable and helpful process. But your skill as an author is in recognising which reviewer comments are accurate and helpful and which may be in error. It is not uncommon for a new author to feel that everything a reviewer says is correct and that you are always wrong. However, you must face up to those comments honestly; addressing them where they raise important points, but also robustly defending your work where there may be misunderstanding.

Most importantly, be sure to constructively address and respond to all of the comments made, whether that is to agree with the comment or suggestion, or to discuss or argue your case. In all cases, you should detail where and why you have made changes to your paper as a result of any of the reviewers' comments, and describe how your changes have addressed the points raised. Remember that your reviewers are objectively working to help you improve the presentation and accuracy of your work, so if you see that a reviewer has misunderstood something, try to think about why they have misunderstood it and attempt to clarify any parts of the narrative or material that could lead future readers to similar misconceptions.

Extremely rarely, you may receive what can only be described as an unconstructive review. This class of reviews may take a very negative tone and may make unsubstantiated comments with no link to the content of your paper. My advice here would be to treat such reviews with the contempt they deserve if it is obvious that a reviewer has made no attempt to rationalise their comments. Make the point that you have no case to address if you have not been given cause to. Your AE will almost certainly have already identified such a review as being worthless to the decision process and may have selected additional reviewers to provide more objective comments. This said, be sure to differentiate between negative but objective reviews that do make specific comments linked explicitly to your work, and reviews that are generally ignorant of its content. In other words, never mistake a review you just don't like but is genuinely raising comments about the content of your work, with a review that makes no substantiated comment at all. The former requires a detailed response, while the latter requires very little. Thankfully, such reviews remain extremely rare, but if you are unlucky enough to receive one, remember that the checks and balances of the other reviewers and the AE, coupled with your right to respond, all serve to optimise the quality of the peer review process.

On submitting your revised paper (if required to do so by the AE), your paper may be sent back to the original reviewers for further comment, or it may now be deemed acceptable for publication without further review. The AE will usually make any decision for further review based on your responses to the reviewer comments, whether he or she feels that you have satisfactorily addressed them all in your response, and that any appropriate and necessary revisions to the paper have been made. In some circumstances, this iterative process can happen several times before the AE is satisfied that all aspects have been sufficiently addressed and final publication can proceed.

Finally, and often several months after you submitted your original article, you may receive an email from the AE informing you that your paper has been accepted for final publication subject to copy-editing and final typesetting. This is a heart-warming moment for any researcher at any stage in their career and it is a cause for celebration. At this stage, you can be rest assured that you have made a contribution to knowledge and that your work will be recorded for future generations to build on. You have become 'a giant'.

2.6 Reviewing papers

Very shortly into any published research career, you may find that you are invited to review papers yourself. Such an invitation is an honour and reflects your growing reputation in your field. It also represents an altruistic duty that all researchers rely upon each other to perform. Without the unpaid work that expert reviewers and AEs do for journals, the peer review process would grind to a halt. And without that process, the quality of published work and the rigour of scientific endeavour would suffer immeasurably. As often very busy people, some researchers fail to see the value to themselves in performing review work, but without that contribution from each and every one of us, their own work would ultimately be devalued. From my own point of view, I try to accept invitations to review at least twice as many papers as I publish myself to ensure that I do my part. As an emerging researcher, I can't speak enough for the value it will give you in being able to critically evaluate others' work; and in that same process to put yourself in the position of someone scrutinising your own work from the outside. It will help you to more easily recognise the pitfalls in your own narrative presentation and therefore to style it for other readers more naturally.

Accepting an invitation to review for the first time can be as daunting as publishing your own work. It is a great responsibility and requires time and effort. After all, you are being asked to provide a judgement on work that another researcher or team of researchers has spent an often enormous amount of time preparing. Your job is to remain objective, constructive and honest, and to only accept a review if you feel that you are reasonably well qualified to comment on the subject matter of the paper in question. If there are areas of the work that you cannot comment on, be sure to make this clear to the AE and the author(s) in your review.

A great way to learn about writing reviews is to read the reviews that others have published online. Many OA journals also have an open peer review process, where the reviews of papers and the responses from authors are published publicly during a discussion phase. The review and discussion boards of some more contentious publications make for some very interesting reading indeed, and can be just as informative as the final article itself. This open discussion is an exciting new addition to the modern era of scientific publication but unfortunately it can also (albeit very rarely) attract some of the more negative aspects of social media such as anonymous trolling. Again, it is important to remember here that the checks and balances of the peer review process prevail in virtually all instances. Another possible criticism with this model of peer review is that it implies that a draft of the paper gets published online prior to peer review. Whilst many may argue that this 'pre-publication' adds to the noise of science, it is also a fair and efficient way of making sure that science is conducted in as open and accountable a manner as possible.

Exercise: preparing for peer review

This exercise will put you in the position of a reviewer and help you to think like one when reading future papers and preparing your own. By thinking like a reviewer when reading, you will remain more objective about others' work and conclusions, and in the process you will improve your own paper writing by putting yourself in the position of someone unfamiliar with your work.

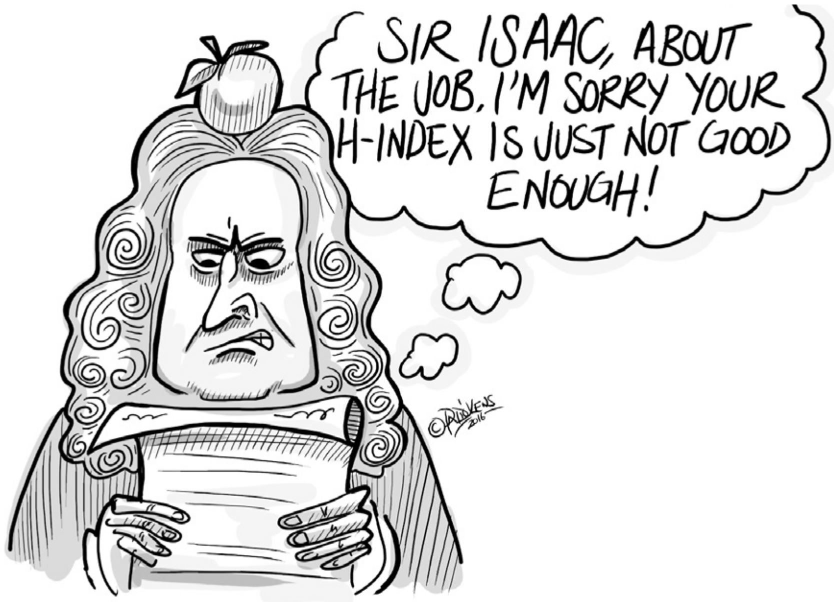
1. Choose a paper that you would like to read and that you have not read before (ideally something relevant to your current research).
2. Write a review of that paper as if you have been asked to review it by an AE. Structure your review as follows: a) summarise the conclusions of the paper and your overall opinion of its importance and quality; b) list your specific comments about aspects of the work that are not clear to you or that you feel may be incorrect, asking specific questions as if you were asking the author; c) list any technical comments such as typos or grammatical mistakes (though there shouldn't be any of these in a published article!).
3. Read over and reflect on your review. If you received this review as an author, how would you interpret it? Are all the points objective and clear? Would your review help the AE to make an informed decision regarding publication?

2.7 Citations and metrics—getting recognised

Earlier, we discussed how the quality of published work is perhaps more important than the quantity of publications in your record. One of the more explicit measures of your work's quality and its importance to science is the number of citations your paper may receive. Clearly, your choice of journal and its IF are a major influence on its exposure and therefore the chance that others will read and build on (and cite) your work. However, there are other ways to raise your work's profile in your field. These concern how you advertise your work to others, and there is much that you can do to bring it to the attention of relevant researchers, beyond simply relying on the journal and random internet searches that others may perform when conducting a literature review of their own. While some researchers I know do still monitor and read every issue of their favourite journals, an increasing number of younger researchers do not have the time to do this, and rely instead on filtered journal alerts or occasional literature searches through internet search engines. With this in mind, there are several ways to make sure that your work appears on the radar of those people that do not actively trawl the contents pages of traditional journals. The first of these is to carefully choose the search index keywords that many journals ask you to specify when you submit an article. You can usually specify several such keywords or phrases that summarise the subject matter or field of your paper. For example, these may be 'greenhouse gases', 'nanoparticles', or 'unmanned aerial vehicles'. Think about what words you would search for when conducting a literature review related to the content of your own paper. Try those keywords out and see if they list similar papers to your own.

Other more active ways to advertise your research include presenting your recent work at conferences, including reference to your papers in any abstracts you submit to them. Some of my colleagues list their three most recent papers in their email signature. And of course, it is always useful to directly email any researchers you know in your field who you think may find your paper interesting, as well as taking every opportunity to advertise your paper through all of the social media channels that you utilise. Some of these channels, such as ResearcherID, Scopus, LinkedIn and Google Scholar (to name only a few), offer the ability to list your publications and form networks with other colleagues and researchers who may be automatically informed when you publish new work; a further discussion of some of these services is given in chapter 7. Some of these services will monitor any new citations of your work and inform you when this happens. And lastly, any organisational or personal websites should be kept up to date with your evolving research interests and publications.

Keeping track of your papers' citations is useful, as it will help you to recognise how your field is developing and to identify which of the papers that you have written have received a good hearing. There are several conventional metrics for this that you can monitor using services such as those listed earlier. These metrics are also often used in academic or scientific-related career promotion criteria, and as such they can be a hotly debated topic. The more common of these metrics include the so-called *h-index* and *i-10 index*. The *h-index* is the most common, and is based



on a set of a researcher's most cited papers and the number of citations that this same set may have received in other publications [8]. The value of the index is calculated such that an *h-index* with an integer value of *h* represents an author that has published *h* papers, each of which has been cited in other authors' papers at least *h* times (see figure 2.1). As such, this index then reflects both the number of publications and the number of citations per publication. For example, an author with 20 publications but with only five papers that have been cited at least five times, will have an *h-index* of 5, while an author with 20 publications, each cited at least 20 times would have an *h-index* of 20. Clearly, this index favours those with consistently well-cited papers, but not those with one stand-out paper and several less well-cited papers. An important point to note is that the *h-index* is rarely relevant when comparing the impact of researchers across different disciplines, due to the differing ways in which different fields publish and cite each other's work. However, it can be an effective way to compare the impact and reach of individual researchers within common disciplines. The most effective way to ensure that your *h-index* continues to rise is to publish high quality papers and bring these to the attention of as many fellow researchers as possible. The *i-10 index* is a measure used solely by Google Scholar at the time of writing. This index is defined as the number of publications written by an author with at least 10 citations. As such, this is a simpler index to understand compared with the *h-index*, but it further amplifies any interdisciplinary comparison bias.

There are many more exotic variations of these citation metrics, all designed to remove the source of discipline bias or age of the author for example; but not all metrics are readily recognised or understood by many (see [8] and references therein

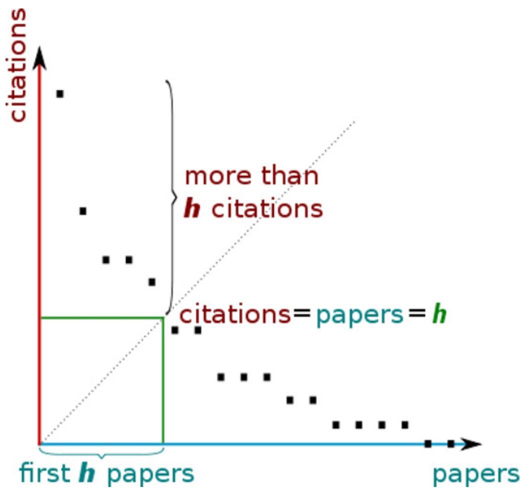


Figure 2.1. Calculation of the *h-index* using the number of papers attributed to a given author and the number of citations each has received. The *h-index* is then the maximum integer value where that number of papers has received at least the same number.

for further examples). A further point is that the value of these indices may vary wildly between different citation-indexing services (see [9]) and that not all organisations recognise indices calculated from some services due to the perceived impurity, or chance of false positive data included in their calculation. It is your duty to honestly examine your citation indices to check that they have been calculated correctly, with the most up-to-date information. This may require you to routinely weed out (or add) any publications or citations that may have been wrongly attributed to you in any specific indexing service.

2.8 Summary

This chapter has described the importance and necessity of paper publication as the mainstay of academic record and communication. We have briefly explored the pathway and the peer review process when submitting scientific papers to traditional academic journals. We have also offered some tips and advice on maximising the exposure and impact of your research outputs, and how to avoid the grasp of predatory journals. Finally, as important as publishing your findings, is your service to the academic community (and science in general) by engaging actively with the peer review process.

2.9 Further study

The further study in this chapter is designed to help you think further about developing your paper writing and reviewing skills:

1. **Read an article from outside of your discipline:** pick a scientific article from a reputable journal that lies outside of your specific area of expertise. Read that article and see how it has been constructed in terms of its structure and

layout. This will help you to defocus a little on the content of the paper, allowing you to reflect on style and structure. Does it present its research findings in an innovative way, or is it overly verbose and difficult to decipher? Are there any lessons that could be learnt for your own writing?

2. **Follow an online discussion:** pick a journal from within your field that has an online and open peer review system. Search through some of the articles until you find one that has a particularly long comments thread (ideally one that has inspired other members of the community, other than the compulsory reviewers, to comment), and see if you agree or disagree with some of the comments that have been made. Have all of the comments been written in a constructive way, or are there instances of unprofessionalism or a lack of objectivity?
3. **Compile some metrics:** pick a couple of very well-known scientists in your respective field, both alive and dead, and compile a list of the various metrics that would be used to rate their publication records. How do they perform? See how they correlate to similar metrics of researchers from another discipline.

Suggested reading

Whilst targeted specifically at the atmospheric scientist, *Eloquent Science: a Practical Guide to Becoming a Better Writer, Speaker, and Atmospheric Scientist* [7] is a book that contains a wealth of generally useful guidance on many aspects of scientific presentation and communication. *The Introduction to Journal-Style Scientific Writing* [10] is a free and public website that offers some very useful and appropriate tips on how to write and structure a scientific journal paper. *The American Scientist* magazine also offers an excellent public resource [11] that discusses methods of data presentation and narrative absorption from the point of view of the reader. It also explores the appropriate and optimal use of English grammar in scientific writing. Finally, *Scientific Writing* [12] offers an in-depth guide to paper writing that includes science writing for non-scientists and also a chapter on thesis writing and preparation.

References

[1] https://en.wikipedia.org/wiki/Predatory_open_access_publishing, accessed 8 July 2016

[2] Kearney M H 2015 Predatory publishing: what authors need to know *Res. Nursing Health* **38** 1–3

[3] Butler D 2013 Investigating journals: the dark side of publishing *Nature* **495** 433–5

[4] https://scholarlyoa.com/individual-journals/, accessed July 8 2016

[5] www.climate-lab-book.ac.uk/2014/end-of-the-rainbow/, accessed July 8 2016

[6] https://en.wikipedia.org/wiki/Open_access_journal, accessed July 8 2016

[7] Schultz D 2013 *Eloquent Science: a Practical Guide to Becoming a Better Writer, Speaker, and Atmospheric Scientist* (Berlin: Springer)

[8] https://en.wikipedia.org/wiki/H-index, accessed 8 July 2016

[9] Meho L I and Yang K 2007 Impact of data sources on citation counts and rankings of LIS faculty: Web of Science versus Scopus and Google Scholar *J. Am. Soc. Inf. Sci. Technol.* **58** 2105–25

[10] http://abacus.bates.edu/~ganderso/biology/resources/writing/HTWgeneral.html, accessed 8 July 2016

[11] Gopen G D and Swan J A 1990 The science of scientific writing *Am. Sci.* **78** 550–8

[12] Lindsay D R 2011 *Scientific Writing* (Clayton, Australia: CSIRO publishing)

IOP Publishing

Effective Science Communication
A practical guide to surviving as a scientist
Sam Illingworth and Grant Allen

Chapter 3

Applying for funding

I require 10000 Marks.

– Otto Warburg

3.1 Introduction

Since the Renaissance period (and until surprisingly recently), academics were often self-funded—born of a wealthy family or made rich by some good fortune or industrial endeavour. Self-imprisoned in their archetypal laboratories, many of the famous names in medieval, and even 19th-century science, used their personal resources to investigate whatsoever scientific direction they saw fit. Their unfettered free thinking and growing organisation gave us much (if not most) of the fundamental understanding of the natural world and its governing physics that underpins all science and technology today. However, the proliferation of science and technology during the Industrial Revolution, and the improvements in education that came from a more progressive society, soon meant that the deep thinkers and innovators of more recent modern history needed to seek external resource to fulfil their ambitions to learn and create. And with that need for resource came the necessity to justify and define the deliverables of projects to potential benefactors, from public agencies and charities to large corporations.

Increasingly, the 'impact agenda' features strongly in any request for funding—the ends must justify the means. Long gone are the days when a scientist could simply name the price of their research endeavours, as in the case of the quotation at the start of this chapter by Otto Warburg to the Emergency Association of German Science in 1921.

Most academic (and plenty of other professional) roles will at some point require you to make a case to some funder or funding body to invest resource in your projects and ideas, in order to allow you the time and money you need to pursue them. In science, this case for support (or proposal) is typically a discussion of the current state of knowledge in a specific field, which aims to highlight a new frontier or challenge that you plan to address within a well-defined and achievable project design.

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A potentially successful funding application essentially needs just three things: a great idea, a great project design, and excellent communication of that project design to those that might fund it. Like everything else in this book, a successful proposal often hinges on the ability to clearly communicate a narrative to a target audience. Your research idea may well be world-changing but if you can't convince others of that potential, you may never get the resource you need to investigate it.

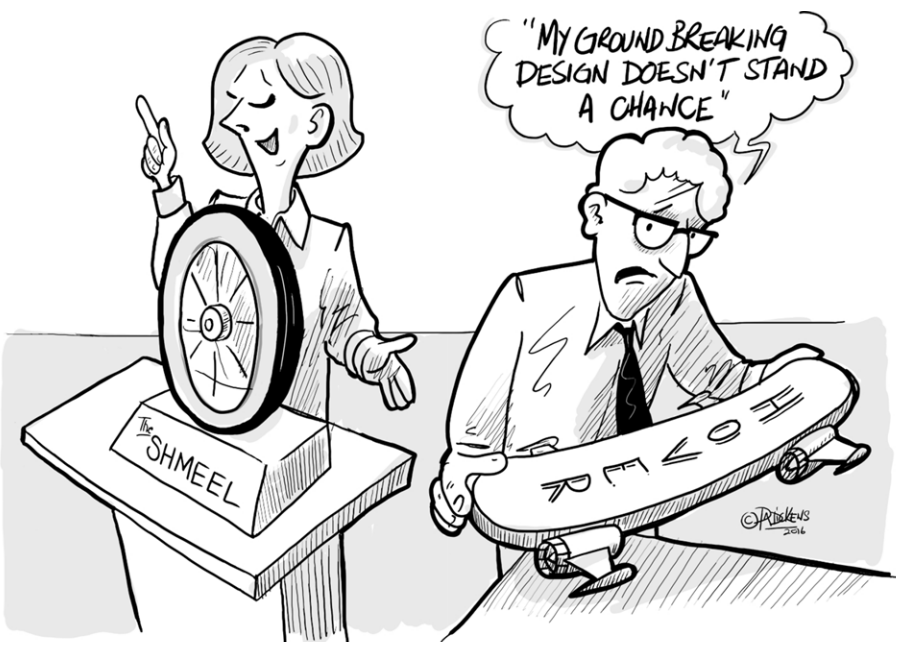
Referring to the triangle of communication that will be discussed in chapter 4, writing a proposal is about self (your idea), audience (the funder) and narrative (why your idea needs investment). The advice given in this book can help you to target and communicate effectively with your potential funding agency, or other investor, and give some useful insight into how to develop scientific ideas into workable projects. But it can't provide those exciting ideas—the truly creative genius is still all very much down to you, which is precisely as it should be.

In this chapter, we aim to take some of the pain out of preparing a scientific proposal. From personal experience, even just the names of some of the elements of a proposal appear daunting to the uninitiated, and the process can appear very mysterious indeed. This chapter will look at the elements that comprise a modern scientific proposal and discuss how to formally develop your science ideas into an achievable project, and then convince reviewers and funders of the need to invest in your work. We will begin by discussing the process of developing your ideas and your project narrative, and then discuss the funding process to offer insight into the machinations of scientific peer review and funding decisions. Much of what will be discussed is directly transferrable to any project proposal (e.g. a business case to a corporate sponsor and investors), but the focus and example here will be on scientific project proposals presented to public funding agencies.

3.2 What makes a good idea?

A million dollar question! This is highly subjective; someone working in a different field may not recognise the importance or feasibility of your idea or project. Thankfully, there are usually checks and balances in the review process that mitigate for this, but this is still something to be aware of when structuring the narrative in any proposal (more on this later in this chapter).

Under-confident researchers (especially those at the beginning of their journey) with truly great ideas can sometimes lack faith in their own creative ability and therefore struggle to express confidence in those ideas. I've also seen plenty of over-confident researchers who have mediocre ideas but believe in those ideas (and their ability) so much that they can present a very strong and convincing case for support. Therefore, perhaps the most important advice I can offer is to be honestly confident. If you're not confident about your ideas and your ability to deliver on them, then it will be impossible to convey that confidence in any research proposal and it will be doomed to fail. The opposite of this would be to present a hollow front for a poor idea, something that is usually blindingly obvious in the cold light of honest academic scrutiny, though of course mistakes do happen. In other words, confidence should flow naturally from a well-reasoned idea that you have invested thought and time into.



Your goal is therefore to think of an idea (or question); first convince yourself that it is important and has potential, and then invest time in the practical development of that idea into a feasible, costed project, before then conveying that natural and bona fide confidence to those assessing the merits of your proposal.

Fundamentally, a good idea has to represent an important new advance in some field of science, and ideally (and increasingly) provide direct and/or indirect benefit to society, e.g. public health, the economy, or the environment. Arriving at that idea is typically a natural process after many years of exposure and research in a specific field such that you find yourself at its cutting edge, for example after completing a PhD thesis. Identifying those ideas or scientific questions is the measure of a truly independent academic that can finally detach from the supervision of a senior academic (e.g. a PhD supervisor) and embark on their own path of investigation. In my own experience, I recall being afraid of any new ideas I had in my early years as a postdoctoral research associate, writing them off in my own head before I'd even realised they were genuinely useful. The reason for this, in hindsight, was twofold: I always thought my ideas must already have been thought of by others; and I didn't think that I had the skills to carry out a project relating to anything other than the immediate research project I was funded to investigate. If I examine those feelings more closely, I can see that they were the result of: a) ignorance—I just wasn't yet fully aware of the state of the field I was working in and therefore didn't know if my ideas were truly novel; and b) in a comfort zone—I didn't realise that the transferrable analytical and self-management skills I had developed could be applied to alternative projects. For me, both of those aspects of my negative thinking evaporated in turn when I pushed myself to write my first independent proposal by investing the requisite time in exploring the field of interest to my idea (to allay my ignorance), and by simply pushing myself to apply and develop my existing skills to new problems (to get out of my comfort zone). Comfort zones are rarely good things. True creativity and enjoyment come when we are able to push beyond them. Therefore, I say again, don't be scared of yourself and allow yourself the time and space to explore your ideas. Discuss those ideas with your trusted colleagues and listen to feedback. And then go ahead with writing your first funding proposal. It may well fail but don't let that stop you trying again and again. Science is built on adventurous and resilient characters that push their own boundaries; and the boundaries, of knowledge in the process.

A good idea is also about the relative balance of risk and reward. Funding agencies often attempt to qualitatively (and sometime quantitatively) assess the risk inherent in any project idea and balance this with the impact and reward that might result in project success. A truly exciting 'disruptive' idea with high risk of failure but high potential reward may well be prioritised over an incremental but relatively safe scientific advance. Many of the projects I receive to assess as a peer reviewer are often safe incremental projects with a sound project design. However, every so often a truly exciting project passes across my desk that really captures the imagination, but that may need a leap of faith to convince that it is a valuable use of resource. My advice here is to be careful but not to be scared. As a seasoned academic with an excellent track record (more on track records later), reviewers and assessors may be more convinced of your ability to deliver on riskier projects, but this should not stop you from trying if you know you have an amazing idea. Just be mindful that any risky project must still have a good project design that minimises, identifies, and mitigates any risks, while also distilling the impacts and rewards that may come if the project is a success.

Let's take two examples here. One that is high-risk–high-reward, and one that is moderate-risk–moderate-reward. Another successful category might be low-risk–high-reward—but my experience teaches me that such proposals are very rare indeed. The first example might be the discovery of the Higgs Boson—a fundamental force-carrying particle that would once-and-for-all complete the Standard Model of particle physics and pave the way for all sorts of new fundamental physics and potential technological breakthroughs. At the conception of the Large Hadron Collider project, this risk was very high—there was no hint of observational evidence, the cost of experimental infrastructure and personnel was enormous, success was far from guaranteed, and the obvious pathways to new technological breakthroughs were not explicitly tangible. However, the case is (and was) compelling, attracting multi-billion euro investment and a stream of keen researchers to the task. The second example might be something like the development of new model parameterisation for weather prediction requiring new field data to validate it—an incremental and easily achievable improvement on an already good weather forecast, using new understanding gained from reliably obtained field data (though my colleagues at the UK Met Office may well argue that such a new advance is far from incremental…).

To summarise, have the confidence to explore your ideas, take the time to research the field of interest, and develop a practical plan (see section 3.3) that turns those ideas into a proposed investigatory project. Consider and highlight the risks and rewards and mitigate, minimize and maximize, respectively. Get advice from trusted colleagues and bring in the skills of those you need to help you to complete your project if necessary. And get thinking! Science needs you.

Exercise: turn an idea into a project

This exercise will help you to think about how to turn an idea into a practically achievable project and the steps involved.

First, write down a list of three science ideas you have that would represent novel advances in your field of interest. This could be the follow-on work you wanted to do when you finished your PhD thesis, some outstanding questions from a recent paper you wrote, or something completely different. Don't play safe—make one of these ideas something truly adventurous and risky (in terms of potential for successful investigation).

Once you have this list, think about what you would need to do to investigate each of them. What equipment might you need? What data do you need? How will you obtain that data and equipment? What facilities do you need? How will you analyse the data or build your prototype? How long will each step take? What can you do yourself and do you need help from others (including people at different institutes) with specialist expertise?

Put these activities into order in self-contained ‘work packages’ and work out the total project time and make a rough calculation of the cost. Think about what can be done in parallel and which work packages depend on the outcomes of another.

For each project, think about the risks at each step. What would it mean if you could not obtain part of the data? How could you minimize the chances of that risk becoming a reality, and what would you do if it became unavoidable? Think about the ‘critical path’ of your project and how you might still achieve project success if part of the project was not possible or yielded a null result.

3.3 How to find a funding body and funding calls

When you have decided you have a good idea and a workable plan in principle, first you must identify a suitable funder or funding agency that fits your idea (and your budget). This may require some leg work if you are new to proposal development. If your idea has industrial applications, you could approach specific companies for investment and ask about their research and development strategies and how to engage with them. For public funding agencies, look up your national science funding council (or councils) and read their webpages to learn what their scientific remit is to gauge whether your project is a good fit to their advertised strategy. In Europe, there is also an over-arching European Research Council that accepts proposals from across the European Union and across many scientific themes. Often, research councils will have email contacts for you to informally discuss whether your idea is eligible and within the council’s remit, and you will usually be pointed in the right direction if not. However, a good chat with more experienced colleagues will normally save you a lot of time here. As discussed in chapter 9, mentoring is a life-long valuable asset in any professional career.

Research councils typically release calls for proposals, or announcements of opportunity, on set advertised dates (with specific deadlines). Other calls for proposals may be open and continuous with rolling deadlines. Spend some time looking at current and past calls for proposals and announcements of opportunity to learn more about what different science funding agencies are interested in, and where you might fit in to their remit. You may also be able to register for email alerts for new calls from funding agencies, and this is a good way to keep track of what opportunities there are coming up, without having to remember to make return visits to webpages.

Sometimes, your idea may need to be adaptive to respond to a specific call that is relatively prescriptive about the science the funder wants to commission. At other times, you may have an idea that is more suited to an open round that accepts ideas across the broader swathe of the funder’s remit. But always make sure that you have identified the right place to submit your proposal to by reading the webpages associated with the funder and any call for proposals.

Perhaps the most important funding opportunity for any new academic, graduating PhD student, or early career postdoctoral researcher, are early career research fellowships. These are highly prestigious awards made to researchers with innovative ideas who show great promise for academic career development. Whilst fellowship opportunities do also exist for researchers at various stages in their career, this chapter will focus on early career fellowships only. Such fellowships are a truly career-advancing opportunity for any aspiring new academic; they are designed to fund your salary and your project costs at a nominated host institute for the duration of the award, and as such mean that you may be free to pursue your project without conflicting demands of teaching and other duties (if this is what you desire and negotiate with your host).

Early career fellowships are as much about an investment in the individual as they are about an investment in a project idea. Funding agencies and reviewers look for proposals from promising new academics with an already strong track record of research outputs, and who have an exciting idea that really capitalises on their existing skill as an independent researcher in their chosen field. Such fellowships may well be hosted at an institute where the candidate is not currently in residence, where the applicant may benefit from new skills and expertise that may be gathered from a world-leading research group that complements their research idea. Equally, it may well be that the applicant has a good case to develop a fellowship at an institute with which they already have much experience. In either case, reviewers will look for evidence that the applicant has a strong record as an independent researcher, and that they know how to synergise with other teams and research groups to meet the objectives of an independently developed fellowship proposal.

Successful fellowship applications (in my experience) are about personal independent idea development, which build on a current track record in a field that is well supported by the host institute. Finding a natural niche within a strong existing research group where you can truly synergise with existing activity is a good formula here. In summary, if you are considering a fellowship proposal, you must also consider the role of your host group (or groups), and the mutual fit of that group to your proposed project idea. You must also demonstrate a longer term career research strategy that justifies the investment in you as an individual academic with career potential.

Once you have identified a funding agency and a call for proposals that you intend to submit to, conduct some more in-depth research to check your eligibility to apply for funding from that agency, and to learn about what components to any proposal may be required in your submission. There is usually guidance and a template that you can follow to make sure that you include all the relevant information the funder needs, for example a CV, budget documentation and a case for support (more on this below). You can typically find all of this information in a funding handbook that can be downloaded or otherwise requested from the funding agency. If in any doubt, always make contact with the funding agency with any questions you have—it is their job to help you. If you are already hosted by an institute that is eligible to apply for funding, always get support there—find out who can help you and let them know about your plans. For example, there may be a research finance office that can help you with costing your project (see section 3.5). Again, speaking with your colleagues is a good way to learn more about what support is available. You should rarely be completely alone in developing a proposal, but you may have to spend some time to learn what support there is.

Exercise: research your funding opportunities

This exercise will help you to think about whom to approach for funding.

For each of the ideas you explored in the previous exercise, do some research into which agencies, companies, etc, you might approach for funding, and find out how to submit a proposal to a call by that funder. Examine the remit of those funding bodies and whether that remit fits your idea. You could begin with a Google search for 'science funding agencies' or at the homepage of your national research council, for example: https://erc.europa.eu/, http://www.rcuk.ac.uk/, http://www.nsf.gov/.

You may wish to register for email alerts with any agencies of interest you find, so that you can be kept up to date on new announcements of opportunity. Also, download any funding handbooks or guidance on preparing a proposal for your funders of interest.

3.4 What are the components of a research proposal?

There is no magic (or ubiquitous) formula unfortunately. However, experienced academics do develop their own formulae when structuring the narrative that is a proposal. There are some key aspects that are essential and ubiquitous to all proposals and there are some that may be interchangeable depending on the funder. Always check your funder's handbook or other guidance to find out what information is mandatory, and any templates that might need to be followed. Sometimes even formatting, font styles and font size are mandatory and may result in outright rejection if the rules are not followed. This can be especially disappointing if you have spent several months of work developing your proposal, only to have it rejected without review due to one line being the wrong font style in an attached CV. The competition for funding can be so fierce and time-consuming that some funding bodies may sometimes be looking for reasons to reduce the number of proposals they have to administer; don't give them an easy excuse to do this.

Some typical components of a modern research proposal may be the following:

- Case for support—justification of your science idea and work plan
- Justification of resources—an itemized budget linked to the work plan
- Pathway to impact—the benefits and legacy that will come from your work and who the potential stakeholders are
- Data management plan—how you will disseminate any data to others
- Curriculum vitae—in an academic style
- Track record—how your experience fits the proposed project

- Project management plan—timelines and responsibilities
- Risk management plan—identification, minimization and mitigation of project risks

There may well be other components depending on the funder and some of these elements may be merged into one document—always check. All of these elements are important, but the case for support is (by definition) where reviewers will look to be impressed by your project. There may also be summary documents that you may be required to supply that explain your idea to a lay audience or to prepare reviewers for the detail in the rest of your proposal. There now follows a more detailed look at two of the most important components: the case for support and the pathway to impact.

3.4.1 Case for support

This is arguably the most important part of any complete proposal. This is where you need to convince reviewers that you have a workable project and an important idea worth investing in. This can be anything from a few pages of A4 to many volumes (for very large and complex projects with multiple work packages, e.g. a new satellite instrument). More often than not, it is a challenge to make your case in the space allowed. This is where your communication skills are important. You must efficiently, succinctly and transparently describe your science idea to the level and range of reviewer expertise. Reviewers are usually selected by the funding agency (see section 3.6), and are typically leaders in the field in which your proposal lies. However, the subject matter of many proposals may be so cutting edge that not all reviewers will have a high level of expertise in the specific area. Therefore you must prepare your narrative for an audience that spans from the general to the highly specialised scientist in your field. For example, in my field of atmospheric science, a proposal about the aircraft-based measurement of greenhouse gases may be reviewed by both someone who is an expert in the mathematics of sampling theory, or by someone who develops sensors to measure greenhouse gases on the ground. Clearly, each reviewer may understand some aspects of the proposal better than others, but it is your job to provide sufficient clarity such that any reviewer can both understand the general thrust of your proposal, yet also access the necessary technical detail they may be looking for on any specialist aspect in their area of expertise.

The best way to do this is to structure your proposal such that you 'funnel' the reader from the overall project idea and deliverables (e.g. an executive summary), through the general scientific context of the wider field surrounding your idea, before finally describing the cutting edge of that field that you plan to address and how you will do this. At each stage as you dive deeper into the technicalities, it is useful to always introduce and summarise each section in turn. Like any story, your case for support, and each section of it, must have a beginning (an introduction and leading summary or abstract), a middle (flowing from the general to the technical), and an end (legacy of the project). This rolling introduction and summary throughout each self-contained section really helps reviewers to digest your project ideas, and works on the principle of triplicate repetition and memory retention—tell your audience what they are about to read, give them the information, and then summarise it for them. If you look carefully, most textbooks (including this one) and research papers follow this exact principle.

Reviewers are typically very busy academics who are not paid for their review work—your job is to make the narrative as easy for them to understand as quickly as possible. A busy reviewer will have no patience to read over your proposal many times to try to understand it. You must capture them on the first sentence and retain their concentration until the last. By taking them on a journey from introduction to technical detail and back to concluding summary, this will make the digestion of the information much easier for readers and reviewers and help them to commit it to memory. It is simple psychology that a pleasurable reading experience will put the reviewers in a better frame of mind to more objectively score your proposal; especially if you've facilitated their understanding of any technical detail by funnelling them through that detail gently and succinctly.

A generalised structure to a case for support might resemble the illustration in figure 3.1, following:

1. a short summary of the project and why it is important
2. an introduction or literature review that discusses the scientific context to your field (e.g. previous work), which culminates at the cutting edge that your project addresses
3. a description of what your project will do, broken down into self-contained but cross-linked work packages
4. a description of the deliverables and outputs of your project linked to those work packages
5. a concluding summary on the legacy of the project and the future science that might be enabled by it

Sometimes, project management and risk strategies may also form part of the case for support—check the funding handbook(s) of your chosen funding agency for detail.

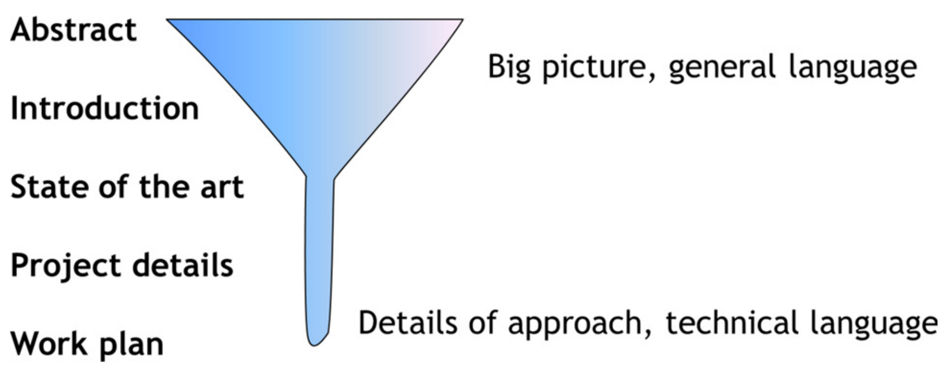


Figure 3.1. The proposal 'funnel'—a narrative journey from the general to the specific.

First-time scientific proposal writers often have experience of writing peer-reviewed papers, and find it difficult to properly weight project design against scientific context, i.e. the underpinning literature review. I often get asked about how much to include on this relative to the details of the project. There is no single useful answer here, but it is important to remember that a proposal is not a research paper. It is important to summarise the state of play in the field that underpins your project and to identify the gap that you will fill, but this is secondary to the details of the project that you intend to carry out. Most reviewers will already be familiar with the field, therefore your introduction and literature review should be a highly succinct summary that rapidly funnels to the cutting edge that you address, before you then start describing your project in more detail. Any contextual discussion is about demonstrating to the reader that you are well informed and at the cutting edge of your field; and proving the importance of the work you propose to do. It is not about regurgitating everything you know about your subject, whilst exhaustively listing and discussing the merits of every paper ever published in the field. When you are limited on space, it is important to get into the project details as quickly as possible and not to bore your readers with what they may already know.

Now let's try and explain this further by way of our example of the aircraft-based measurement of greenhouse gases mentioned above, albeit in a very simplistic and abbreviated way so we can see the general flow and structure of a proposal:

1. **Summary**—measuring greenhouse gases is important to understand climate change. Using aircraft sensors is a good way to measure them. This project will do that and provide new data to climate scientists.
2. **Context**—lots of work has been done to measure greenhouse gases on the ground but more data is needed in places that only aircraft can get to. Complex computer models can be used to calculate emissions using this data.
3. **Work Packages—**this project will: a) install a new instrument on a plane; b) provide data from the new instrument in a special field campaign; c) interpret the data using complex computer models to derive new maps of greenhouse gases and their sources.
4. **Deliverables**—this project will provide: a) new datasets for use by scientists; b) new understanding of greenhouse gas sources in new places; c) papers, conference presentations, etc.
5. **Legacy**—new maps of greenhouse gas sources will allow future work to update climate predictions and target policies for emissions reduction.

If you can leave the reviewer with a clear and complete story about what you want to do, why it needs to be done and how you will do it, you have succeeded in writing a good case for support.

3.4.2 Pathway to impact

This is where you explain how the deliverables of your project will benefit others. It is about recognising how your work fits into the wider community and society, and how to make sure that you are not the only human being to know about your exciting work. It is a more detailed description of the legacy of your work, and should contain a description (pathway) of how any potential benefits will be realised in practice.

The first step here is to list the stakeholders in your research—who benefits and why. These stakeholders could be other academic beneficiaries who may wish to use your data for other projects. They could be members of the public who will benefit directly or indirectly because of some change brought about by your research (e.g. a new drug that will improve lives, or an improvement in air quality due to new policy advice). They could be industrial partners who will use your research to develop new technology and generate economic benefit. Or they could be schoolchildren and interested individuals who will learn about your work through targeted activities and knowledge exchange events.

The key here is to think about the wider beneficiaries of your research and then think of ways to maximise that potential through knowledge exchange pathways. For example, if your work has an economic benefit, how will you engage with companies who might want to use it? How will other academics learn about your new datasets? How will you inspire others? Do you need time and money to do this? Might the media be interested?

Keep in mind that your work should always be about the construction of new knowledge, and how this can be used to benefit others and the world around you. If you remember this, and take some time to think about how you can make that happen, this should be a natural and simple part of any proposal.

Exercise: write an impact plan

For the ideas that you developed in the first exercise in this chapter, list all the stakeholders you can think of for each project. These may be other research communities, specific companies, public bodies, policy makers, educators, and groups of the general public. Write a line or two about what outcomes of your project are relevant to each one. For each stakeholder, think about how they might interface with your project or its outputs and how you might facilitate knowledge exchange, e.g. publications, conferences, workshops, stakeholder events, policy guidance, one-to-one meetings, follow-on projects, etc. How will you engage with each stakeholder and at what point in the project? Finally, write about what might come from this engagement and the benefits to you, the stakeholder and society in general.

3.5 Budgeting

It can sometimes be difficult to know exactly what resources you will need in order to carry out a project. This is definitely an area where you should seek help from finance administrators at your host institute, who can calculate costs for you once you have defined what you need (e.g. two years' salary for a research assistant to help you).

It can often be tempting to reduce costs to make a proposal look more attractive to a funder. Much care is needed here. The best advice I can offer is to resource exactly what you calculate you will need, justify the resource, and ask for not a penny less, or a penny more. And make sure the project design fits within the budget available. Don't be tempted to propose an overly ambitious project that you cannot afford to do within the budget that is available. Reviewers and funders will look for justification of the resources requested and also look to see that the project is properly funded. If you have asked to conduct a field project but you have forgotten to ask for the cost of travel and accommodation, a reviewer may ask how you intend to pay for this. Equally, if you have costed a stay in a five-star hotel and a three-course meal every evening, a reviewer may ask why this is justified.

In summary, it is more important to resource your project fully to meet all the needs of the project design than it is to miss anything out to make it appear cheap. And in all cases, your total cost must be less than or equal to the maximum budget that may be set by your funder. Your costs also need to be realistic and appropriate. It is usual to assume some contingency (e.g. inflation over the course of a project), but wild estimates of costs for items on your proposal will make you look greedy (does that laptop you need really cost as much as you suggest?). You may need to seek multiple quotations for expensive new instrumentation and you may need to attach these with your proposal. You may need a research assistant to help you, who will then need to be costed by your host institute. If you find that the calculated costs exceed the allowed maximum, you may need to redefine the project activities. It is better to do this at the planning stage than to find yourself unable to carry out the project after you have received an award.

In most cases, your host's finance administration will help you with (and usually must approve) costs for staff and other items. But the costs of any equipment, travel or consumables must be calculated by you and provided to them. And all costs must be justified against the needs of the project, and itemised for scrutiny by funders in the justification of resources information.

Finally, it can be a very useful exercise to think about and plan how you might leverage funding or contributions-in-kind from other partners, or from any other grants you may have been awarded. For example, if a colleague at a laboratory at a different institute or company has offered you free access to their unique facilities for your work, or someone has agreed to provide you with a unique dataset and advice in using that dataset; these in-kind contributions represent significant added value to any proposal and can help to bolster the quality of any proposal, not only by adding value but by benefitting from expert support and guidance, thus minimising risk and serving to enhance impact and knowledge exchange. To this end, think carefully about how you can garner support from your colleagues at other institutes and how you might be able to work together for mutual interest and support. If such support is forthcoming, be sure to gather letters of support from those partners explaining what their contribution to your project might be, and why they are supportive of your project ideas.

3.6 The funding process and peer review

One of the most frustrating things you may have to learn to be resilient to in your career is that the majority of your proposals may simply not be funded. I do not know any academic (even Nobel laureates) who can honestly say otherwise. The reality of modern funding frameworks, both in publicly funded science and in industry, is that the pot of money is not bottomless, and there is a large pool of very clever and competent people out there, all with great ideas that are often in direct competition with you for funding. All that you can do is to present your ideas and case for support in the best way possible, rejoice and excel in success, and learn from feedback on your failures. Often, you may find that reviewers and funders may have recommended your proposal to be of high priority for funding, only to find that the finite pot of money means that other proposals higher on that priority list receive the funding available at the time. In this scenario, it is important to keep trying, refining your ideas in the process and not treating them as failures.

Finding your potential funder and writing your proposal are the part of the process that you have complete control over. Once you have submitted your proposal, the process of review and assessment begins. To give yourself the best chance possible after submission, ask senior colleagues to look over your proposal and provide an internal peer review. Do this well before any deadline and you will have time to build on their constructive comments. Many institutes require formal internal peer review prior to approval for submission to funding agencies in any case.

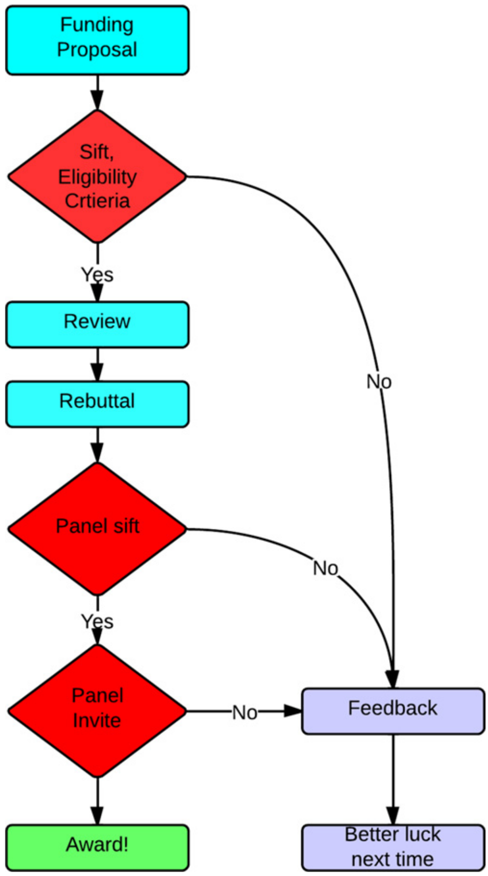


Figure 3.2. Flow diagram of the funding process, from proposal submission to award.

The typical pathway to a successful (or unsuccessful) funding award may follow that outlined in the flow diagram shown in figure 3.2. You can find the exact pathway for your funder from their guidance information—for example, not all proposals require a face-to-face interview with a funding assessment panel, and not all funding calls allow you the opportunity to respond to reviews. Typically your proposal will be first reviewed and scored by experts. Those reviews, sometimes together with your response to them, will then be passed to a specially convened funding panel consisting of several members, who will then judge the relative merits of each proposal based on the reviews and responses, and make a recommendation on priority for funding (usually assigning a score against criteria you can examine). A rank order will be defined by this panel for any single call, and the funder will then award money to those proposals down the list until the money available is exhausted. We will now briefly look at each of these stages in turn.

On submission of your proposal, a funding agency will first check for the individual's eligibility and whether the science proposed is a fit to their remit. They will then check any formatting requirements and check that all components of the proposal are present. Some funding agencies can be quite unforgiving at this stage and may reject a proposal without scope to put things right, so make sure you have provided everything required exactly as it is asked.

After this initial check, the funder will select and invite potential reviewers to report on and score your proposal against pre-defined criteria. You can usually find information on the questions reviewers will be asked and the scoring criteria in the guidance provided by the funder. It is always useful to examine these, and to make sure that your proposal clearly provides information to help the reviewer. You may also be asked to provide the contact details of potential specialist reviewers who are not connected with the project. This does not guarantee that those individuals will be approached by the funder, but it is very good practice to provide names for professionals that you are aware of, and who may be best placed to understand and comment on your project idea. The funder can then judge the fit of any reviewers you suggest and may choose to invite them.

The pool of reviewers that a funding agency calls on is typically carefully constructed, and consists of leading experts in the fields within the remit of that agency. However, some proposals may well be reviewed by academics or professionals with only limited expertise in your area. Reviewers are usually experienced and objective and will make clear to the funding panel where the limitations in their review may be. They will be asked to comment on the scientific import of your project, your ability as a project manager to carry out the work, and the efficacy of the project design in terms of its strengths and weaknesses. They may be asked to comment on any risks, and they will be asked to comment on the impact of the project and the justification of resources. In the case of fellowship applications, they may also be asked about the track record of the applicant and their potential as an independent researcher.

Depending on the funder and the call, you may get the chance to respond to (or rebut) any reviews to help to clarify any misunderstandings. If this is the case, you may receive any number of reviews (usually an absolute minimum of two, and typically more). As discussed in chapter 2, it is important not to see your reviews as personal indictments—they are expected to be an objective discussion of your proposal and you should see your response to them as equally objective. At times, you may feel like the review is an attack on your proposal. And in many ways, that is exactly what it is supposed to be. It is your job to defend your approach (if you feel the reviewer is wrong) and answer any questions raised. Address each comment in turn politely. And be honest. If a reviewer has truly misunderstood some aspects of your work, the funding panel (more below) who make the final decision will read both the review and your response and reach a judgment. In many cases, the funding panel can completely disregard reviews it feels are not accurate or objective, so don't be too disheartened if you receive negative reviews. It is actually better to have a detailed review than it is to have a very short, shining endorsement of your proposal that contains nothing that the funding panel can make a judgment on.

An awards panel is convened by the funder to prioritise and score proposals after peer review. The panel typically consists of leading academics drawn from the peer review pool whose expertise covers the range of topics in the submitted proposals, a chairperson (to manage the discussions and keep the panel on track), a secretary from the funding agency to advise on procedural issues, and a funding agency observer who may sit on several panels to monitor consistency in funding panel decisions across the various calls administered by the funding body. Your proposal will normally be described to the entire panel verbally by a first introducer that has been asked to read your proposal, the reviews of your proposal, and your response to the reviews in advance of the panel meeting. A second introducer will be asked to do the same in turn, and the chairperson will then ask the two introducers to discuss the strengths and weaknesses of the proposal and invite others on the panel to comment. Ideally, all members of the panel will have read every proposal and are free to do so. However, in practice, each panel member may be asked to introduce many individual proposals and the total being assessed in any one panel may be very large indeed, meaning that panellists typically may only read and comment on those proposals most closely aligned with their expertise. The first and second introducers will then be asked to agree on a score that is recorded by the secretary. Having sat on several such funding panels, it is an exhausting, but very objective and transparent, process. The panellists will do their best to assess the relative merits of your project, and the checks and balances of the panel process and peer review really help to ensure neutral objectivity. However, the process works best for you when you can really make it as easy as possible for all concerned to fully understand and access your project. Try to put yourself in the position of a panellist when writing your proposal—make sure that every word and sentence is meaningful and useful, and that its structure allows a very busy person to absorb it easily. If you don't get this right, you risk your ideas being lost in the noise.

After the panel have scored your proposal and all others, a rank order of the scores will be compiled by the panel secretary. Many proposals may have equal scores and those that do have equal scores must be placed in priority order relative to those around them. At this point, the panel may briefly re-examine those proposals and rank them again such that a monotonic rank order is achieved.

Finally, the funder will allocate funding down the list and draw a line when the money is exhausted. If your proposal is above this line (and scored fundable in principle), then congratulations! However, the vast majority will typically be below this line. It is not unusual that fewer than one in five proposals (and sometimes even fewer) will make the funding cut. With this in mind, remember that you may have to write five good proposals before you have an odds-on chance of beating the average. Your job is to stack the odds in your favour by writing excellent proposals based on exceptional ideas.

If you have been unlucky, you may be able to request feedback on the comments of the panel, outlining the reasons for a lack of award. Reflect on those comments, learn from them and consider resubmitting your proposal in future by addressing any comments from the panel and reviewers. The important thing is not to give up and not to take it personally. Our role as a scientist is to discover, question, and defend the truth. This is precisely what the peer review process mirrors. Don't be afraid of yourself, your ideas, or those that rightly question them.

3.7 Summary

This chapter has described how to apply for funding and how to frame scientific ideas in the form of a well-structured case for support narrative. We have explored the machinations of the typical funding agency peer review process. But most of all, this chapter has explained how any good proposal and project idea is born out of confidence in exploring your own creativity and reflecting constructively on your own ideas. Be confident, be resilient, be methodical, seek advice and support, and give it a go. Good luck!

3.8 Further study

The further study in this chapter is related to your grant writing skills; it should make you think further about what is necessary for successful writing:

1. **Read some successful grants:** ask the research and knowledge exchange office (or equivalent) at your institute to see a selection of successful bids. Alternatively go to a funding body's website and look for past examples of previous successful applicants. Reading a selection of successful bids will help you to understand what is required of you, and will help you to develop your own writing style.
2. **Make a list of upcoming deadlines:** select a number of funding bodies that you are interested in working with and make a note of their upcoming calls and their respective deadlines. Are any of these achievable for you to apply for?
3. **Prepare a research proposal:** if you are ready, select your most promising idea and write a case for support, using the responses that you have provided to the other exercises in this chapter to help you. Note any deadlines for submission and plan your time for writing the proposal, allowing plenty of time for development and discussion with trusted senior colleagues.

Suggested reading

Scientific Writing and Communication: Papers, Proposals, and Presentations [1] covers both written and oral presentations in significant depth. As one of only a few known books that cover proposal writing, this resource is highly relevant to this chapter. However, it also represents a potential one-stop shop for further reading on both technical writing and presentation. The United States National Science Foundation (NSF) funding handbook [2] is a great first place to learn about the components and structure of any scientific proposal. While targeted at those wishing to apply to the NSF, much of the more general information is relevant to any national funding council. *Getting Funded: The Complete Guide to Writing Grant Proposals* [3] (now in its fourth edition) focusses entirely on proposal development, from scoping an idea to the submission and review of a full proposal. It also deals with budgeting and human resourcing. Finally, *Proposal Writing: Effective Grantsmanship* [4], whilst written by academics, covers proposal writing for submission to a wide range of potential funders other than national scientific funding councils, including corporate sponsors and philanthropic foundations. It provides some useful guidance on choosing an appropriate funding agency and also deals with logistical aspects such as budgeting.

References

[1] Hofmann A H 2010 *Scientific Writing and Communication: Papers, Proposals, and Presentations* (New York: Oxford University Press) pp 186–219

[2] United States National Science Foundation *Funding Handbook* www.nsf.gov/funding/, accessed 8 July 2016

[3] Hall M S and Howlett S 2003 *Getting Funded: The Complete Guide to Writing Grant Proposals* (Portland, OR: Continuing Education Press)

[4] Coley S M and Scheinberg C A 2007 *Proposal Writing: Effective Grantsmanship* (Thousand Oaks, CA: Sage Publications)

IOP Publishing

Effective Science Communication
A practical guide to surviving as a scientist
Sam Illingworth and Grant Allen

Chapter 4

Presenting

Nothing in life is to be feared, it is only to be understood.

– Marie Curie

4.1 Introduction

Sooner or later in your academic career you are going to be asked to give a presentation. This may be at a weekly group meeting, or at an international conference; both of which have their unique set of potential hurdles to overcome. Presenting to any audience, and in any context, can be a difficult and demanding exercise, and no matter what anyone tells you it is something that needs to be worked at. Colleagues that profess to make it up as they go along, or 'wing it', are either seasoned professionals who have delivered similar material many times before, or else they are deluded and they are not actually that great a presenter at all.

There are various audiences that scientists may communicate with, and it is important that we choose our narrative carefully, depending on who we are engaging with. It is equally important that we consider how we present ourselves in the process. This chapter is focussed in particular on giving scientific presentations, such as at scientific conferences or to colleagues in smaller group meetings. Communicating to other audiences is addressed elsewhere in the book, mainly in chapters 5 (the general public), 6 (the media) and 7 (online). Whilst this chapter will focus on presenting to a mainly scientific audience, it also provides practical advice to help you to be a more successful public speaker. However, the biggest piece of advice that we can give is perhaps the most obvious: practice makes perfect. As the noted American author and humourist Mark Twain once said, 'It takes three weeks to prepare a good impromptu speech'. Regarding the delivery of a successful presentation, the following adage holds true: *fail to prepare and prepare to fail*.

4.2 A three-way approach

There are many theories on the best way to create and deliver a presentation, but the approach discussed here is based on the work of Edward Peck and Helen Dickinson [1],

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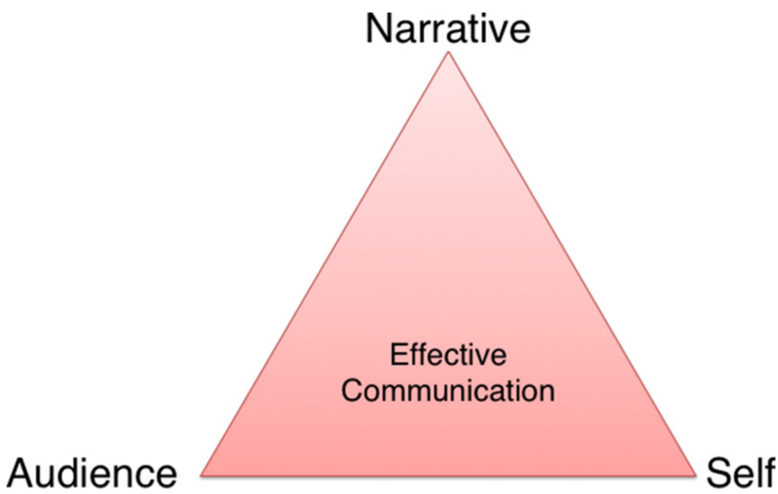

Figure 4.1. The triangle of effective communication.

who outlined the three areas that need to be considered in order for effective communication to take place: the narrative, the audience, and the self.

Figure 4.1 outlines this three-way approach in the form of a geometric shape: the triangle of effective communication. Without all of its three components, the concept at the centre cannot exist. That is to say that in order to communicate effectively, you need to consider the audience, the narrative and the self, and that if

just one of these components is missing then the effectiveness of the message that you are trying to deliver will be reduced. We will now consider these three components, and discuss what is necessary to ensure that they are well-developed instruments in your presentational toolbox.

4.2.1 Developing your narrative

The ultimate purpose of a presentation is to communicate some pieces of information to an intended audience. This information might be that you have found some interesting findings as a result of your research, or it might be an update on some recent problems that you have been having. No matter what it is that you are trying to communicate, there will be some take-home messages that you want to be imparted to the audience. In order to ensure that your audience have taken away from your presentation the message that you intended, it is important to do a little planning first. A very effective method of doing this is outlined in the following exercise.

Exercise: three take-home messages

Think about the next presentation that you are going to give. Now, sit down at your desk or computer and imagine an idealised world in which your audience leaves the presentation knowing exactly what you wanted them to know. What would that be? Write (or type) down the three key take-home messages for your presentation. For example, if you were giving a presentation on 'Effective communication in presentations', you might want your audience to leave knowing about the importance of audience, narrative, and self.

Once you have written down these three take-home messages you can use them to create the structure for your presentation, as ultimately these are the important points that must be communicated. These three points can also be used as the final slide in any presentation, as it will serve to further highlight their importance to your audience.

Of course finding the three take-home messages and then using this to structure your narrative shouldn't be restricted to presentations. This is also an incredibly useful technique that can be utilised in any form of communication, from international teleconferences to meetings with a supervisor or line manager. Next time you have something important that you need to communicate, sit down and work out what your key take-home messages are first; it will help you to align your arguments and will make it far more likely that you achieve what you set out to do.

Once you have your key take-home messages it is time to start building the narrative that will allow them to be communicated in a succinct and logical fashion. Giving a presentation is effectively like telling a story, which means that the same basic concepts of narrative that are applicable to storytelling are also applicable when structuring a presentation.

In their most basic format, stories have a beginning, a middle and an end, and in this respect scientific presentations are no different. You must begin by introducing your audience to the narrative, by providing background and context to your results and analysis. Without this introduction you run the risk of alienating your audience, but similarly if this introduction is overly long then you are in danger of losing your audience's attention before you have even got to the juicy bits. The introduction is also necessary to justify to the audience that the story you are about to tell is worth listening to.

The middle part of a story is where the crux of the plot takes place and develops. Having laid the scene with the introduction, the storyteller is now able to explore the more interesting elements of the narrative. In a scientific presentation, this is where the methods, results, and analysis would be found; having explained the context or theory and justification in the introduction you now have the opportunity take the audience on your journey of discovery. What did you find and how did you find it? What do you think that this might mean?

The end of the story is where the loose ends are tied up, where the storyteller skilfully gathers together all of the different elements in a final passage which gives insightful context to the narrative. In a scientific presentation it is the conclusion that fills this requirement, in which the presenter must gather together all of the previous strands and then present them as a final analysis. Having laid out the experimental process and the reasons for doing so, were the results as expected, and what will be your future direction(s)?

An overview of a science story is shown in figure 4.2; there are of course some narratives that make a conscious decision not to tie-up all of the loose ends, but rather to leave things relatively open-ended with the audience left asking for more (see *Gravity's Rainbow* by Thomas Pynchon or *Everything is Illuminated* by Jonathan Safran Foer for literary examples). The reality of science means that in many instances there is no 'neat ending' to these stories either, but rather a series of questions that await further analysis. The skill is to gather all of these elements

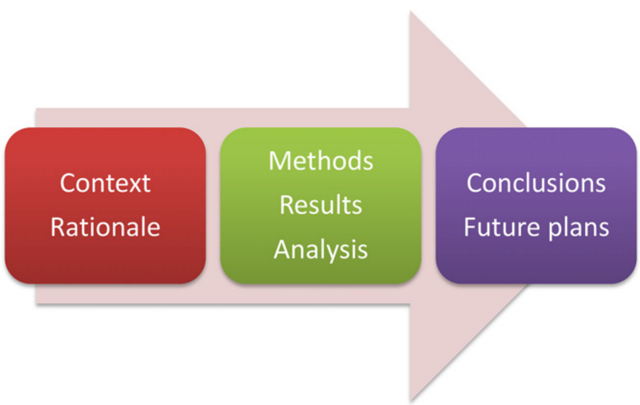

Figure 4.2. Telling your science story using a linear narrative for a scientific audience.

together, and to not only leave the audience wanting more, but to hopefully prompt them into offering useful suggestions. It is also important to note that this particular linear storytelling device is also dependent upon the audience. For example, when giving a presentation to journalists, it may be more useful to start with the conclusions and most important points about the research in order to grab the audience's attention early on. These points will be discussed further in chapter 6.

4.2.2 Understanding your audience

The second aspect in the three-way approach to effective communication that needs to be considered is that of your audience. Without the audience you may as well be giving a presentation to a blank wall, and sadly in some cases this appears to be the exact technique that a not insignificant number of scientists are still adopting. Talking about your research is an excellent opportunity to promote yourself, and to impress the importance of your work upon the people in the room. If you are speaking as if no one is there, then that is precisely how many people are going to be interested in what you have to say.

There appears to be an unwritten understanding that speaking in front of your peers is a terrifying experience. Whilst we will deal with issues of nervousness later in the chapter, it is worth taking a moment to reflect on this misconception. In almost all instances, the audiences that you will be presenting to are understanding, considerate, and willing you to do well. There are of course exceptions, but the important thing to remember is that you are not the opening act for a provincial stand-up comedy tour. The audience is not baying for your blood, they are almost certainly there because they want to hear what you have to say, and most of them will be sensitive to the fact that they have (probably very recently) stood in your shoes.

Given the understanding, considerate, and patient nature of your audience, it would surely be unfair to dismiss them entirely out of hand and to speak as if they were simply not there. Your audience are an integral part of your presentation, and by working with them, rather than ignoring them, you stand a much better chance of not only effectively communicating your message, but of enjoying yourself in the process.

Now that you have decided to acknowledge your audience, the least that you can do is to consider their needs. Whilst they are not expecting a rendition of *Hamlet*, they will still expect to be entertained. And in order to entertain them it is first important to speak to them in a language that they understand; the following exercise should help with that.

Exercise: know your audience

You have one sentence to explain your research to a five-year-old child. You should avoid using any scientific jargon, or indeed any words that would not be understood by the target audience. Once you have done this, read it out loud and see if it would actually be understood by a five-year-old, or even better find an actual five-year-old and see if they understand what on Earth you are talking about; if not then start again.

Taking that idea a little further, write one sentence that explains the crux of your presentation to a lay audience. Once again, avoid using any scientific jargon, or indeed any words that would not be understood by the target audience. To make this easier, try using the 'Up-Goer Five' text editor [2], which restricts you to using the one thousand most used words in the English language. This fabulous tool is based on an equally fabulous comic from xkcd.com [3], which presents a diagram of the Saturn V rocket using only the one thousand most common words in the English language. Once you have done this, test out your sentence on a member of the general public and see if they understand it. If not try again.

Continue this exercise by writing two sentences: one that summarises your presentation to a general scientific audience, and one that explains it to a highly specialised audience. Try these out on the respective audiences, and then use them to help you to form the central narrative of your presentation (depending on your audience), as outlined in the previous exercise.

By considering the audience that you will be presenting to, you will avoid the dual pitfalls of either patronising or baffling your audience. Obviously, with larger audiences, it might be difficult to cater to the needs of every individual. However, by considering the scientific expertise of the majority of the room, you will help to ensure that you maintain their attention throughout.

Considering your audience does not only mean speaking in a language that they can understand, but also involves highlighting the aspects of your work that they would most likely find the most interesting and engaging. For example, it would be far more interesting to an audience if you were to tell them that your research involved 'studying the chemistry of water that drips inside caves to find out what the climate was like in the past', than it would be if you simply told them that you 'use instruments to study the chemistry of water that drips inside caves'. Likewise, it is important to give consideration to what elements of your research your audience might need to know more about, or which sections require less attention. For example, if you were presenting your research on the effects that climate change has on bird migration patterns to a room full of experts on the subject, they may require less of an introduction to the topic than if you were speaking to a room full of climate change scientists with no knowledge of bird habitats or behaviours.

A final issue to consider is the use of jargon in a scientific presentation. Introducing a large collection of words that are alien to your audience is the quickest way to disengage them with your subject matter. There is nothing wrong with introducing new terminology, but it is important that you explain what you mean, ideally by contextualising the term. It is also important to remember that jargon doesn't just mean words that are not understood, as it can be equally applied to words or phrases that may have a different meaning depending on the field of expertise. For example, if you were talking about long timescales, the understanding of this term would vary considerably between a meteorologist and a palaeontologist.

4.2.3 Managing yourself

The third component of the effective communication triangle is you. Without you there is no presentation, and it is important that you spend as much time thinking about how you will present yourself, as you do on considering your audience and the narrative of your presentation.

At first, the concept of managing, or presenting, your self can seem like quite an abstract concept. However, it can be easily broken down into a handy mnemonic, as shown in figure 4.3.

If you are able to master all of these components, then you will have succeeded in managing your self. Taking each one of these in turn:

Stance—the way in which you physically stand is vital in providing positive reinforcement, both to your own confidence and to that which the audience has in you as a presenter.

Assurance—being confident should not be confused with being arrogant or cocky. Your demeanour should highlight the fact that you are authoritative in your subject matter, but that you are also approachable. Above all else, it is important to be yourself.

Voice—your voice is the most versatile and important tool at your disposal. Take time in getting to know it. Consider how your pitch, rhythm, tone or volume can affect your delivery and *always* remember to warm it up properly.

Figure 4.3. SAVE your self.

Eye contact—try and make eye contact with everyone in the room at least once during your presentation. However, be careful not to be too intense, or to focus on one person for any prolonged length of time.

If you are someone that naturally uses a lot of gesticulations, then don't be afraid to use them as you talk. If you don't then it will probably feel unnatural to you, which will affect your assurance and ultimately lead to a poorer presentation. Similarly, if you are someone that does not normally use gesticulations, then please avoid trying to shoehorn them into your delivery, as they will become an unwanted disruption to both you and your audience.

Despite what you may have heard there is absolutely nothing wrong with injecting a bit of your personality into a presentation, in fact many audiences will thank you for it. However, it is again important to consider both your audience and your self in this process. Don't do anything that doesn't feel natural to you, or which would leave you feeling awkward, as this is easily picked up on by the audience. Being an assured presenter does not mean that you have to be an extrovert, it is all about feeling comfortable in your own skin, so that when you speak you are in a place that feels comfortable to you. For example, humour can be used incredibly effectively in communicating your narrative. Some presenters use humour to great effect, whereas others should leave it well alone.

These ideas are developed further in an accompanying video, available at http://ej.iop.org/images/books/978-0-7503-1170-0/live/bk978-0-7503-1170-0ch4f3.m4v.

4.3 Dealing with nerves

One of the major things that needs to be considered when giving a presentation is nerves; specifically, how to deal with stage fright. Well-worn advice on this topic is that everybody suffers from nerves, and that you simply need to harness this nervous energy in order to give a fantastic presentation. Whilst elements of this may be true, it is not particularly practical, nor is it helpful to many would-be presenters, who are perfectly capable of rationalising their fears, but are still unable to master them.

The best way to prepare for a presentation is to practise it until you are completely comfortable with the content and with your delivery. Often, nervousness arises from the fear of the unexpected. If you are confident with the content and with your delivery, then you will be far less likely to get nervous.

It is advisable to practise your presentation until you are able to deliver it without notes, doing so will greatly help both your nervousness and your engagement with the audience. After all, if you don't have any notes then you don't have anywhere from which to physically lose your place. Similarly, it is advisable not to work off a script, as doing so will affect your delivery and will lead to further nervousness if you lose your train of thought, or accidentally stray from the written word.

The most effective way to practice your presentation is to perform it about 5–10 times, each time aiming for a few key points and phrases that you can iterate with each repetition. This will result in the most natural delivery style, and will also present you with the least stressful situation in terms of recollection during the actual delivery process. Practising without your slides is also a good idea, as it will allow you to imagine where the transitions are without an over-reliance on visual aide memoirs.

If speaking in front of a small group of people does not faze you, but the idea of talking to a larger audience fills you with dread, then there are a couple of things that you can do to overcome your worries. If you have the time, then practise in front of a gradually increasing audience size. Start off with a small group that you feel comfortable with, and then increase this until you are speaking to 20–30 people in a room, for example during a research group's weekly meeting. At this point it might be difficult to continue to practise in front of an incrementing audience, but the confidence that you have gradually built up should help you to make the leap to a larger number of people. Another tactic for dealing with large groups is to make a note of where a friend or colleague is sitting in the audience. Begin by pitching the speech to them, and then gradually as you gain in confidence start to expand out to the rest of the audience. Whatever you do, do not picture the audience in their underwear; this will only serve to present awkward moments later on, when you are talking to these people after your fantastic presentation.

Meditation is also a useful way to calm your nerves, prior to the delivery of a presentation. If you can find a quiet space in the build-up to your presentation, even if it is only for a couple of minutes, then use it to relax and to gather your thoughts.

Above all though, it is important just to be yourself. If you have that assurance, then you will find the extent of your nervousness to be greatly reduced.

4.4 Rhetoric

The ancient Greek philosopher Aristotle defined rhetoric as ‘the faculty of observing in any given case the available means of persuasion’. Rhetoric was originally abhorred in ancient Greece, on the grounds of it being used for the promotion of the subjective truth of the speaker, rather than the objective truth of the argument. However, Aristotle saw the necessity for rhetoric, effectively so that those who were arguing for the search of an absolute truth could do so using the same tools as those who were pedalling their own agendas. Whilst today rhetoric may be seen by many to be a euphemism for ‘all style and no substance’, or as the exclusive tool of politicians and snake oil salesman, this need not be the case. It is incredibly useful to understand the three basic elements of rhetoric, as they can then be harnessed in order to help deliver more effective and thought-provoking communication.

Ethos is an appeal to *ethics*, and it is a means of convincing an audience of the character or credibility of the persuader.

For example, when applying for a job you would want to convince the interviewer of your suitability for the role, and might draw on previous experiences and responsibilities to convince them that you have the necessary expertise.

Logos is an appeal to *logic*, and is a way of convincing an audience by reason.

For example, when explaining to an audience the validity of your data, you might take them through a step-by-step process, in which you remove all doubt that what you have observed is spurious or unrepeatable.

Pathos is an appeal to *passion*, and is a way of convincing an audience of an argument by creating an emotional response.

For example, when having an argument with a loved one you might choose to recall a particularly hurtful example of when you had been let down by them in the past. It is important to remember that pathos is an appeal to all emotions, not just positive ones.

Whilst the use of rhetoric most readily lends itself to the construction of your narrative, there are still many occasions in your interaction with the audience and the consideration of your self to which it can be applied. For example, in the UK many dignitaries and celebrities wear a poppy when they are being interviewed on TV around the time of Remembrance Sunday. This indicates to the audience that this person is respectful (ethos), whilst also creating an emotional response in the viewer (pathos), depending on the connotations that they associate with the poppy in this context.

4.5 Using your tools

According to the well-known, and rather chauvinistic, idiom, ‘it is a poor workman who blames his tools’; this is a statement that is especially true in the world of presentations. Many people talk about ‘death by PowerPoint’, and how ‘PowerPoint is to blame for all of the atrocious presentations that I see’, but the only thing that PowerPoint is really guilty of is being an extremely versatile and easy-to-use toolkit.

Yes, PowerPoint can be used in such a way as to infuriate and bore in equal measure, but if used correctly it can also be an exceptionally effective device that can help to ensure that your narrative is communicated in an engaging and informative manner. There are many books that have been written on how to create an effective PowerPoint presentation, but presented here are some tips that will help to ensure that you get the most from this presentational scapegoat:

1. **PowerPoint is not a crutch**. At most it should be thought of as a visual aide memoir. It is a piece of software, not a sentient being. Ultimately it is you that will have to give the presentation, not PowerPoint (or Keynote if you are a Mac user).
2. **A picture tells a thousand words.** Why use words to describe what you want to say, when a picture or graph can often do so much more effectively? This will also mean that the audience is able to fully listen to you whilst looking at the picture, as opposed to half listening to you whilst trying to read paragraphs of text on the screen.
3. **Avoid PowerPoint karaoke.** If you do have to use text, *please* avoid reading it verbatim from the screen. Your audience is perfectly capable of reading for themselves.
4. **Use your take-home messages for the final slide.** Once you have determined what the take-home messages are for your presentation, use these as a single bullet-pointed list and leave it up as the final slide in your presentation. You do not need to read this out, but your audience will thank you for providing them with a helpful summary that they can easily take note of.
5. **Use spellcheck!** There is nothing more unprofessional than a PowerPoint presentation with typos and grammatical mistakes. Please take the time to make sure that there are no errors in your slides, and if possible get someone else to check them through for you.
6. **Think about slide design.** Choose your theme carefully. See section 4.8 for further advice on colour schemes, but it is important to pick a colour scheme that can easily be read from far away. Likewise, it is advisable to use one easy-to-read font and to be consistent with it throughout. Ideally all of your slides should have a similar layout, and where possible should also include slide numbers, as this makes it easier for the audience to make a note of anything that they might want to discuss with you later.
7. **Make sure everything works!** You should always take the time to make sure that your presentation works correctly, including the streaming of any videos or audio. Arrive early and get everything set up, as this will allow you to avoid any unnecessary technical distractions. It is equally important to make sure that none of your images are pixelated, and that you have chosen the correct aspect ratio for the projector.

Of course, PowerPoint (or Keynote) isn't the only presentation software that is available to you. It is therefore recommended that you try out a number of different pieces of software until you find one that you feel most comfortable with, and which affords you the most assurance in your delivery. Listed below are three examples that are well worth investigating further:

1. **Prezi** [3]: unlike PowerPoint, Prezi is not constrained to rectangular slides. Instead it focuses on the construction of frames of different shapes and sizes, which can be zoomed in and out of to create a very aesthetically pleasing visual. A word of warning though: be very careful to not overuse the zoom function (the same can be said for animations in PowerPoint) as this can have the unintentional effect of making your audience feel quite nauseous.
2. **Kahoot!** [4]: an interactive piece of software that allows audience members to vote or answer questions, using only their smartphones. It is free to use, and does not require the audience to own any fancy pieces of kit other than their smartphone. Another benefit is that the audience responses can be downloaded for later analysis. If using Kahoot! always remember to check that there is a good Wi-Fi or internet connection available for you the presenter, and that there is decent enough 3G or 4G signal (or a readily accessible Wi-Fi connection) for the audience to participate.
3. **Poll Everywhere** [5]: similar to Kahoot! in that it encourages audience members to interact with the presentation using their mobile phones. Unlike Kahoot!, it also supports the use of text messaging, so audience members without smartphones can also get involved. There is a free version of the software, but for larger audiences a paid-for pro license is necessary. Again a good Wi-Fi or internet connection is essential for the presenter.

Finally, you should consider using no slides at all, instead focussing on delivering your message to the audience in an effective and engaging style. You might alternatively consider the use of a single image summarising your key take-home messages. Whatever piece of presentational software you decide upon, it is important to find one that you feel comfortable with, and which will help you to reinforce your narrative, rather than to dilute it or cause the audience to become distracted.

4.6 Timings

You will often be in the situation where you have a limited time in which to deliver your presentation. If this is the case, then please do keep to time. It is extremely impolite to overrun; as it gives the impression that what you have to say is more valuable than anything that anyone else is saying. This is simply not true, despite what you (or your supervisor) might think. In conference situations, it will fall upon the chair to make sure that the session is running to time, but you should not rely upon them to drag you from the stage kicking and screaming once your allotted time is up. Instead, practise your presentation with the timing firmly in mind. And don't overstay your welcome!

In order to perfect the timing of your presentation, it is advisable that you first practise it with a stopwatch clearly visible, and which you can keep referring back to. As you gain confidence in your presentation and timings, gradually start to look at the stopwatch less and less, until you no longer need it. When you come to give the presentation itself, the chair or organiser will normally offer you a two-minute warning (or longer depending on the length of the presentation). If they do not, be sure to ask for one, as it can help you to focus. Many presentational facilities will also provide some form of stopwatch that you can refer to throughout your talk if needs be. It is also worth remembering that when you come to give the presentation, adrenaline will mean that you normally speak faster than you do in practice. However, this should only be considered and not relied upon, i.e. do not prepare a 20-minute presentation for a 15-minute timeslot in the hope that nerves will cause you to speak faster than normal!

4.7 Answering questions (and asking them)

One of the most nervous aspects of giving a presentation is the knowledge that you are probably going to have to answer questions about what you have just said. In almost all circumstances this will be in a formal Q&A at the end of your talk, although there are instances (normally in more informal environments, such as group meetings) in which you might be asked questions during the presentation itself. If that is the case, then most of what follows is still relevant, but take special care not to let a particularly difficult question upset you or cause you to lose the flow of your presentation.

The following list presents some useful tips on how to deal with questions, but as with all elements of presenting it is important for you to first try them for yourself, so that you can find the combination with which you are most confident:

1. Where possible take three questions at once. This is a trick that is commonly employed by politicians. Doing so allows you to answer the easiest question first, and gives you time to ruminate over the more difficult ones.
2. If you don't feel confident enough to answer the question in such a formalised setting, then offer to speak to the questioner 'off-line'. This simply means that you can speak to them after the talk, in a one-to-one environment (e.g. over coffee at a conference); this will give you more time to think, and will probably yield far more useful discussions.
3. If you don't feel entirely comfortable with a question, but still want to address it, then try subverting the question slightly. This will allow you to focus on something that you are more comfortable with, but should still give the questioner the satisfaction of being answered.
4. If you absolutely do not know the answer to a question, then do not be afraid to say so. There is no harm in not knowing everything, and it may be that the questioner has considered an angle that you had not previously imagined. Offer to speak to them 'off-line' to further probe their line of enquiry, it might be that they are able to significantly help you with your research. It might also be that they have simply misunderstood what it was that you were saying.
5. Prepare some additional material. If you know that your presentation is likely to raise questions that you are unable to address in your allotted timeslot, make sure that you have some material (be it in the form of additional slides, handouts, or simply a well-rehearsed riposte) prepared that will allow you to address them when the inevitable hands are raised into the air.
6. Prepare for questions that you think you might get asked. By practising your presentation, you will almost certainly know which areas might need further explanation, or are potentially the most contentious. If you have the time practise in front of some friendly fellow scientists, and see if you can address their questions, before you later go on to give your presentation 'for real'.

Learning how to ask questions is almost as important as learning how to answer them. Here is a list of **DO**s and **DON'T**s that will help to ingratiate you with your fellow scientists:

DO make sure to preface your question with a compliment regarding the nature of the talk or the effectiveness of the speaker. You would expect the same.

DO take notes of the presentation, and use them to make a list of suitable questions to ask at the end. This is especially important if you are the chair of a session, as there might not be anyone else asking questions.

DO consider talking to the presenter after their talk, instead of during the Q&A session. Especially if you have a difficult question, or multiple questions that require further discussion.

DON'T ask a question simply to let everyone else in the room know that you have been listening, or that you have expertise in this field.

DON'T use a question to advertise your own work. You will have time to do that in your own presentations.

DON'T ask any question that you cannot formulate succinctly.

4.8 Poster design and etiquette

Presenting a poster is often seen as secondary to giving an oral presentation, especially at a major scientific conference. However, this need not be the case, as presenting your poster generally provides you with the opportunity to talk in greater detail about your research to an audience, in a far more informal and relaxed environment. However, as with giving an oral presentation there are some general **DO**s and **DON'T**s that you should follow in order to make sure that your poster stands out, and that you maximise the use of your time:

DO use your poster's structure to tell a story. Consider the layout so that it presents the reader with a logical flow, from rationale and results to analysis and conclusion.

DON'T have too much text. Your poster should mainly consist of images and diagrams highlighting the work that you have done, with a few lines of explanatory text. You will normally be there to discuss the finer details of the research, and you can always prepare some handouts with further information on for the reader.

DO stand by your poster for the allotted time period. Even if there might not be any interest in your poster initially, this might be because you are at the end of a row, or because a parallel session at a conference is overrunning.

DON'T just follow the same old template design of everyone else in your research group. Consider using pictures from your research, and adding an element of personalisation. Remembering of course to include any insignia that is required, e.g. logos from funding bodies or research institutes.

DO bring some business cards and PDF handouts of your poster with you. That way people will have an easy way to contact you after the event. You can also leave these with your poster during the times that you are not required to stand with it, or for when you have to take a comfort break.

DON'T use a colour scheme that makes the poster difficult to read. Use a colour wheel (see figure 4.4) to help you match up complementary colours (opposite each other on the wheel). For example, if you are using a predominantly dark green background, then red text will be the easiest to read, and vice versa. Also, be careful not to overuse colour as it can easily become distracting.

DO give proper consideration to the use of font and colour. Certain fonts such as Comic Sans should be avoided altogether, as they can be very difficult to read. The Elements of Style website [7] provides excellent further advice on how to use graphic design to enhance communication in scientific posters.

DO smile and look interested, otherwise why would anyone want to stop and chat?

DON'T pressure people the second that they arrive. Give them the chance to read your poster, and let them know that you are there to answer any

Figure 4.4. Colour wheel. This image has been obtained by the author from the Wikipedia website [https://commons.wikimedia.org/wiki/File:BYR_color_wheel.svg], where it was made available by Sakurambo under a CC BY-SA 3.0 licence. It is included within this article on that basis. It is attributed to Sakurambo.

questions that they might have. Remember, you are a scientist, not a sales clerk on commission in a boutique jewellery store!

DO take the time to get to know your audience. In oral presentations you normally have to make some general assumptions about the level of scientific understanding of your audience. In a poster session though, you can just ask your audience. This can cut down on awkward moments where you might otherwise spend a long time explaining the first principles of your research to an expert in the field.

Exercise: you be the judge

Three posters are shown from figure 4.5 to figure 4.7. Which of these posters do you think most closely adheres to the rules for good poster design that are laid out above, and which of them needs the most attention? What would you improve about these posters, and what do you think illustrates good practice in both design and storytelling?

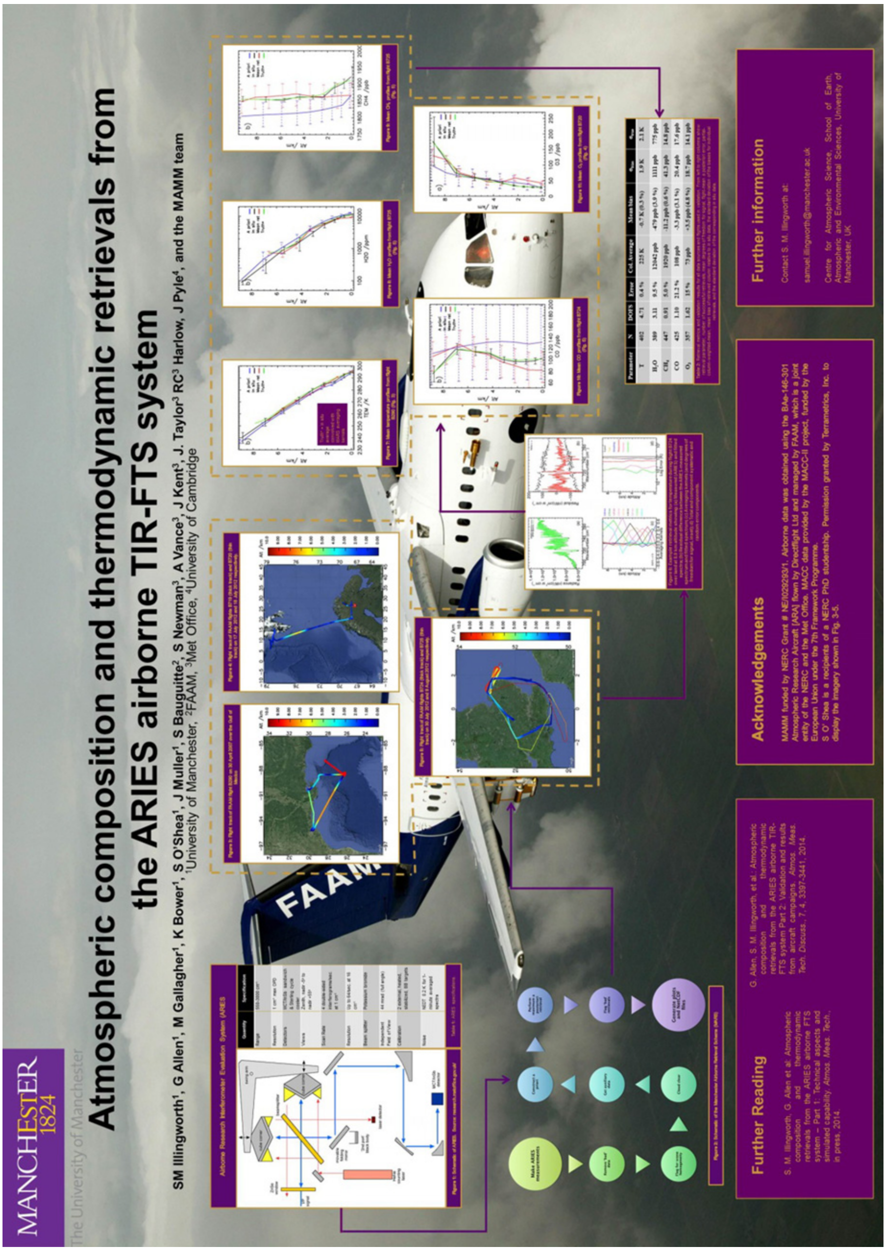

Figure 4.5. Poster 1 (reproduced with the kind permission of the Centre for Atmospheric Science at The University of Manchester).

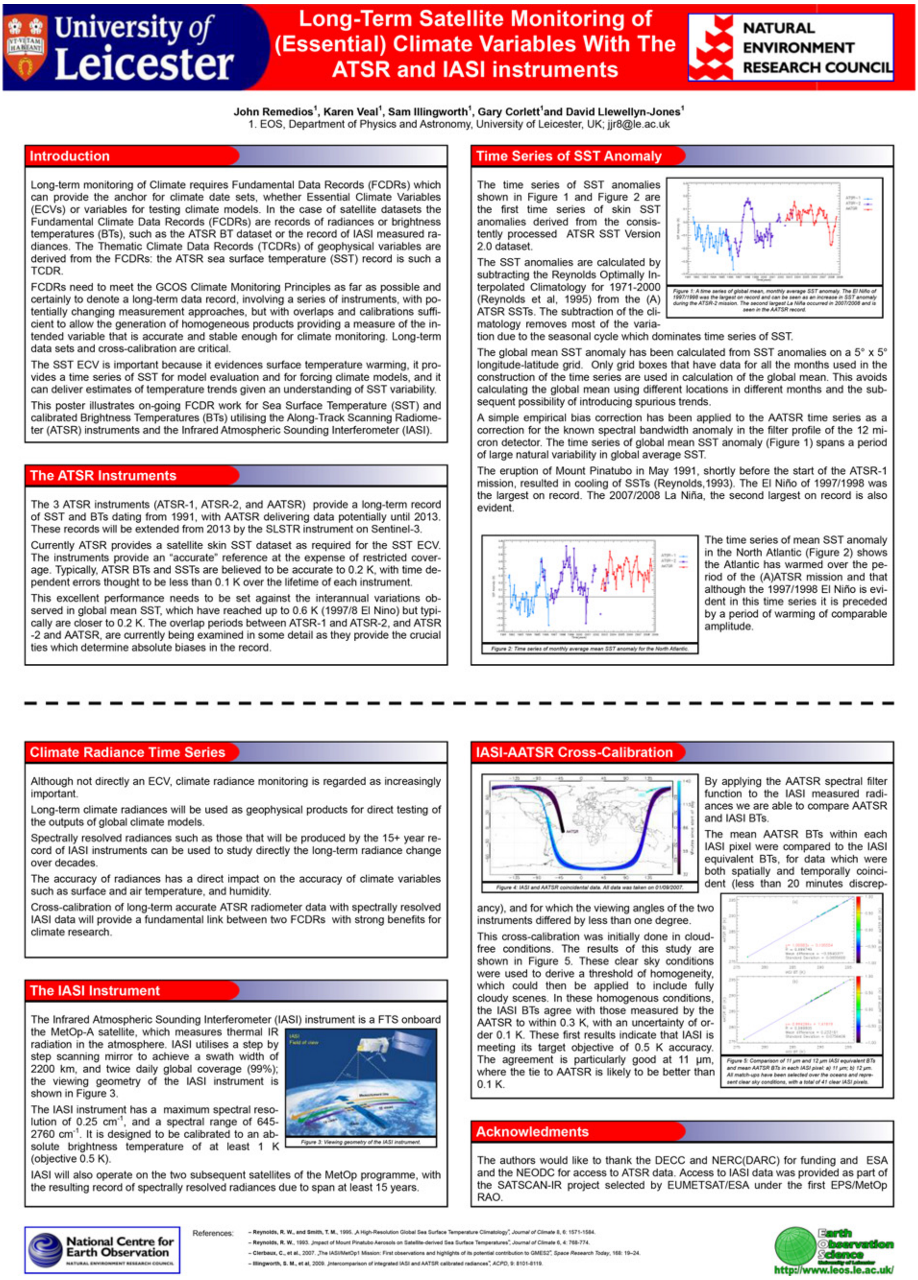

Figure 4.6. Poster 2 (reproduced with the kind permission of the University of Leicester and the National Centre for Earth Observation).

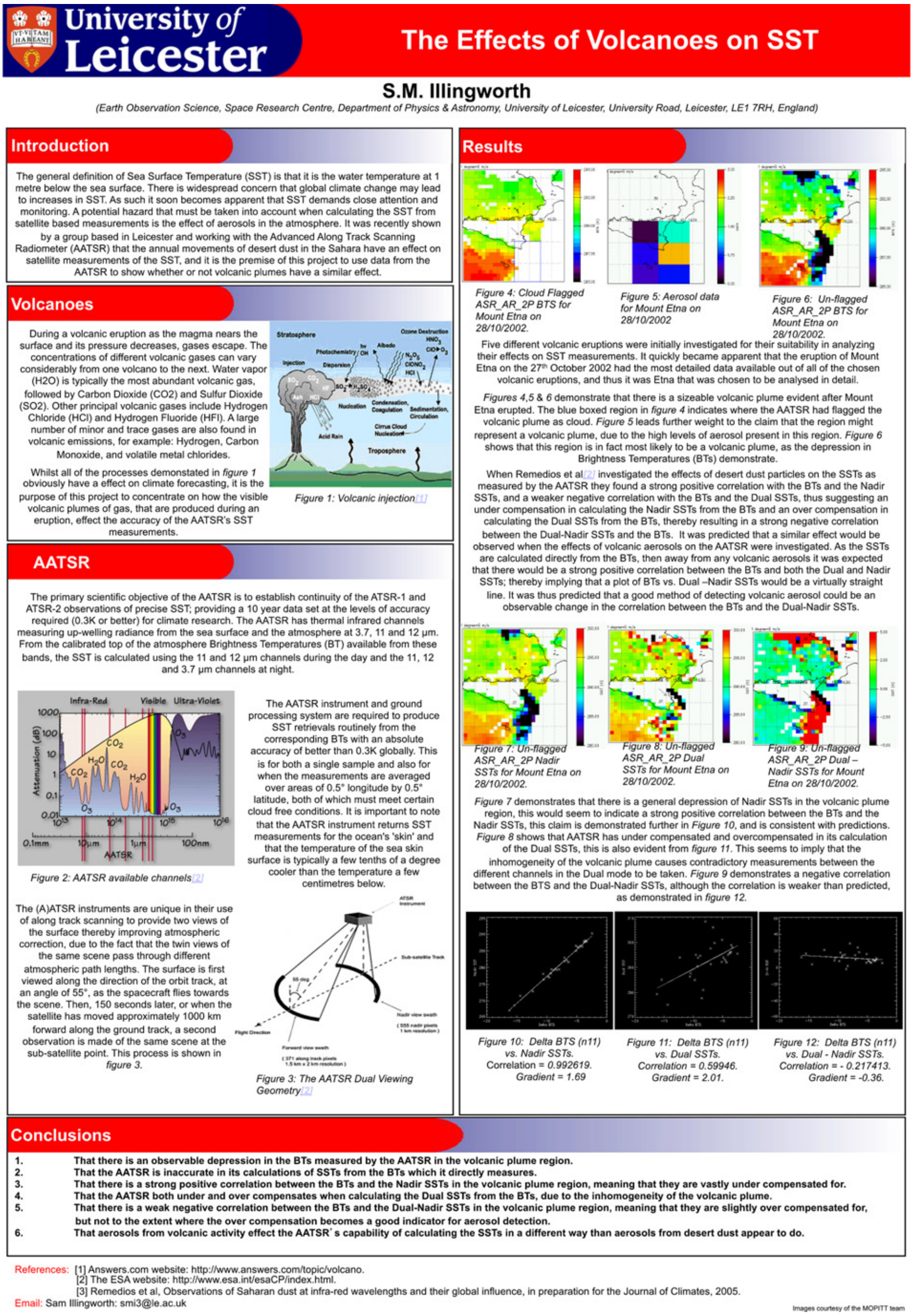

Figure 4.7. Poster 3 (reproduced with the kind permission of the ATSR Principal Investigator team at the University of Leicester and the National Centre for Earth Observation).

Some conferences these days offer a combination of oral and poster presentations, in which you have a couple of minutes to verbally advertise your poster before the session begins. These short pitches should not be treated as a challenge in which you are expected to cram a 15-minute presentation into 60 seconds. Rather, they should be seen as an opportunity to tease your audience, to hook them in and leave them wanting to find out more; which is exactly what they can do in the ensuing poster session.

Some poster sessions are now also adopting a new digital format, in which participants are expected to present their work using interactive touch-sensitive screens. As with learning to use the right tools for your oral presentations, it is important that you get to grips with the relevant tools (e.g. HTML5), and that you utilise them so as to communicate your central narrative in the most effective, logical and aesthetically pleasing manner.

4.9 Summary

This chapter has discussed the skill set that is necessary to be a confident and engaging presenter. In order to be an effective communicator, you need to consider your audience, your narrative and yourself Using rhetoric is an incredibly powerful way of speaking so that people will listen to what you have to say, and it is important to remember that PowerPoint (or any other presentation software) does not give a presentation for you. The etiquette of Q&A and poster presentations was also discussed, and if you take the time to participate in all of the exercises in this chapter then you will be well on your way to becoming a first-class orator. The only trick to remember here is that practice really does make perfect.

4.10 Further study

The further study in this chapter is related to your skills as a presenter, and should make you think further about what does and does not work for you during any presentation that you have to give:

1. **Self-reflection:** think back to the last presentation that you gave and consider how you dealt with the narrative, the audience, and yourself. Take some time to reflect on whether or not you gave sufficient consideration to each component of the triangle of effective communication. Was there anything that you did particularly well, and what could you improve for the next presentation that you have to give?
2. **Record yourself:** the next time you have to give a presentation, make a recording of yourself practising the delivery. Then watch it back, and see if you are considering all of the elements of the SAVE mnemonic. Decide if your message has a concise and logical narrative, and if what you are saying is suitable for your intended audience. Then, with these notes in mind, practise a couple more times before filming yourself again. When you watch this next clipping see if you have taken on board your own direction; you will probably be surprised at how much you have improved.

3. **Learn from the best:** when you next watch a politician make a public speech (either in person or on the television), try and break down their message into the three different forms of rhetoric. When are they appealing to your passion, when are they driving home the logic of the story, and when are they reminding us of their ethics? You will soon realise that a lot of politicians are experts in using rhetoric for often very subtle manipulation.

Suggested reading

There are many books and websites dedicated to helping you become a better public speaker, however some of the best are freely available via resources such as the Technology, Entertainment and Design (TED) talks. One of the best and most effective is a video from the audio expert Julian Treasure, entitled 'How to speak so that people want to listen' [8].

For those of you wanting further guidance on how to design aesthetically pleasing presentations and posters, *Designing Science Presentations: a Visual Guide to Figures, Papers, Slides, Posters, and More* [9] is highly recommended. There are also a couple of short and useful papers on communicating effectively using PowerPoint [10] and posters [11].

If you are interested in finding out more about rhetoric, it is best to refer to the master himself. Aristotle's *Rhetoric* [12] is a truly astounding book, and as well as expanding on the concepts discussed here, it offers sound advice on how to survive in love, war, and everything in between.

References

[1] Peck E and Dickinson H 2009 *Performing Leadership* (London: Palgrave Macmillan)
[2] Up-Goer Five: http://splasho.com/upgoer5/, accessed 8 July 2016
[3] xkcd Up-Goer Five: http://xkcd.com/1133/, accessed 8 July 2016
[4] Prezi: https://prezi.com/, accessed 8 July 2016
[5] Kahoot! https://getkahoot.com/, accessed 8 July 2016
[6] Poll Everywhere: www.polleverywhere.com/, accessed 8 July 2016
[7] *The Elements of Style*: https://science.nichd.nih.gov/confluence/display/~jonasnic/Elements+of+Style, accessed 8 July 2016
[8] Treasure J How to speak so that people want to listen *TED* www.ted.com/talks/julian_treasure_how_to_speak_so_that_people_want_to_listen?language=en, accessed 8 July 2016
[9] Carter M 2012 *Designing Science Presentations: a Visual Guide to Figures, Papers, Slides, Posters, and More* (San Diego, CA: Academic Press)
[10] Collins A 2004 Giving a PowerPoint presentation: the art of communicating effectively *RadioGraphics* **24** 1185–92
[11] Erren T C and Bourne P E 2007 Ten simple rules for a good poster presentation *PLoS Comput. Biol.* **3** e102
[12] Aristotle 1991 *Rhetoric (The Works of Aristotle 9)* (Engl. transl. W Rhys Roberts) free ebook available here: https://ebooks.adelaide.edu.au/a/aristotle/a8rh/index.html

Chapter 5

Outreach and public engagement

Science is an absolutely essential tool for any society. And if the scientists will not bring this about, who will?

– Carl Sagan

5.1 Introduction

Why even bother to communicate with the world outside of the scientific community? Well, as discussed in chapter 3 it is now a requirement of most research grants to demonstrate how your science has impact, i.e. how you have ensured that other societal groups are aware of your research, and the affect that it will have on them.

Beyond that requirement though (and as discussed in chapter 1), there is an obligation for scientists to communicate their research to the rest of society, to inform them about scientific advances, and to ultimately engage them in two-way dialogue so that the general public does not just understand what science is doing, but that they also have a say in what is being done. After all, it is largely their taxes that fund much of the research that is carried out. It is also ignorant and arrogant to assume that scientists alone have all of the answers, and historically there have been a number of examples of members of the general public significantly contributing towards scientific understanding (see section 5.5 for some specific examples).

Outreach and public engagement activities can also provide benefits to the scientists conducting them, which are just as varied and consequential as those offered to the learners, including:

- Improved communication and organizational skills
- Increased confidence
- Enhanced teamwork and interpersonal skills
- Acquired ability to ‘translate’ scientific expertise into accessible terms
- Greater understanding as to the benefits of knowledge exchange
- A reminder as to why a career in science was pursued in the first instance

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The most obvious impact of these skills is that researchers can benefit from them in the communication of their research, both within the broader scientific community and in university-level teaching. Interpersonal and teamwork skills are also essential to success within interdisciplinary scientific research.

For those scientists who wish to pursue a career outside of academia at the end of their PhD or postdoctoral positions, these activities provide communication and other key transferable skills (see chapter 9 for more details). The initiative shown in participating in these activities can also look encouraging to employers, and demonstrates that the candidate has experience of working outside of academia.

Exercise: WWW

Before setting out on any public engagement or outreach activity, you need to ask yourself three questions:

1. What do you want to communicate?
2. Why do you want to communicate it?
3. Who do you want to communicate with?

It might be that you know exactly what it is that you want to communicate (perhaps your latest research findings or the life and times of an unfairly unrecognised scientist in your field), but that you are unsure of who would best benefit from this. Similarly, it might be that you feel as though you want to engage with a local community group, but are unsure which aspect of your research would be most appropriate.

By spending time thinking about these three questions you will be able to develop the focus and rationale that is necessary to underpin any successful outreach or public engagement activity.

5.2 Nomenclature

Science communication can effectively be split into two, as illustrated by the two faces of Janus (the ancient Roman god of transitions and beginnings) shown in figure 5.1. So far in this book we have discussed aspects of 'inwards-facing' science communication, i.e. that which deals with improving your own personal communication skills in order to improve as a scientist. This chapter will be devoted to the 'outwards-facing' aspects of science communication, and will introduce you to the ways and means in which your science can be shared and communicated with society at large.

Science communication is often analogously and interchangeably referred to as science outreach, public engagement, widening participation, and/or knowledge exchange, but what do these terms actually mean? As well as institutional and national biases towards the 'correct use' of these terminologies there exist personal nuances in terms of their interpretation, which oftentimes depend upon the role of the person in question and how they perceive science communication to fit into their research and teaching practices, and beyond.

Based on the current science communication literature, the following broad definitions are offered for each of the four considered topics:

Outreach: a one-way discourse, in which scientists communicate their research to the general public, with particular focus on schoolchildren and young people.

Public engagement: a two-way dialogue, in which scientists converse with members of the general public in a mutually beneficial manner.

Widening participation: any activity that engages with social groups under-represented in higher education, in order to encourage them to attend university.

Figure 5.1. The two faces of science communication. This image has been obtained by the author from the Wikipedia website [https://commons.wikimedia.org/wiki/File:Janus_coin.png], where it is stated to have been released into the public domain.

Knowledge exchange: any activity that involves engagement with businesses, public and third sector services, the community and the wider public, and which is monitored for funding purposes.

It is acknowledged that there is still some overlap between these definitions, for example a presentation given by a university researcher at a local school might be classed as being an outreach, widening participation, and knowledge exchange activity. In such instances it is important to consider the context of these classifications. In this example, the researcher's funding body might classify the activity as outreach, the university's widening participation team (or equivalent) may catalogue it as a widening participation activity, and the university's knowledge exchange offices (or equivalent) could acknowledge it in their records for the Higher Education Funding Council for England (or equivalent).

Widening participation and knowledge exchange as defined above are beyond the scope of this chapter, which will instead focus on outreach and public engagement activities. A further consideration of the nomenclature of science communication in the UK is given by Illingworth *et al* [1].

5.3 Working with children

Working with children can be an extremely rewarding and enjoyable experience. However, it can also be demanding, difficult and at times disheartening. As with any public engagement or outreach activity, it is important to go into it with your eyes fully open, and to carefully consider the what, why and who of the activity, with extra thought given as to why it is that you want to engage with schoolchildren in the first instance.

The next question that you need to ask yourself is what relevant experience do you have in dealing with pre-university schoolchildren? It is arrogant to assume that you will simply be able to waltz into a classroom or a more informal setting and instantly be able to command the room because you are *a scientist*. Before developing and delivering an activity aimed towards working with schoolchildren it is advisable to first get some relevant training and experience.

The Science, Technology, Engineering and Maths Network (STEMNET) [2] is a national organisation that is dedicated to providing outreach activities in STEM subjects across the whole of the UK. STEMNET provide a fantastic opportunity to receive bespoke training for working with schoolchildren. They also have a list of ready-made activities that are being run by schools or other organisations, which you can participate in to receive the experience that is necessary for you to start thinking about designing your own activities. In addition to this, your research institute or university will almost certainly have an outreach, public engagement, or widening participation team that you can get involved with, and which will often provide bespoke training opportunities, as well as valuable experience.

If you are working with children in the UK then you need to have a Disclosure and Barring Service (DBS) check, to make sure that you are fit to work with children. You can find out more about the DBS checks on the UK Government's disclosure barring service site [3]. There is normally a small fee attached to having one of these checks performed, but organisations such as STEMNET will usually pay these for you if you are doing outreach activities through them. It is important to note that you should **never be left alone in a room with a child or group of children**, even if you have been checked by the DBS. Having a teacher or a guardian in the room with you at all times is a necessity, and guards against any potential claims of malpractice.

The age of the schoolchildren that you are working with will, to a large extent, determine the type of activity that you will be engaged with. It is wrong to generalise and say that all secondary school students are moody teenagers who have no interest in or passion for science, as that is simply not the case. However, what is true is that some of these students may have become disenfranchised by science because of a lack of engagement, poor teaching, or even previously ineffective science communication activities!

Working with younger children can be a liberating and exhilarating experience. They are yet to develop the cynicism and awkwardness that can sometimes make engaging with older children so frustrating. They can also surprise you in the most wonderful ways. Carefully developed activities can educate and engage younger students, thereby instilling a love of science at this early and impressionable age. Such activities can have a large influence on the degree to which they decide to sustain their scientific education, which will ultimately have a profound effect on them far beyond the confines of the classroom. Of course all of that extra enthusiasm can also mean that you feel absolutely shattered by the end of a session. It is also important not to patronise the students, but to pitch the material at a level that they find engaging.

Exercise: what does a child know?

It is easy to forget that as a scientist you know (and are surrounded by colleagues that know) a lot about many different types of science, and also the scientific process in general. What you consider to be common knowledge might in actual fact be highly specialised, especially to schoolchildren.

The next time that you have the opportunity to speak to a young child in an informal and supervised location (this could also be a friend's child, or even one of your own), ask them what they know about science. Start off with questions that are quite general (what does a scientist do? what is physics?), and then begin to specialise (what is acceleration? what is gravity?). You will probably be surprised to find out what the children do not (and in some cases do) know, and you should keep this in mind when you are next explaining your research to a group of schoolchildren.

5.3.1 Children in a formal environment

Most science communication activities that involve children in a formal environment (i.e. the school classroom) can be thought of as being outreach activities. The purpose of these activities is usually to engage with a group of schoolchildren about a particular area of science, and whilst you should aim to design activities that are immersive and engaging, they will primarily be delivered using a one-way discourse.

However, just because a one-way approach is used does not mean that a deficit model should be adopted. Rather than focussing on the students' lack of knowledge, a student-centred approach based around the understanding of the learner and the learning process should instead be considered.

Building on what the students know involves not only a detailed knowledge of the curriculum, but also an in-depth understanding of the needs and abilities of each of the students in the classroom. This is a lengthy process that cannot be fast-tracked, nor is there a need to do so when the student's teachers already have all of that information at their fingertips.

In developing an outreach activity for schoolchildren, to be delivered in the formal environment, it is advisable to involve a teacher in the design process as early as possible. Their knowledge of the curriculum and of general learning behaviours within the school environment will ensure that the message you are trying to convey through your outreach activity does not fall on deaf ears. They will also be able to provide constructive feedback as to what they know will and will not work in their own teaching environments. The teacher will be able to assist with basic logistics such as room setup, and will also be able to ensure that the class is grouped (where necessary) to avoid wanton disruption.

Even if the activity has been run successfully in a formal environment before, it is good practice to engage with the teacher of every class that the activity is delivered to. It is wrong to assume that what works for one group of students will work for another, and by providing a basic summary of the planned outreach to the teacher beforehand, they will be able to give useful feedback as to what they perceive will and will not work well with their students. This can be the difference between genuinely *engaging with* the classroom, and *talking at* a group of uninterested pupils whose minds have long since left the learning environment.

Here is a classroom survival top five:

1. **The children are not your mates**: ultimately they are there to learn, and whilst it is important that they have fun in the process, it is important to establish boundaries. And remember; if you have to try to be 'cool' then you have already failed.
2. **Stick to time:** the students will not thank you for eating into their lunch break, no matter how engrossing your activity. And for activities that take place in the afternoon, remember that there are school buses to catch and parents waiting in cars!
3. **You know more science than they do**: a common fear of many scientists doing schools outreach is that they will be 'caught out' on an area of science that they do not know. Ninety-nine times out of a hundred that is simply not the case, and you will be able to answer any of the questions that the children can throw at you. And for that one-hundredth time, simply commend the student on their question, and tell them that you will have to conduct some research and then get back to them. Admitting that you don't know will also help to encourage the teacher (who might not have the

same science background as you) that it is okay to not immediately have all of the answers to hand. If you have the time, you could even offer to find out the answer together as a class, or else design an activity to help investigate it further the next time you visit.

4. **Expect the unexpected:** be prepared to answer questions about your life as a scientist, and indeed your life in general. Young children in particular will be fascinated about what it is like to be a scientist, what your most dangerous experiment is, and of course the big one: what your favourite colour is.
5. **Don't get disheartened:** sometimes there will be activities that absolutely just do not work. This may be for a number of reasons: the class, the facilities of the room, the alignment of the planets. It is important that you do not let this get to you, and that instead you reflect on what went wrong and how you can go about making it better next time.

Exercise: design an activity for the formal environment

Follow these steps and devise an activity to communicate your research to schoolchildren in a classroom setting:

1. What do you want to say, why do you want to say it and whom do you want to say it to?
2. How will you best communicate your message? Is it via a short presentation, a series of demonstrations, some hands-on experiments or something more creative?
3. How does this tie into the National Curriculum? Your activity will be much better received by schools and teachers if the topics that you are covering can be linked to the curriculum. This is especially true for students in studying for their GCSEs and A-levels (or their non-UK equivalents), where classroom time is precious and often on a tight schedule.
4. Run your ideas past a teacher. They will be able to advise what will and will not work in a classroom environment, and will also be able to help with linking the activity to the taught curriculum.
5. Beta-test your activity. It is very important that you have at least a couple of dry runs before taking the activity into a school, as this will help you to iron out any issues beforehand. Undergraduate and postgraduate students are great for trying out your ideas on and with.
6. Trial your activity. Get in contact with the teacher that you spoke to in the design process, and see if they are willing to let you try out your outreach activity in their class.
7. Reflect on the trial. What went wrong and what went right? Ask for feedback from the teacher and their class, and also from the people that were involved in the beta-testing process. How can you use this feedback to improve your activity, and do you need any further support and/or resources to better implement it?

5.3.2 Children in an informal environment

Of course, learning doesn't just happen in the classroom. There are many different environments outside of school in which students can continue to learn about science in a more informal setting, including museums, science centres and even zoos. Informal learning can be considered to be that which occurs outside of the traditional, formal schooling realm. However, informal science education is not just defined by learning that takes place outside of the classroom, but as something that is self-motivated and guided by the learner's needs and interests.

Large science events often take place in these informal settings (i.e. not in schools), and include science festivals, science fairs, and public lectures, many of which have specific events or activities for schoolchildren. For example, the Royal Institution Christmas Lectures in the UK have been running since 1825 (see figure 5.2), and are aimed at a mainly teenage audience, taking place at the Royal Institution in London each year.

Informal science activities have been shown to foster a strong commitment to science and science learning, with informal learning also being shown to have a strong impact on future academic career choices amongst undergraduate students.

When running an activity in an informal environment that is aimed primarily at schoolchildren, most of what has already been written in the previous sections is still relevant, with the following caveats:

1. A teacher might not accompany the children; instead a guardian might accompany them, or they may attend by themselves. In any case, the children will behave differently outside of the school environment. They may feel less

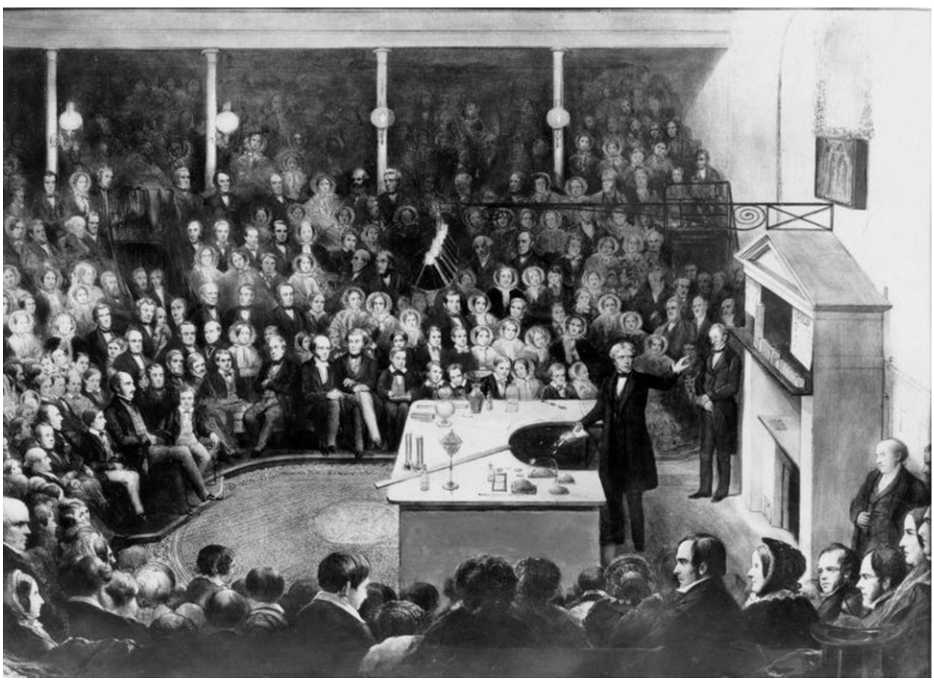

Figure 5.2. Michael Faraday giving a Christmas Lecture in 1856. This image has been obtained by the author(s) from the Wikimedia website https://en.wikipedia.org/wiki/Royal_Institution_Christmas_Lectures#/media/File:Faraday_Michael_Christmas_lecture_detail.jpg, where it is stated to have been released into the public domain.

awkward, but similarly there may be behavioural issues that need to be kept in check without the presence of a teacher. In these informal environments it is just as imperative that you are **never left alone with any children**.

2. The children might not be expecting a science activity. If your activity is not part of a larger science festival, or is alongside other events that are not science-themed, then your participants may not be expecting to do any science. This is a fantastic opportunity to catch them off their guard, and to demonstrate that science is all around us, in almost all facets of our lives.
3. There might be a larger or a smaller influx of people than you were expecting. Plan for both eventualities, especially with the number of facilitators. Try to have different levels of engagement for your activities, so that you can spend longer with participants if the numbers are small, or deal with a large number at once if there is a sudden surge.

Exercise: finding your niche

Absolutely anything can be a science communication activity, from poetry [4] and performance to comedy [5] and ceilidhs [6]! What do you like to do in your spare time, outside of your scientific pursuits? Take a couple of minutes to think about ways in which your hobbies and pastimes could be used to communicate any aspect of science, ideally the area that you currently research. Linking your professional and personal lives in this manner is a great way to create something truly unique, and which you can get genuinely enthused about. Choosing areas in which you have previous expertise will also give you further confidence that you have the required skills for an effective and successful delivery.

5.4 General public

The general public is effectively made up of three categories: children, adults and families. Talking to adults about science can be a daunting task, but it is also incredibly worthwhile, and is a great way of helping to further break down barriers between science and society. Most of what applies to working with children applies, especially in an informal environment. As you would expect, adults are as diverse a group as children; they all have different learning styles and preferences, different interests and different potential levels of engagement with science.

This section does not aim to cover every eventuality that you are likely to encounter when communicating science to the general public; rather it presents a number of tried and tested formats that should act as a starting point for your own ventures into effective science communication. As discussed earlier, the only limits to the type of activity that you end up running are your imagination, and if you can incorporate any of your passions or expertise from outside the world of science, then even better!

Public talks

The most standard form of communication with the general public is a science talk. This may take the form of a formalised talk with a Q&A session at the end, or it may be a more relaxed affair, for example at a Café Scientifique [7] or a SciBar [8] event. Whatever the situation, remember the lessons learnt in chapter 4: consider your narrative, your audience, and yourself. Also, just because you are not speaking at an international conference, do not assume that there are no experts in the room! Try to find out who your audience will be, so that you can avoid making the errors of overestimating what the audience knows or underestimating their intelligence.

Panel discussion
A panel discussion is a very effective way of showcasing a variety of different opinions and information on a certain topic. They are also a useful way of demonstrating that science is a varied and much-debated topic, in which there are sometimes quite fierce and contrasting views. If taking part in a panel discussion, make sure that you know in advance what the format of the discussion will be (round table discussion, questions from the audience, short presentations, etc) and also who your fellow panellists will be. It is extremely useful to know in advance who and what you will be up against! If you are organising a panel debate then make sure that the topic is something that can actually be debated, and that you invite a wide range of panellists, who are able to present both sides of the argument. You should also consider inviting panellists from outside the world of academia, and ensure that you have a chair who is both impartial and commanding, just in case things get a little heated! In the UK, the British Science Association run a very interesting series of policy debates [9], for which they also provide some limited funding for potential hosts.

Book clubs
A book club is a great opportunity to mesh science and popular culture in an accessible and engaging format. If you plan on running a book club then it helps to have an overarching theme that is not too broad, for example books that deal with 'time travel', rather than 'science' in general. Meeting once a month will give people enough time to get to grips with the key material, and choosing books that are readily available from local libraries will help to keep the costs down. It is also recommended that you plan out a number of books in advance, and that each member of the group gets the opportunity to select a book as well as to take part in the discussions.

Science busking
Science busking involves capturing people's attention in a public place using nothing but the magic of science! When done right this type of activity is an effective, enchanting and innovative way of engaging with a potentially large group of people. When starting out on your outreach adventure, successful science busking may seem like quite a distant milestone, but with patience, persistence and politeness it can become a useful utensil in the outreach practitioner's toolkit. For novices and experts alike, the British Science Association has created a really helpful pack [10] on science busking, which includes a large number of activities to get you started with.

Exercise: risk assessment

It is important that you carry out a risk assessment for any activity which involves the general public. If you are going into schools then the teachers will need to have this well in advance of your proposed activity. The Health and Safety Executive in the UK provide a great resource [11] for carrying out risk assessments. Download one of their templates and fill it in for your proposed activity. Remember to get it signed off by somebody who is qualified to do so.

Certain venues may also require you to have public liability insurance, and so this is a conversation that you need to have with the legal team of your university or research institute. Usually you will be covered, but it is important that you check for every event.

5.5 Citizen science

The majority of the activities that have been discussed so far in this chapter can be thought of as outreach activities, insofar as they are mainly concerned with communicating science *to* the general public. As discussed in the introduction to this chapter, public engagement can be thought of as a much more two-way process in which scientists and members of the general public interact to help further the development of science. An example of a public engagement activity that is currently de rigueur in scientific communication circles is citizen science. In essence it can be thought of as a form of collaborative research that involves members of the general public (or citizens), and which actively involves them collecting, generating and analysing data.

There are many examples of citizen science projects, but probably the best known is Galaxy Zoo [12], which asks participants to classify different types of galaxies according to their structure. The reason for this is that the human eye is better equipped at making these distinctions compared to a computer. This project has been an enormous success, with more than 50 million classifications received by the project during its first year, contributed by more than 150 000 people. There have also been a large number of peer-reviewed scientific papers [13] published as a result of the project.

Another example of a 'data mining' citizen science project is Old Weather [14], which aims to help scientists recover Arctic and worldwide weather observations made by US ships since the mid-19th century, by enlisting citizens to interpret old transcriptions (e.g. track ship movements) in order to generate new data. Such information ultimately improves the collective knowledge of past environmental conditions, with a better understanding of these past occurrences ultimately leading to an improvement in modelling future events.

There are also a number of citizen science programmes that actively source data directly from members of the public. For example, the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS [15]) is a non-profit, community-based network of volunteers who measure and map precipitation using low-cost measurement tools with an interactive website. The project started in Colorado in 1998 and now has networks across the US and Canada, involving thousands of volunteers, making it the largest provider of daily precipitation observation in the US.

The main objection to these types of citizen science projects is that they are potentially tantamount to free labour; with scientists using the general public to collect and/or analyse vast swaths of data, whilst they steal all of the 'glory', perhaps in a matter analogous to a particularly unsympathetic professor and their post-graduate students. After all, whilst there are many incentives for mining and analysing the data, it is not the citizens whose names will necessarily be appearing on the research papers and grant applications. By appealing to the noble intentions of the citizens, and placing an emphasis on the progression of science for the greater good, there is a risk that some of the researchers sitting atop of these projects come across as hypocritical.

Perhaps the most famous example of a truly collaborative citizen science project is the Human Genome Project [16], an international scientific research project with the goal of mapping all of the genes of the human genome from both a physical and functional standpoint. It remains the world's largest collaborative biological project, and serves as a great example of science genuinely being conducted for and on behalf of the greater good. Whilst publically acknowledged projects such as this are obviously an extreme example (the Human Genome Project was conducted using $3 billion of public funding), there is still plenty of opportunity for researchers to ensure that the citizens that they recruit are properly recognised. For example, in the UK Community Rain Network (UCRaiN) [17], all of the participating schools were given credit in the acknowledgments section of the research article that was produced as a result of the study. The UCRaiN project is also a good example of a citizen science project that involves the general public in a two-way dialogue, but which is reasonably inexpensive to set up. For setting up your own citizen science project, the UK Environmental Observation Framework has produced a very useful and free guide [18].

Overall, citizen science projects are becoming an increasingly popular means by which to engage the public, whilst also benefiting scientific research, especially given the growing ubiquity of social media and other communications platforms. However, there is a need to actively involve the participants in these projects, and to ensure that they receive the appropriate acknowledgments; otherwise scientists run the risk of treating their new colleagues as nothing more than second-class citizens.

5.6 Funding

Now that you have planned your event how do you go about funding it? Even the most basic of activities will have some consumable costs, whilst larger events will also have to account for travel and venue hire plus maybe even a contribution to staff wages. Listed below are five potential revenue streams to help you get the funding that your activity so clearly deserves:

1. **Public engagement funding:** the National Co-ordinating Centre for Public Engagement (NCCPE) has produced a helpful resource [19], which lists most of the funding grants available for outreach and public engagement in science and engineering (as well as for other disciplines) in the UK. All of the advice offered in chapter 3 still holds, whilst getting match funding from one of the other sources on this list will undoubtedly strengthen your case when applying for these grants.
2. **Universities:** most universities will have a widening participation team, and some will also have a dedicated public engagement and outreach department. As well as going to these teams for advice and contacts when setting up and developing your event, they might well have some money to help you fund your project, especially if it relates to something that they are already doing, or that they have planned for the future.
3. **Existing research grants:** most major research grants must now demonstrate 'pathways to impact', i.e. they must show how they are making a conscious effort to inform society of the research that they are doing, and the relevance that this has to the wider community (see chapter 3). Funds will normally have been set aside to do this, and therefore represent a potential revenue stream for your project.

4. **Local councils:** your local council will have certain allocations of funds that they must use to help educate and inform the local population. As such they are definitely worth talking to; they are also a very useful source in terms of school and community contacts and will often have venues that they can offer for use at a reduced rate, or free of charge.
5. **Learned bodies:** almost all of the learned bodies offer some kind of support for outreach and public engagement activities, and again they are a very useful resource for when you are developing your activity. The public engagement resource for the Institute of Physics can be found here [20][1].

5.7 Spreading the word

With the funding sorted and the event planned, how do you go about making sure that anyone bothers to turn up for it? If you are doing an outreach event that involves going into schools, or having schoolchildren come to you, then it is necessary for you to make prior arrangements with the schools that are involved. For other events, it is vital to ensure that you advertise your event effectively and in plenty of time. The most important question that you need to ask yourself is: who is likely to come to this event, and how do I ensure that they attend?

Mailing lists are a useful way of engaging with an interested audience. The PSCI-COMM [21] and NCCPE-PEN [22] email discussion lists in the UK are great for this purpose, and will reach a large number of people with an interest in science outreach and public engagement; people on these lists also often recommend other local interest groups that would be interested in your events. On the other hand, emails that are sent out in an ad hoc manner to a large group of people will probably not even be opened by the majority of the recipients.

It is certainly worth contacting local newspapers and magazines, as well as international publications with regional offices and events listings, such as *Time Out* [23] magazine. As well as the option for paid advertisements, many of these publications also run free listings, in both online and print formats. Posters and flyers can also still be extremely effective, especially if put up in places where people cannot help but look at them, such as in elevators or toilet cubicles.

Social media is an excellent way to make a large group of people aware of your events in a relatively short amount of time. However, as will be discussed in chapter 7, social media is just a tool to utilise; it cannot simply be relied upon to guarantee an audience, especially if it is used ineffectively. If your event is aimed at a particular audience (e.g. amateur astronomers), or if it is related to a local or global event (e.g. World Aids Day), then you should also be targeting your event via the social media channels of associated organisations. Learned societies and other bodies that are somehow related to the topic of your event should also be informed in advance, as should anyone who has provided any degree of revenue stream for the event itself.

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[1] Interestingly, whilst the webpage is called 'Public Engagement' the web link is '/outreach'. This is a fine example of the lack of consistency in the nomenclature when dealing with 'outward-facing' science communication.

The logistical side of ticketing for an event has been made much easier with the advent of free online tools such as Eventbrite [24], which help enormously in terms of event management. Experience seems to suggest that as a rule of thumb, for free and ticketed events an attrition rate of about 30–50% is the norm. Of course Murphy's law suggests that were you to allocate over 100% of seats to account for this attrition rate, then everyone would turn up and fire regulations would be breached! To counteract for this it is good practice to have a reserve list, or to consider introducing a small surcharge to encourage attendance; it is amazing how even a small fee can cause people to forget all about their headaches or a bit of light drizzle. There is also an argument to be made that charging (even a relatively small amount) for an event gives implied value that might actually increase attendance rates. Despite the software available to help with the logistical side of things, ticketing is a fine art that benefits from experience, and sadly one for which there is no one-size-fits-all solution.

5.8 Evaluation

Failing to properly evaluate any outreach or public engagement activities means that you are wasting a great opportunity to not only further develop and strengthen future events, but also to assist in the overall understanding and development of science communication.

As an absolute minimum you should be recording the metrics (number of students, age range, name of school, etc) for the activities in which you are involved, for your own records and also for those of your universities and any external funding bodies. A short personal summary of the activity is also good practice, as by recording your own thoughts on what did and did not work you are able to ensure that the next execution of the activity is an even greater success. Even if it was a one-off event, such summaries can still help you in developing and delivering future activities.

In order to really assess the relative successes of the outreach activity, though, it is necessary to get feedback from the participants and demonstrators. However, obtaining this feedback needn't be overly complicated, for example you could use SurveyMonkey [25] or Typeform [26] to construct a straightforward questionnaire (what did you like? what would you do differently? what surprised you?) that can be filled out immediately following the activity. By analysing the results from these surveys (again SurveyMonkey and Typeform can be used to do this) you can really start to get a better picture of what did and did not work in your activity, and how it can be improved upon for future events.

Evaluating an event needn't be a boring process for all concerned. Indeed, the evaluation process can be built in as an interactive part of any activity. For example, the evaluation form that is shown in figure 5.3 was used to evaluate a SciBar event that involved a public talk on the geographies of light and dark. These forms were printed out on two sides of A5 card, and were handed to participants, along with pencils and pens at the end of the event. This resulted in an innovative and fun method of collecting feedback, which was also enjoyable to collect and analyse.

Pick **two** words from the front of this card and **draw** or **write** about them.

If you are happy for us to contact you via email, regarding future events, please provide your name and email address below:

Name ....

Email Address: ....

Geography •	**Nature** •	**Science** •	**Happy**
Difficult •	**Space** •	**Solar** •	**Scientist**
Dark •	**Mind** •	**Easy** •	**Authority**
Exciting •	**Human** •	**Light** •	**Power**
Challenge •	**Boring** •	**Beer** •	**Climate**

Figure 5.3. Sample evaluation form.

However, in order to truly evaluate your activities, you need to start applying the ‘scientific process’. The scientific process is pictorially represented in figure 5.4; you start with a hypothesis, you then test that hypothesis, and based on the outcomes of the test you either accept the original hypothesis or adjust it and continue once more with the cycle.

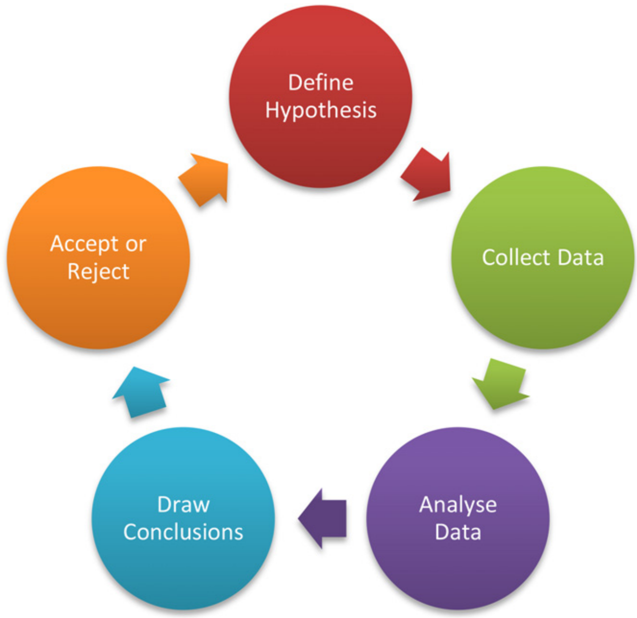

Figure 5.4. The scientific process.

For example, for a school outreach activity the hypothesis would be that 'this activity raises the awareness of the student's knowledge in subject X'. However, it is impossible to test if this hypothesis can be accepted or not without first assessing the base level of knowledge that the students have about X. Therefore, the evaluation process really needs to take place before you even set foot in the classroom.

Assessing base knowledge needn't be overcomplicated; if for example the activity aimed to improve the participant's knowledge of global warming, then their initial familiarity with the subject could be assessed by asking them: 1) what is global warming? 2) what causes global warming? 3) what can be done to reduce global warming? These same questions can then be asked after the outreach activity, and the hypothesis can either be accepted or rejected based on the comparison of the participants' pre- and post-understanding of the subject. Finding a way to assess if the activity has had any lasting impact on the students after a prolonged length of time, for example by asking them to complete a short questionnaire six months after the event, will also lend further credence to your evaluation and conclusions.

This particular approach to assessing the prior and posterior level of understanding can, for some, be overly reminiscent of 'assessment', resulting in negative implications for the activity. In such cases it might be better to adopt a more informal 'focus group' approach, where the students are encouraged to chat about subject X both before and after the activity, with their comments and remarks recorded and later analysed by the facilitators.

It can help to justify the legitimacy of any outreach or public engagement activity to the powers that be (your line manager, head of school, or external funding body) if you are able to point them in the direction of peer-reviewed publications that have been produced as a result of your outreach activities. However, in order to publish in pedagogical journals such as *Physics Education* [27], it is essential that the analysis and conclusions are defendable, and in order to do that it is necessary to approach these activities using the scientific process outlined above.

5.9 Training

As mentioned earlier in this chapter, it is advisable to attend some training in outreach and public engagement events before attempting to develop your own events and activities. Whilst a lot of this training can come from getting involved with other outreach activities and initiatives that are being run at your research institute, there are also some dedicated training sessions that will be of great benefit.

In the UK, STEMNET currently offers its registered STEM ambassadors two optional, free training packages. One of these is aimed at helping to build your confidence and presentational skills when working with young people. The other course is designed to help you to start to develop your own activities. Both of these courses are available free of charge, as either face-to-face training opportunities, or via an online toolkit.

The Physics in Society team at the Institute of Physics run a series of one-day training workshops [28] designed to develop the skills and confidence of people who want to get involved with outreach and public engagement. Both of these courses are free to Institute of Physics members, with some limited travel bursaries also provided.

Some funding bodies offer training to researchers who want to develop outreach and public engagement activities based on their research. For example, the National Environmental Research Council (NERC) in the UK offers an excellent course for NERC-funded students and researchers [29] to develop their science communication skills.

In addition to the opportunities listed above, many universities and research institutes also provide free training in outreach and public engagement, although these tend to focus more on delivery than development. It is also worth seeking out your local outreach or public engagement officer, whether in your research group or faculty, as they will be well experienced and should be able to provide you with lots of useful advice, as well as opportunities for further honing your skill set.

When you have been doing outreach and public engagement events for a while, and feel more comfortable and confident with the material, approach and delivery, remember to get other people from your group or wider scientific community involved. After all, it is now these people who will benefit from your own experiences and advice.

5.10 Outreach checklist

Table 5.1 presents an outreach checklist, which should help you in the planning and delivery of any outreach activity.

Table 5.1. Outreach checklist.

	Targeting
Message	**Who do you want to target?** If targeting a school does your university/institute have widening participation targets and a network of schools you can work with? **What do you want to say?** What are the take-home messages of the event? **Why do you want to say it?** This will help you to target the audience, and make you consider the importance and relevance of the event.
	Planning
Development	**Are you developing an event for schoolchildren?** If so, then work with a schoolteacher in the development process, this will ensure that your message is suitable for the students and curriculum. **Are you developing an event for a specific community?** If so, then work with a member from that community in the development process, this will help to ensure that your message is suitable for all.
Funding	**How will you fund the event?** Don't forget to include transport and refreshment costs. Are there any funding schemes that you can apply for?
Advertising the event	**How will you advertise the event?** Use university/institute social media accounts e.g. Twitter and Facebook. Remember that targeted marketing campaigns are much more effective than sending a large number of autonomous emails.
Staff	**Have you got enough volunteers?** Do the volunteers feel as though they are really involved with the process? Have the volunteers checked with their line manager for permission to attend? **Have you provided training and DBS checks?** All staff and students who are working with under-18s need to be briefed on safe and appropriate ways of working with young people. **Is there appropriate staff and facilitator identification?** Wearing badges/t-shirts/fleeces, etc can make it easier for participants to get help.
Insurance	**Do you have valid public liability insurance?** Your university or research institute should be able to help with this.
Risk	**Do you have a risk assessment?** You should complete a risk assessment for each of your activities, and have it signed off by the venue, and event organisers.
Materials	**Do you need any materials?** Prepare any resources and take-away materials. Have you got extra copies of *everything*?

(*Continued*)

Venue	**Have you considered your AV/ICT requirements?** Do you require computer/Wi-Fi access? Will you require audio visual hire and IT support? **Have you confirmed the room with the venue?** Can you get it set up the way you want it? **Does your venue have all the equipment you need?** Do you have extra equipment/a backup plan in case they don't? **Is there adequate visitor parking?** Are people aware of where to park and what restrictions apply? **Have you got adequate signposting?** Can visitors find your event, and do they know where the toilets and other amenities are?
	Delivering
Participant information	**Have you received parental consent and emergency contact information?** This should all be kept secure, and destroyed after the event. **Have you printed off photo and video consent forms?** For larger events, you should try and give stickers to those who do not want to be filmed or have their images used.
Health & safety	**Are you aware of the fire procedure?** Is there due to be a fire drill? Where do you assemble in the event of a fire? Have you ensured that fire alarms are turned off for any events that may generate smoke? **Do you know how you would access first aid?** All events should have at least one person professionally trained in first aid, and with an up-to-date qualification. For larger events consider asking an organisation like St. John's Ambulance [30] to help out.
	Evaluating
Monitoring/ evaluation	**Have you recorded the metrics?** Record the metrics of the event: number of participants, reasons for coming, etc. Produce some sort of report/summary (half page at least) on every session. Get feedback from all of the involved parties. **Have you done a proper evaluation?** The evaluation begins before the delivery; try to assess the participants' level of prior knowledge. Can your activity be turned into a publication? Have you carried out an ethics check, if required, for any research that may result from this activity? **Have you advertised your success?** Remember to advertise the success of your activity via social media and your host institution's website, but *always* check that you have permission for photos etc first!

5.11 Summary

This chapter has outlined the different ways that scientists can work with the general public in order to engage them with their research. It has introduced the nomenclature of this outward form of science communication, and has tried to make explicit the difference between outreach (a one-way communication of ideas, from scientist to non-scientist) and public engagement (a two-way discourse between scientists and non-scientists), providing examples of each.

When you are designing and delivering your outreach and public engagement activities just remember what you are saying, why you are saying it, and whom you are saying it to. Of all of these it is the whom that is undoubtedly the most important. Science is an incredibly empowering tool, and at its heart it is all about having the integrity to come up with the right questions, and the confidence to ask them. It is all too easy to develop an outreach activity for 'the scientifically converted', i.e. those people that already have an interest in science and are aware of what it does and can do for them. Instead you should think about ways to bring science to those who have slipped through the cracks, those for whom science is an abstract construct that further alienates them from the rest of society. It is these people that will benefit most from your expertise, passion and engagement, and we should all be working together to ensure that science becomes the enabling and aspirational vehicle that it can so clearly be.

5.12 Further study

The further study in this chapter is designed to help you think further about developing and delivering an outreach or public engagement activity:

1. **Become a citizen of science:** go to zooniverse.org [31] and find a citizen science activity that you like the look of, and then take part. After you have devoted endless hours of your life to finding galaxies or identifying whale song, tear yourself away from the screen and ask yourself if any of your research could be done in a similar way.
2. **Order some science:** find your nearest Café Scientifique or SciBar event. Go along to one of them and see what it is like. If you like what you see, then offer your services to the event organiser. These public lectures are an excellent forum to learn your craft as an effective science communicator.
3. **Get out there:** go and find the widening participation office at your university or research institute, or failing that any outreach, public engagement or schools liaison officer. Invite them for a brew and start to pick their brains about communicating your science to the wider public. It will almost certainly lead you down some interesting paths…

Suggested reading

There are a number of online resources that provide useful hints and tips on how to engage the general public with your research. For advice on how to best engage with schoolchildren, the GeoEd column [32] on the blog of the European Geosciences

Union [33] offers regular articles. The *Science Communication* journal [34] and the *Journal of Science Communication* [35] are both useful resources for examples of best practice via innovative case studies. These two publications also offer useful insights into both the internal and external roles of science communication in general, and are highly regarded journals in which you could aim to publish findings from your own outreach and public engagement activities. Finally, the NCCPE are a great resource for a lot of public engagement and outreach resources, including detailed evaluation strategies [36].

References

[1] Illingworth S *et al* 2015 What's in a name? Exploring the nomenclature of science communication in the UK [version 2; referees: 3 approved, 1 approved with reservations] *F1000Research 2015* **4** 409

[2] STEMNET: www.stemnet.org.uk/, accessed 8 July 2016

[3] Disclosure and Barring Service: www.gov.uk/disclosure-barring-service-check/overview, accessed 8 July 2016

[4] Bright Club: www.brightclub.org/, accessed 8 July 2016

[5] Science ceilidh band: www.scienceceilidh.com/scienceceilidh/, accessed 8 July 2016

[6] The Poetry of Science: http://thepoetryofscience.scienceblog.com, accessed 8 July 2016

[7] Café Scientifique: www.cafescientifique.org/, accessed 8 July 2016

[8] SciBar: www.oxfordscibar.com/, accessed 8 July 2016

[9] British Science Association *Policy Debates*: www.britishscienceassociation.org/policy-network, accessed 8 July 2016

[10] British Science Association *Science Busking Guidance*: www.worc.ac.uk/documents/CampusScience.pdf, accessed 8 July 2016

[11] Health and Safety Executive *Example Risk Assessments*: www.hse.gov.uk/risk/casestudies/, accessed 8 July 2016

[12] Galaxy Zoo: www.galaxyzoo.org/, accessed 8 July 2016

[13] Galaxy Zoo *Papers*: www.zooniverse.org/publications?project=hubble, accessed 8 July 2016

[14] Old Weather: www.oldweather.org/, accessed 8 July 2016

[15] CoCoRaHS: www.cocorahs.org/, accessed 8 July 2016

[16] Human Genome Project: www.sanger.ac.uk/about/history/hgp/, accessed 8 July 2016

[17] Illingworth S M *et al* 2014 UK Citizen Rainfall Network: a pilot study *Weather* **69** 203–7

[18] UK Environmental Observation Framework *Guide to Citizen Science*: www.nhm.ac.uk/resources-rx/files/guide-to-citizen-science-117061.pdf, accessed 8 July 2016

[19] National Co-ordinating Centre for Public Engagement *Public Engagement Funding*: www.publicengagement.ac.uk/plan-it/funding/health-science-engineering, accessed 8 July 2016

[20] Institute of Physics *Public Engagement*: www.iop.org/activity/outreach/, accessed 8 July 2016

[21] Psci-comm *Mailing List*: www.jiscmail.ac.uk/cgi-bin/webadmin?A0=PSCI-COM, accessed 8 July 2016

[22] NCCPE-PEN *Mailing List*: www.jiscmail.ac.uk/cgi-bin/webadmin?A0=NCCPE-PEN, accessed 8 July 2016

[23] *Time Out*: www.timeout.com/, accessed 8 July 2016

[24] Eventbrite: www.eventbrite.co.uk/, accessed 8 July 2016

[25] SurveyMonkey: www.surveymonkey.com/, accessed 8 July 2016

[26] Typeform: www.typeform.com/, accessed 8 July 2016

[27] *Physics Education*: http://iopscience.iop.org/0031-9120/, accessed 8 July 2016
[28] Institute of Physics *Training Resources*: www.iop.org/activity/outreach/resources/training/page_47911.html, accessed 8 July 2016
[29] NERC *Media Training*: www.nerc.ac.uk/skills/mediatraining/publicengagement/, accessed 8 July 2016
[30] St John's Ambulance *Events Services*: www.sja.org.uk/sja/about-us/event-services.aspx, accessed 8 July 2016
[31] Zooniverse: www.zooniverse.org/, accessed 8 July 2016
[32] GeoEd *Blog*: http://blogs.egu.eu/geolog/category/regular-features/geoed/, accessed 8 July 2016
[33] European Geosciences Union: www.egu.eu/, accessed 8 July 2016
[34] *Science Communication*: http://scx.sagepub.com/, accessed 8 July 2016
[35] *Journal of Science Communication*: http://jcom.sissa.it/, accessed 8 July 2016
[36] NCCPE *Evaluation Guide*: www.publicengagement.ac.uk/how/guides/evaluation/resources, accessed 8 July 2016

Chapter 6

Engaging with the mass media

There are only two forces that can carry light to all the corners of the globe ... the Sun in the heavens and the Associated Press down here.

– Mark Twain

6.1 Introduction

As scientists we are driven to explore the unknown and analyse information honestly and rigorously. This curiosity to know the truth is, and should be, the essence of our professional identity. However, it is also incumbent on us as scientists to record and communicate any original knowledge that we discover and to inspire others to be curious about nature. There is little point in being the sole person to know something and so it is our duty in equal measure to discover, disseminate and inspire new science.

The means by which we communicate our science to stakeholders are the various 'media'. Depending on the group or individual with whom we may wish to convey knowledge, different forms of media (or methods of communication) may be relevant. In academic circles, peer-reviewed journals and scientific conference presentations may be the most obvious media for this relatively closed audience, but it is also important to bring our science to the attention of wider audiences, including the general public, and to use science to inspire and empower people (see chapter 5). These latter forms of communication are often daunting to some scientists who typically (and perhaps stereotypically) feel much more comfortable communicating with their peer group. It is not unusual for researchers and academics to struggle to break down their often technical scientific understanding for a wider—and much less technical—audience. This potential mismatch between self, narrative and audience can lead to all manner of misunderstandings, sometimes with subtle but important consequences for the direction of public and policy debate. However, this should not put us off engaging with the mass media, and using it to the advantage of all. Instead we should embrace it as a powerful tool by which our

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science can really make a difference and have impact. After all, this is the point of our work. But it is important to know how to effectively wield this power for the purposes of truth, awareness, and meaning.

Chapters 2 and 4 of this book cover some of the specific specialist academic media that researchers use to communicate predominantly among themselves. In this chapter, we focus on what we might more conventionally think of as media, such as the mass communication methods of television, radio and the printed press. The specific cases of engaging with modern social media and the internet will be discussed in chapter 7. We shall discuss how to construct a useful and succinct narrative for the often fast-paced environment of the mass media, and how to remain focussed under the often stressful, and sometimes hostile, scenario of being interviewed by journalists and presenters.

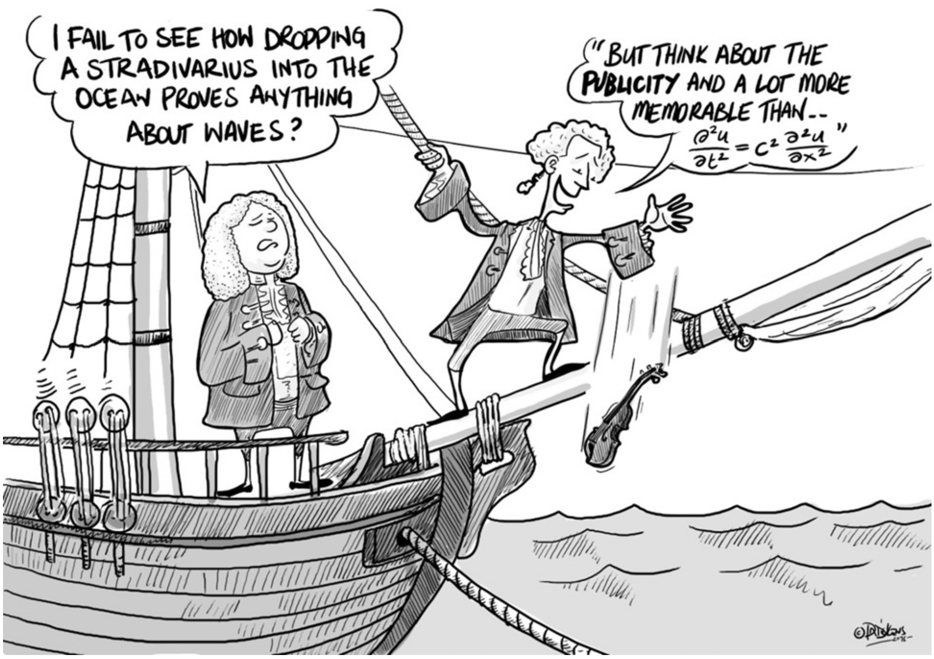
6.2 Why, when, and how to, engage with the media

In section 6.1, we summarised why it is important to engage with the mass media. Mass media are the routes by which science can raise awareness among the general public (and/or less specialised audiences) about the conclusions of research and what it may mean for human society and the world. By spreading knowledge wide and far, others may see possibilities to take your research in all sorts of tangential directions, by linking it with their specialist knowledge in disciplines that may be otherwise inaccessible to more specialist media. Mass media is a vehicle to brief enormous audiences that may not otherwise seek out information from more academic settings.

Mass communication is also a means by which we can inspire the next generation of scientists, and instil the philosophy of science and the honest pursuit of knowledge as cornerstones of our civilizations and cultures. A respect for the truth, and the freedom to pursue it, is undoubtedly the reason that homo sapiens have been so successful on Earth to date. By conveying that sense of academic freedom and knowledge to others, we encourage and empower others to question, to reach informed opinions, and to rationalise and understand the world around them. I can recall a childhood filled with TV documentaries by the likes of Carl Sagan and David Attenborough, whose knowledge and inspiration drove me to study science and to think about my place in the Universe. Such luminaries are the defenders of truth and reason and we should not shy away from seeking to do the same.

This brings us to the question of when and how we should seek to engage with the mass media. In the examples of Carl Sagan and David Attenborough, their wide and expert knowledge of whole fields of science (as well as their innate passion and charisma and the skills of expert producers in the background) made them ideally placed to become the icons that they undoubtedly are. However, for most of us, especially at the start of our career, we must decide when we have a story worth telling or a comment worth making, and how best to communicate it.

Engaging with the media is either a passive or an active process. You may wish to alert the media to something you have to say (e.g. through a press release) or you may be consulted for comment (e.g. by a request for comment through your organisation's press office). Only you can decide when you have something worth saying, and it is always important to ask yourself if you have valid, accurate and useful information to convey. However, press officers can help to suggest when there is research done by a particular scientist that is of interest to the media. Many scientists don't realise when their research is of interest to the media, and there are also some who think their science is exciting for journalists when it isn't. Getting in contact with your institution's press office (or the press office of the publisher that you've submitted your work to) means that they can help you to find out whether your research is newsworthy, and if it is then how best to go about ensuring that it reaches the widest possible audience. The next step is to consider your narrative or message, to think about the audience you want to reach, and how best to say it in a succinct but accurate and informative way. In the rest of this chapter, we shall look at some of the ways you can engage with the media and how they may pick up your story.



6.3 Press releases

Press releases are an active way (from your point of view) of engaging the mass media. These are a useful tool when you know you have an important story that you feel a mass audience may want to hear.

A press release is typically a short (often one page of A4 at most) layperson description of some new scientific conclusion, or exciting new project that carries interest to the media. It will typically contain a short title (perhaps a sentence), a description of the science and why it is important news, and often contains one or two quotations that might be used, in addition to contact information for journalists to get in touch with you or your team for further comment. Drafting a good press release typically requires training or skill and it is often appropriate to get help from professionals such as a press officer (if you have access to one). However, with experience, an individual can draft a good press release with minimal help. One thing to bear in mind is that you must always seek approval for, and submit, a press release through formal channels at most institutes or companies, especially where your affiliation may be used. This offers protection for you and may avoid embarrassing or legal issues if serious mistakes are otherwise made.

Many of the science news stories you will have seen on TV or heard on the radio will have first been picked up by a science journalist specialising in scientific news by reading a press release. Other press releases may be sent directly to specific news organisations' news desks. Those journalists will make a decision on whether they would like to pick up the story and then typically discuss it with their editor. They may then attempt to make contact with you to discuss the story further or they may take the information they need from your press release. A press release may have been sent to a large database that alerts potential journalists, or it may have been sent to specific journalists in a more targeted way.

I have submitted several press releases through my university's press office that have resulted in over a hundred live or recorded TV news items, radio interviews and newspaper articles over several years. I have also submitted releases that have not attracted any media interest, and there are many factors that are simply beyond your control when it comes to whether or not a press release is successful. Often the success or take-up of your press release might depend on the coverage of big news stories in the press at the time, or on editorial policy, which is why it can also be important to consider the timing of releasing your story to the world.

An example may be useful here. In 2012 I was the Principal Investigator for a funded project to measure the air quality around London from a specialised research aircraft [1], part of which involved measuring how a cloud of pollution from London was moving over areas far away from the initial sources of pollution within the city limits. This measurement field campaign coincided with the 2012 London Olympics, and there was a lot of attention to the problems of air quality in the news because of earlier potential athletic performance impacts during the Beijing 2008 Olympics. I clearly had something useful to add to the news debate at the time, and I knew that being able to show people how we can measure this from an aircraft would be a good way to showcase cutting edge research methods, and help people to understand how air quality impacts are felt much further away than the cities in which pollution is emitted. I issued a press release through my university press office that described the project, which was picked up by the BBC Science Editor who then asked to join us on a research flight around London to film and interview the team, while they recorded and discussed data in real-time as it was measured. Before filming, the editor and I discussed what we each wanted to talk about and what questions would be asked. This allowed me to plan my narrative and set constraints on what I would and would not talk about. Not all media interviews afford you the luxury of a detailed discussion on the contents of an interview in advance. And live interviews do not offer you the chance to re-record (see section 6.5), but setting your personal constraints in advance (if only in your own head) is always important for any interview, as we shall discuss in section 6.4.

Other ways to get involved with the media include registering your field expertise with national science media organisations such as the Science Media Centre [2] in the UK, for example.

Exercise: draft a press release

This exercise will help you to formalise a media message and help you to think about which aspects of your research might be ripe for media attention.

1. Think about your research or a topic of research that interests you. Make a list of some of the recent key findings from that discipline or from results of your own research.
2. From this list, rank or group those findings in order of which you think may be of most interest to the public.
3. Create a maximum 10-word title that encapsulates your highest ranked finding or group.
4. Create a 50-word summary or sub-title for this aspect.
5. In a further 200 words, explain the context and background to this aspect and explain why it is an important story for a mass audience.
6. Finally, give two quotations (up to 40 words each) that could be used without further permission from you, and which convey a central message about this finding.
7. List who to contact for further information.
8. If you have access to a press office in your organisation, pass this press release to them for comment and advice. But make sure you tell them you don't want to release it!

6.4 Constructing a narrative for mass media

Formalising and scoping a media message depends on what form of media you are dealing with, and how much space (in the case of a written article) or time (in the case of an interview) you are given to present it. But there are some common rules to all media content to keep in mind, in order to help ensure that your message is understood by as many people as possible. These are to:

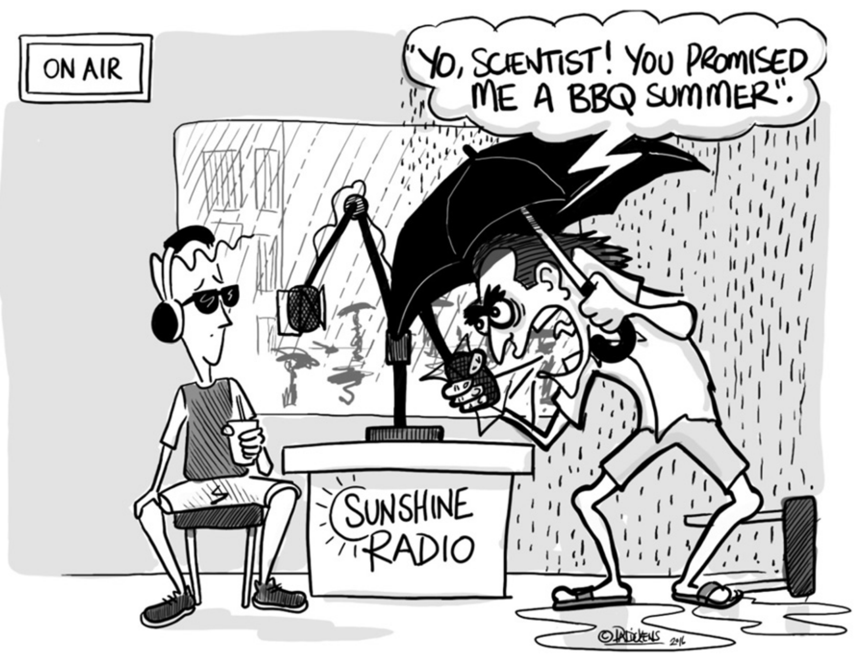
1. Keep it simple—talk in non-technical language wherever possible.
2. Keep it on point—define and discuss a narrow scope and don't stray, ideally identifying one key point you know you need to make.
3. Be clear—do not make vague statements and don't use ambiguous language.
4. Be accurate—make sure you have researched what you are saying and you know what you are talking about (otherwise why are you doing it?).

The most important thing to keep in mind is that you must be careful that a journalist, reader or viewer cannot pick and choose something you are not happy to say from your press release, article, comment or interview. You may hear of people who have been aggrieved because they were misquoted or misunderstood in the press. In science, this is perhaps rarer than in a field like politics, where debate is often concerned with attitudes and viewpoints as they evolve. But contentious and emotive debates do surround science—take human-made climate change for example. Editorial policy may direct the context of how you might be quoted or questioned. However, much of the time any misunderstanding may be completely unintentional and due to an unbiased journalist simply not understanding what it is you are trying to tell them. Your job is to minimise the risk of misunderstanding by carefully constructing any quotation, article or press release; and (where possible) first discussing your story with your press office, journalist or producer informally so that you each have the chance to make sure there is a mutual understanding of the facts and the tone.

It is extremely rare that you will be led into a false sense of security and understanding only to be later thrown to the wolves. This has happened to me only once. I agreed to be interviewed live on a New York radio station about the impacts of volcanic ash on planes over Europe after a volcanic eruption in Iceland in 2010. I was fielding so much media attention at the time that after a very quick telephone call with a polite producer telling me I would be interviewed about the science of volcanic ash transport in the atmosphere, I found myself personally accused (live) of being responsible for grounding aircraft over Europe, and was told that I had inconvenienced thousands of New Yorkers! Without any chance to reply the phone was put down on me and I never heard from the producer again. In this specific case, I suspect the producer was just looking for anyone that the radio presenter could have a one-way rant at. They certainly weren't interested in what I had to say. Pretty much all I said was 'hello'. And they certainly didn't bother to find out if I was the right person to interview for what they wanted to talk about. The lesson to be learned here is to always do your own background check on the TV channel, show, presenter or newspaper before diving in. And make a judgement about the chances of being allowed to present the message that you want to get across. If you find yourself faced with an interviewer, panel member or audience question where your viewpoint or science may be attacked, it is always important to remain calm and objective, no matter how unnerving this may seem. It helps to remember that the mass media is ostensibly concerned with open debate, and that open debate is best served through a rationalised discussion of facts from the viewpoint of the researcher. While heated debate and personal accusation can make for exciting reality television, for example, scientific debate is rarely convincing or useful to anyone when it strays too far from objective reasoning. In this scenario, it is more important than ever to remain focussed on a discussion of the facts as you understand them and not to be drawn into a wider discussion where you may not be qualified to speak. A calm and professional demeanour is always preferable whilst getting any message across.

It is important to emphasise that despite the one rather amusing and unfortunate example above, the vast majority of my dealings with the press have been overwhelmingly positive. Most journalists will take the time to make sure that they understand any story from your point of view and give you a chance to comment or change anything they write or present. Often, the more serious and professional media organisations may even go a step further and check that what you have said is accurate by consulting other sources, and you may even be asked to reconfirm your story. Only rarely may you be asked to speak or comment without having a chance to discuss the detail of any interaction in advance, even when preparing for live interviews. And most importantly, if you're not comfortable or confident that what you have to say will be accurately presented, you should say so and withdraw from the process; especially if they happen to be live radio interviews for a New York radio show you are not familiar with!

So how do you construct an infallible and accurate quotation or story for the mass media? There are a number of common steps you should take to prepare beforehand, whether your means of engagement is live, recorded or written. You need to break down the information you want to convey into simple and self-contained blocks and define (at least to yourself) where your story begins and ends so that you don't veer off topic, and end up talking about aspects which you are not qualified to discuss professionally. And if you ever do mix personal conjecture and scientific fact, you should be very clear to point out which is which. Much like in the question and answer session of any scientific conference presentation (see chapter 4), don't try to answer a question that you don't know the answer to.



Here are some useful tips to use when preparing any content (including an interview) for mass media:

1. Write a mock press release, whether you intend to submit it or not (see exercise above). This is useful even if preparing a written article for a scientific magazine. It will help you to formalise your thoughts and present them in non-technical terms.
2. Try to read your press release from the point of view of a non-expert. Ask a non-expert for help if you have the time. Identify where there is scope for any confusion, such as vague statements or overly assertive statements that are not as balanced as they may need to be. Correct these or remove them. Or much like a literature review, make sure you understand all sides of any balanced arguments that you may need to raise.
3. Write down a simple sentence that describes the one over-arching aspect, point, or conclusion that you wish to get across. You may only get the chance to present one aspect, so make sure this simple message is front and foremost in your mind.

6.5 Television and radio interviews

Earlier in this chapter we looked at preparing a narrative for mass media in fairly general terms. Here we will talk about what it is like in practice to give TV and radio interviews. We will approach this from the point of view of someone doing this for the first time and we certainly fall well short of discussing how to present a TV or radio show; something that requires specialist training and experience and likely a broader career aspiration.

Of all the mass media, exposing oneself to a television camera or a live microphone can be the most unnerving. After over 100 such interviews, both live and pre-recorded, it is still natural and perhaps useful to feel a little nervous. But it is equally important to keep calm and not panic. Different people will react differently—some of us are more confident than others—but with preparation, training, practice and experience (and breathing), it can become easier and more rewarding. In this section, we will attempt to take some of the mystery out of the process of appearing on television and radio by citing personal experiences and offering some tips and advice. It is also worth noting that much of the advice presented in chapter 4 is also extremely useful for these situations.

As already discussed, preparation is the first step. This involves scoping out what you want, and don't want, to say and discussing the content of any interview or line of questioning with the journalist, producer or presenter beforehand. In the case of live TV news or radio interviews, you will usually be contacted by a producer who will discuss and agree any interview with you over the phone well in advance. This may be several hours prior to, or even the day before any interview, and you will be invited to talk informally about the subject you will discuss on air. You will have a chance at this stage to make sure that both you and the producer know what you will and won't feel comfortable in discussing. This is a two-way preparative exercise—the producer will be looking to gauge how well informed you are, and whether you will be able to articulate your message live on air, whilst you need to make sure you ask any questions to put your mind at ease. You may then be invited and given a time to arrive at a studio, or told a time that a presenter and camera crew will come to you. This may then give you some time to prepare.

Live TV news interviews to camera can take one of three forms: a face-to-face interview with a presenter or anchor in a studio; a remote interview from a regional studio, where typically you will only hear (and not see) the presenter through an earpiece; and face-to-face interviews with a presenter out in the field. The remote studio interview is perhaps the most unnerving to the uninitiated. You will typically meet with a producer or crew member in the green room of a studio, where you will have a final opportunity to discuss the interview before being taken to a sound-proofed room with a member of technical crew who will prepare you for camera and sound. You will then briefly talk over the microphone to a member of the gallery, which consists of a team of directors and technicians, who will check that you can hear the studio and warn you of when you will be live with the presenter. At this stage it is important to take deep, slow breaths and to calm yourself as much as possible. You can typically hear the live sound feed at this stage, and so you should take the luxury of the few moments you may have at this stage to listen to the news as if you were at home. If you are well prepared at this stage, thinking further about the interview can be counter-productive and only serve to add nerves. But it is important to find what works best for you.

You may find the actual interview quite automatic, especially if you and the producer have scoped it out well in advance. Try to make sure that your one key point has been made early and answer any questions that you feel able to; and don't answer those that you may not know the answer to. Remember to breathe deeply during any pauses and try to be conscious of any body language or nervous fidgeting. A good way to mitigate this is to practise in front of a webcam or camera at home, and to watch out for anything that may not look professional on camera. Actions such as scratching rarely come across well. But appropriate use of hand movements, head tilt and good eye contact with the camera can really help to emphasise your message. Body language such as this can be unnatural for some, but with careful thought and avoidance of more negative body language, it is possible to project confidence and clarity. Simple measures such as maintaining an upright and straight stance when sitting or standing can also help in this regard.

Face-to-face live studio interviews are perhaps a little more comfortable as you can see the presenter and benefit from being able to interact with their body language in a way that you cannot in remote studios. Field interviews tend to be more comfortable still, since the field presenter (if not acting as an anchor) typically has some time to talk to you ahead of the live interview and discuss any questions further, which you may find naturally helps to put you at ease.

Live radio interviews are not so very different from those for television. The process and setting are broadly the same—you may be face to face with a presenter in a remote studio (or speaking on the phone), or out with a roving reporter.

I approach radio interviews in exactly the same way as TV interviews, and when speaking to a presenter I behave exactly as I would on any TV interview, including using gesticulations or body language, which naturally help to project clear oral communication.

Some personal tips on handling live interviews are:

1. Always be respectful—don't continue talking about a drawn out subject when the presenter has asked you to stop.
2. Don't interrupt. Or be interrupted…
3. Demonstrating passion for your message can be important—speak clearly, loudly, confidently and with intonation.
4. For TV—be mindful of nervous body movements and actions like swaying, scratching your head or playing with your clothes.
5. Use emphatic body language such as a head tilt and hand movements if these come naturally to you. But use these sparingly and with subtlety.
6. Sit or stand as tall and upright as possible.
7. Try to avoid using 'erm' or 'so' at the start of sentences. Instead, take a quiet moment to compose your answer if you need to. These 'filler' words are often used to help us formulate a response in stressful situations, but they do not present well.
8. Don't attempt to answer anything that you do not know about.
9. Remember you are on the record: be mindful about not saying anything you wouldn't want to see reported or quoted and attributed to you.
10. And finally, practise in front of a camera yourself. You'll be surprised how any recording device can naturally force you to behave as though there was really an audience there.

As well as the interviewer–responder setting of a live interview, recorded interviews can also include features for science documentaries or other media outputs. These settings are broadly similar to live interviews, with the exception that you may have the chance to re-record any sections you are unhappy with. In addition, the production team may have the opportunity to edit any material prior to release. Curiously, I have often found that simply knowing that I have the luxury to re-record material means that I often make verbal mistakes in pre-recorded settings, whilst the pressure of live interviews seems to always ensure that I get it right first time! This has especially been the case when recording one-way monologues for documentaries, and is perhaps due to the fact that the absence of someone asking specific questions means that we are left to formulate our own thoughts, meaning that what we have to say becomes less of an automatic response and more of a voluntary choice. In such a setting it can help if you ask your presenter or crew to give you prompts. These could be written cues or verbal questions that remind you about what you have prepared in advance, thereby helping to break down any monologue into manageable sections. However, in all cases, it remains important to scope out and list the general content of what you need to say, especially if this concerns any important facts or figures that it may be important not to get wrong!

Exercise: practise for a live interview

This exercise will help you to prepare for and perform confidently in interview and in front of a microphone or camera.

1. Pass your press release prepared in the earlier exercise to a friend or colleague who is willing to help you by acting as a TV news anchor and interviewer. Ask them to prepare a list of questions to ask you based on the press release, but ask them not to share this with you in advance.
2. Set up a webcam or video camera with a microphone in a quiet room where you and your interviewer can attempt to recreate a live interview experience. Focus the camera on you from a frontal aspect but with your interviewer out of view. This is because we want to simulate the pressure and attention on you (and not your interviewer).
3. Ask your friend or colleague to interview you about your chosen topic and record it.
4. Watch the interview back, preferably with your friend or colleague, and reflect on how well your message(s) came across. Focus also on your style of delivery, confidence, clarity, and body language. Is there anything that you are unhappy with or which you could improve?
5. Repeat this as many times as you can until you feel more confident and natural in front of a camera.
6. To take this further, you could consider making this scenario a regular part of your professional life by recording a podcast or video blog about popular science in your field and uploading this to a video hosting site such as YouTube (see chapter 7 for more details).

6.6 Summary

This chapter has explored several methods of engagement with the mass media, and provided tips and advice on preparing for recorded media interviews from the viewpoint of a researcher wishing to convey a scientific message. The key to successful engagement concerns preparation, practise and confidence. Whilst media engagement can be unnerving, it is a powerful way to educate, to inspire others, and to affect meaningful change as a result of scientific progress.

6.7 Further study

The further study in this chapter is related to gaining experience with the mass media, it should make you think further about how best to get their attention and to promote yourself and your research in an effective way when you do:

1. **Pitch an idea:** go to the website of a popular science magazine or TV show and look for their submissions page. Using the press release that you have developed in the chapter, along with the guidance for submissions, pitch an idea based around your current or future research.

2. **Listen to a science radio show:** find a regular scientific radio show (e.g. *The Life Scientific* with Professor Jim Al-Khalili on BBC Radio 4). Make a note of what you find interesting about the programme. Is there any aspect that you find unengaging? Could you imagine yourself being a contributor on that programme? If so, then how do you go about becoming one?
3. **Watch other scientists:** look online for a recent TV interview with a scientific researcher. Do they come across well? Are they able to communicate their research in a succinct and entertaining manner? Do they engage with the other people in the studio? Try and observe if there are any other examples of good practice that you could learn from, or any bad habits that you potentially see in yourself and which should be avoided.

Suggested reading

Chapters 1 and 2 of *The Sciences' Media Connection—Public Communication and its Repercussions* [3] are especially relevant to this chapter and discuss the impact of science and science communication in society. *Introducing Science Communication: a Practical Guide* [4] also offers some great advice on dealing and engaging with the media. The Science Media Centre [2] in the UK promotes engagement between academics and the media by acting as a proactive link through which the media can solicit expert quotations and interviews on topical stories; and through which academics can raise the profile of any outputs that they may wish to make the media aware of. Their website provides advice on how to register as an expert, allowing you to receive email alerts and requests for comment.

Besley and Nisbet (2011) [5] present a large study of UK and US scientists' perceptions of the media and the public, and how they generally and statistically perceive the public audience and media and their own experiences of engagement. Similarly, de Bruin and Bostrom (2013) [6] examine how groups and individuals process scientific information and how this is used to develop personal and public opinion. To this end, the article also discusses how to present information in suitable ways for a given audience to obtain maximal absorption. Finally, Bauer and Jensen (2011) [7] discuss a scientific study of the effectiveness and motivations of public engagement by scientists and, as such offer an interesting insight into the role and practice of science communication. It is part of an interesting wider special issue in this highly relevant journal that should be consulted for even greater depth on this topic if desired.

References

[1] FAAM: www.faam.ac.uk, accessed 8 July 2016

[2] Science Media Centre: www.sciencemediacentre.org, accessed 8 July 2016

[3] Rödder S, Franzen M and Weingart P (ed) 2011 *The Sciences' Media Connection—Public Communication and its Repercussions* vol 28 (Berlin: Springer)

[4] Brake M L and Weitkamp E (ed) 2009 *Introducing Science Communication: a Practical Guide* (London: Palgrave Macmillan)

[5] Besley J C and Nisbet M 2011 How scientists view the public, the media and the political process *Public Understand. Sci.* 0963662511418743
[6] de Bruin W B and Bostrom A 2013 Assessing what to address in science communication *Proc. Natl Acad. Sci.* **110** (Supplement 3) 14062–8
[7] Bauer M W and Jensen P 2011 The mobilization of scientists for public engagement *Public Understand. Sci.* **20** 3

Chapter 7

Establishing an online presence

The amount of control you have over somebody if you can monitor internet activity is amazing.

– Tim Berners-Lee

7.1 Introduction

The twenty-first century is a marvel of scientific invention and technological advancement, but arguably the greatest impact that any of this has had on the rest of society is the development of the internet; from a limited browser used by a select and dedicated few, to a ubiquitous entity that permeates almost every facet of our existence.

Whilst it has its distractions and detractors, there is no denying that the internet has helped to revolutionise science and the scientific process. We can now simultaneously edit documents with colleagues from across the world, or converse with them via video conferencing facilities. The internet has also opened up a wealth of possibilities in a personal capacity, with people now able to share images, videos and stories with friends and strangers at the click of a button or the touch of a screen.

With this capacity for sharing and instantaneous connection, it has become almost a prerequisite for today's scientists to have some sort of digital footprint. Whilst this is not to everyone's taste, it is important to realise that establishing an effective web presence can not only help you to be a better communicator, but it can also help you to be a more effective scientist. This chapter will provide useful advice on how to create a digital footprint that is specific to you, and one which will help you to communicate more effectively.

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7.2 Blogs

One of the most straightforward and rewarding ways that you can start to build your digital footprint is by setting up a weblog, or 'blog'. A blog can be thought of as an online collection of your writing, whose form is pretty much only limited by your imagination. You can write about your research, or give your reflections on a recent field campaign. Or you might want to write about a recent paper that you have read, or the political state of affairs of science in your host nation. Similarly, blogs don't just have to be words; you might decide that you want to share pictures from your research, or a time-lapsed video of a particularly impressive experiment. With so much to potentially share it is important to once again ask yourself what, why and who. What do you want to say? Why do you want to say it? And whom do you want to say it to?

When figuring out what it is that you want to say, it is a good idea to look at other science blogs to see what's already out there. There are a variety of different blogs, from professional science bloggers like Ed Yong [1] and Alice Bell [2], through to active researchers who write fascinating and articulate blogs about their work, many of which are hosted by blog networks such as at the *Guardian* newspaper [3] and *Scientific American* [4]. Reading these blogs, it quickly becomes apparent that the most successful (in terms of quality and readership) are those which have something new to say, and which say it in a strong and discernable voice. Much like writing a scientific journal, there is no point simply rewriting something that someone else has already done. Equally there is no point in writing something that only two or three people in the world will understand.

Almost all of the most successful blogs are those that are written for a general audience, and unless you have a specific reason for writing for a more specialised readership, you should be writing your blog with a general readership in mind. Here are five useful tips for writing an engaging and effective blog:

1. **Keep it short:** aim to keep your blog posts somewhere between 400 and 600 words. There may be instances that call for a more in-depth account, but this will almost certainly result in a smaller readership.
2. **Use a pyramid structure:** start with the key results, and then tell the story of how you got there. If there is not enough of a hook in the first two sentences, then people will stop reading. These two sentences are normally what will appear on search engines as well, so if they are interesting enough then more people will read them. As shown in figure 7.1, this style of writing is almost the mirror image of what you would expect when reading a scientific article in a journal. Many non-experts will simply not have the patience to wade through pages of background and context before getting to the juicy bits!
3. **Get your granny to read it:** when you are writing your first couple of blog posts get a friend or family member that doesn't have a scientific background to read your post, and to highlight the bits that they don't understand, or that don't scan well.
4. **Be original, and maybe even a little provocative:** nobody is going to read something that they have seen before. Likewise, there's no point sitting on the fence, and whilst you should always be respectful, there is no harm in presenting your opinions. Providing of course that you are willing and able to defend them should the need arise!
5. **Post regularly:** try to write on at least a fortnightly basis, and when you have got the hang of it, kick it up a notch and start posting weekly or even more frequently. People aren't going to keep checking your blog if you only update it every six months!

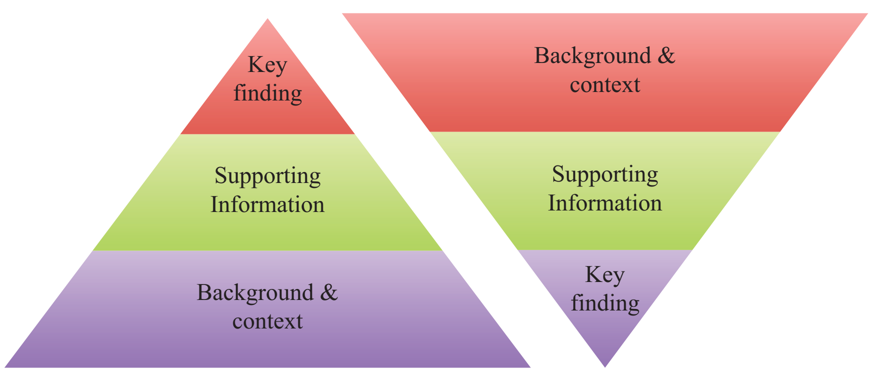

Figure 7.1. The difference between the structure of a news article (left) and scientific paper (right).

When you are starting your blog, it is important that you consult your line manager, that you run the idea past your institute's legal team, and that where appropriate you include a disclaimer. As a rule of thumb never say anything that you would not be willing to say in person at a scientific conference. Also, make sure that if you are publishing preliminary results that they are not going to jeopardise any potential future publications that you or your colleagues are working towards.

Now that you have decided what you want to say, why you want to say it, and whom you want to say it to, you need to think about where you are going to host your site. There is an extremely large number of sites that can host your blog, either for free or for an administration fee, and it is really up to you to determine which ones you think most closely match the ethos of your message and your writing (or picture, video, etc) style. Two of the most popular (and free) blogging platforms are Wordpress [5] and Tumblr [6], although there are many more for you to choose from. All of these sites provide comprehensive tutorials on the technicalities of setting up a blog, and there are also dedicated user groups within each community that will be able to help you as you go.

Interacting with other blog users, either on your blogging platform or across sites, is a great way to attract followers and to begin to build a community. Commenting on other blog sites will encourage those bloggers to investigate your own site, and it is important to realise that no blogger is an island. Similarly, if people post comments to your site, then try and respond to them in a punctual and engaging manner. Don't be afraid of defending you opinions, but likewise as a scientist you should be prepared to admit to the times when you have got something wrong.

You will probably have heard about internet trolls, people who write defacing and inflammatory comments whilst often hiding behind a fake identity. If you encounter any trolls on your blog (which is probably pretty unlikely, unless you are

maybe writing about something particularly contentious), then remember that as the owner of the site you have the ultimate control. Simply delete the comment without responding to it, and report the person who sent the comment to the administrative staff of your blogging platform. The best way to deal with bullies is to starve them of the attention that they so desperately crave.

If you find the notion of writing a blog post on a weekly basis to be a daunting task, then consider writing as part of a collective group of bloggers. Either find some colleagues with whom you share a similar vision, or reach out and interact with communities that already exist, such as ScienceBlog [7] or more parochial sites such as The Brain Bank [8], based in the north-west of England.

Exercise: write a blog

Begin by sitting down and planning out exactly what it is that you want to say, and why you want to say it. Will you be writing blog posts that detail interesting aspects of your research that you are currently involved in, or do you want to showcase some of the exotic microorganisms in your laboratory? Whatever it is, try to keep the theme sufficiently broad so that you will still have something to write about in six months' time.

After you have worked out the what and why of your blog, think about your target audience, and then go and have a look at some of the different blogging platforms. Which one works best for you? Try and plan out about five or six topics in advance, and follow the tips for writing a blog that are listed above. Remember to get involved with your blogging community, and to respond to any comments in a timely fashion. Pretty soon you'll be a blogging expert, able to communicate a variety of subject matters in an innovative and engaging format to a wide and varied audience.

7.3 Podcasts

Another great way in which you can start to establish a digital footprint, or to build on the one that you already have, is by creating a podcast. A podcast is effectively an audio blog that allows you to communicate to an audience via the medium of sound. It can be an incredibly effective science communication tool, and is also a fairly easy way of establishing an engaged and interactive audience.

You might think that recording a podcast is a difficult and expensive process, but really all you need is a computer with some editing software (the majority of which is available for free), a reasonably decent microphone (although the built in microphone of most modern laptops will suffice), and somewhere online to host the podcast once you have recorded it.

As with writing a blog, the first thing that you need to do is to determine what you want to say, why you want to say it and whom you want to say it to. Once you have determined this, follow these five simple steps and you'll be good to go:

1. **Decide upon your format**: will you be recording a series of interviews, a round-table discussion, or live audio from the field? Whatever you are doing,

remember that you are using the medium of sound, so make sure that you include some relevant noises or effects to emphasise your points, or to bring your story to life. For example, if you are talking about the atmospheric effects of a recent rainstorm, then why not have some light rain playing in the background. Freesound [9] is a great resource for free sounds to use in your podcast.

2. **Decide upon your recording and editing software**: it is worth having a play with a few different toolkits until you find one that works for you. Audacity® [10] is a fantastic starting point, and a great free piece of open source, cross-platform software that allows for incredibly professional recording; it is also very easy to set up.
3. **Find a good place to record:** if you are recording inside then make sure that you are in a quiet room that is free of noise, and where there are no possible distractions. Turn all mobile phones off, and if you are recording using a computer, remember to turn off email alerts etc, so that they do not interrupt the recording! Don't be afraid to record outside, and if you are on location try to find somewhere where the background noises will lend ambience to the piece, or aid in your communications. For example, if you are talking about the effects of methane emissions on a farm, then try recording a segment in a farmyard.
4. **Consider your transitions:** in the theatre if the scenery change is done in a heavy-handed and inconsiderate manner, then it can really affect the overall quality of the performance. The same goes for the transitions between different segments of your podcasts. Carefully considered segues, as well as suitable intro and outro music can really make the difference between a good podcast and a great one.
5. **Decide upon where you want to host your podcast:** there are many free options for you to consider, some of which have premium options if you want to upgrade to more data or take advantage of marketing opportunities. Amongst the best are SoundCloud [11] and PodBean [12]. You can of course eventually register your podcast for download on iTunes, who also provide a set of FAQs for hosting podcasts on their store [13].

Many of the other best practices for maintaining a blog also apply to managing a successful podcast. These include posting regularly and making sure that you become an active part of the user community, rather than simply someone who just posts audio recordings without any further interaction.

7.4 Social media platforms

Social media can be thought of as any web-based application or website that can be utilised to communicate with a network of people. As such, blogs and podcasts can also be considered to be social media, and as has been outlined above there is a great variety in the different platforms that are available within each of these spheres, e.g. Wordpress, Tumblr, SoundCloud, etc. In addition to these, there are also a number of other social media platforms that could and should be utilised in order to be an effective science communicator, and which ultimately can help to promote, and in some cases advance, your research.

New platforms arrive on an almost daily basis, with the popularity of such platforms also in a constant state of flux. As such, to attempt to outline all of the different platforms would require many hundreds, if not thousands, of pages, with all of the detail becoming quickly redundant due to the transient nature of the interfaces. Instead, outlined below are a number of different social media platforms that are currently amongst the most useful for effective science communication. Again, going into any detail regarding the technicalities of using these platforms has been purposefully avoided, as this is something that can easily change, and which is best found out via experimentation. Instead, a brief overview of each platform is given, with advice on how to best utilise that platform to maximise its potential.

When considering which of these social media platforms to use, the most important thing is to find the one(s) that works for you. It is important to be canny in your selection, and to find the medium that you feel is the most suitable for what you want to achieve, and which best matches your own preferences in terms of interface and ease of use, etc.

7.5 Twitter

Twitter [14] is a social media platform, which enables you to connect with other users by sharing your thoughts in 140 characters or less. Whilst many people consider it to be the preserve of sports fans or popular music stars, when used effectively it can actually be an extremely effective tool for science communication. One of these 140-character messages is called a tweet, and as well as tweeting text you can also include hyperlinks, images and video, each of which will currently (at the time of writing) fill a maximum of 22 of your 140 characters.

The social aspect of Twitter involves ‘followers’. These are the people who have decided to follow you, either because they know you or because they find what you have to say interesting or entertaining. Your tweets will appear on their Twitter timeline, just as the tweets from the people that you follow will appear on yours.

If you want to tweet somebody specific then you should address them using their unique Twitter handle, which is indicated by the ‘@’ symbol. For example, if you wanted to tweet the Institute of Physics to tell them how much you are enjoying this book you would write something like this:

‘@IOPPublishing I am really enjoying learning how to be an effective science communicator!’

One important thing to remember is that if you start a tweet with a Twitter handle, then the only people that will see it are those people that are following both you *and* the person that you are addressing. In the previous example, only people who were following both you *and* @IOPPublishing would be able to see your tweet. You can also use Twitter to send a direct message (or DM) to one of your followers (providing that you are both following each other!), which will only be seen by the two of you, and is a convenient way to communicate discreetly. Just remember to check that it is definitely a direct message that you are sending! The blog 'Mom this is how Twitter works' [15] provides more details on the different ways to interact via Twitter in a light-hearted and informative way.

Top 10 tips for effective Twitter usage:

1. **Write a good bio:** make sure that your Twitter biography is not only unique, but that it describes what you do in either an informative or playful (or both) way. Also make sure to include a good profile photo, and some interesting images for the background!
2. **Tweet regularly:** in order to gather and retain followers, you should aim to send between three and five tweets per day as a minimum. This will ensure that you are sending out relevant information to a large variety of people.
3. **Follow interesting people:** as well as following some of the big hitters in your respective scientific fields, you should also consider following tweeters who have something interesting to say about science in general.
4. **Advertise your research:** make sure that you tweet a link to your latest paper or talk. It will ensure that it reaches an even larger audience than it would do normally; you can find out exactly how many with the inbuilt Twitter analytics toolkit. It will also improve the altmetrics [16] of your research articles. Be sure to use Twitter to advertise all of your other digital engagement as well, e.g. blogs and podcasts.
5. **Use hashtags:** A hashtag (#) is a great way of documenting a series of ideas or processes, they also make it even easier for a large audience to find and access your Tweets, as you can search for different hashtags on Twitter (topics with the most popular hashtags are said to be 'trending'). For example if you are tweeting about the virtues of open access, try and leave room in your tweet for #openaccess, as it will help to make your tweet more visible.
6. **Be concise:** you only have 140 characters to play with, so every letter counts! Rather than seeing this as an obstacle though, you should take this as an opportunity to be succinct in your communiqués!
7. **Introduce a bit of you:** whilst you should avoid posting anything too personal, it is important that your followers understand that you are a real person, with real interests, likes and dislikes. Just remember that they probably don't want to hear about what you had for dinner.
8. **Be polite:** don't say anything on Twitter that you wouldn't say in a room full of crowded people, or to the face of the person you are tweeting about. This is good protocol for all social media platforms, but is especially true for Twitter, where it can be quite easy to fire off something that you later regret.
9. **Use tweet chats:** these are a great way of getting involved with a large community-based dialogue, in an engaging and low-maintenance way. A very good tweet chat to introduce you to the concept is the Early Career Researchers (#ECRchat) [17] tweet chat, a global fortnightly discussion for the early career researcher community via Twitter. It is good practice to

forewarn your followers before you participate in such an event, so that they are prepared for the sudden deluge of Tweets!

10. **Tweet at conferences:** this is a great way to connect with your community, and is also an extremely useful resource for those unable to attend. Remember to use the hashtags of the conference and the sessions (if there are any), and also to warn your followers in advance of your rather active timeline. If you are unable to attend a specific conference then following the official hashtag (which almost all conferences have these days) is a great way of finding out what is being discussed, and also gives you the opportunity to join in with any online discussions.

Exercise: write a tweet

Think of the next presentation that you are going to give. Try and condense all of the key points into a 140-character tweet. What is at the absolute crux of what you want to say, and how can you communicate this in a concise and informative manner? For bonus points try and include some relevant hashtags.

7.6 Facebook

Facebook [18] is an online social networking service in which you can share information, photographs and videos with your friends and also the wider community. By creating a profile, you are able to present your likes and dislikes, as well as aspects of your personality to everybody that you wish to share that information with. The use of security settings means that when you post certain items to your Facebook 'wall' you can decide who can and cannot see them. Posts from people that you are friends with and groups that you like will appear on your 'News Feed'.

The social aspect from Facebook comes from your ability to 'like' certain posts, and also to comment on them, thereby initiating a conversation that either a very small or very large number of people can become involved with. There is also the opportunity to send personal messages, and to set up group chats, in which you can also share files, much like can be done with regular email.

As well as setting up a personal profile, Facebook also presents you with the opportunity to create a page for your business or other interests, which you can then invite people to like, and which can ultimately serve as a hub for your enterprise(s). On this Facebook page you can share your photos and videos and also advertise anything of note that you might want to make people aware of. You can also create events and then advertise them here, and invite your friends and followers to attend. One of the biggest advantages of Facebook is the ability to create a sense of community, and there is also the opportunity for people to review your page, and to share it with their friends and colleagues.

Perhaps the two biggest potential drawbacks of using Facebook in your capacity as a scientist are: it is very easy to get distracted, and it can easily become a dumping ground for articles rather than a vibrant community engaged in two-way dialogues. In order to not get distracted by the personal and social aspects of Facebook, it is important to remember that when you are using it as a scientist, that this is the only capacity that you should be using it in. Having a meaningful discussion with people who have posted comments on your posts is a productive use of your time, but playing games is not. In order to help your Facebook page grow into a vibrant online community hub, remember to post content that encourages interaction (for example by posing a question or including a survey), and as with blogs think about the timing of your posts, as well as making sure that the content that you are posting is engaging. As with Twitter, it also helps to inject a little bit of your personality into your page, just not too much. Examples of fantastic Facebook science pages include: News from Science [19], the *Scientific American* magazine [20], and NASA [21]. All of these pages post regular content that is both informative and interesting, and they go to a great deal of effort to engage with their community in an effective and meaningful way.

7.7 LinkedIn

LinkedIn [22] is a business-oriented social networking service that is mainly used for professional networking. It differs from Facebook in that it is strongly focussed on making and maintaining links with people in a mainly professional capacity. After creating a profile, which effectively acts as a digital CV, there is the opportunity to join different groups, and to connect with people that you know on either a personal or professional basis. In terms of effective science communication, LinkedIn is best used as: 1) an interactive discussion board, and 2) a job market.

If you want to use LinkedIn as an effective discussion board, then it is important to find a number of groups that will be of the most benefit to you. Many of these groups have moderated membership, and so you will need to provide evidence that you deserve to be included, either through allegiance (for example university alumni groups) or through merit and/or your relevant expertise. Once you have gained membership to these groups, the discussion boards can be a great way to keep on top of several of the current debates that are currently happening in your field. Joining these discussion groups is also an effective way to connect with other colleagues in your field from across the world, and to demonstrate your own prowess in your discipline. Whilst groups can be an effectual way of cross-advertising other aspects of your digital footprint (e.g. blog articles), it is important to not simply use them as a marketing tool, but rather to include new material that initiates conversation, and genuinely adds something new to the on-going discussions.

As well as being a great resource to actively look for advertised jobs, LinkedIn is also a shop window for future opportunities, some of which you might not even have been aware existed. By maintaining a current profile, and taking an active role in a number of groups and online discussions you are able to proficiently market yourself to a wide range of future employers. Just make sure that you keep your profile up to date with regards to your employment history, qualifications, and also publications. Creating a unique LinkedIn URL (which is free to do) is also a very good idea, as

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Figure 7.2. Example of CV header, showing LinkedIn and ORCID information.

this can then be placed at the top of more traditional résumés, thereby providing a potential employer with even more detailed information about your career and skill sets than would previously have been possible. Figure 7.2 gives an example of what the header of a typical CV might look like, complete with LinkedIn and ORCID (see section 7.10) identifications.

LinkedIn also presents you with the opportunity to list your skills, which can then be endorsed by your connections. This is a useful way of demonstrating that you are not just blowing your own trumpet, but that you are a recognised expert in the field. Furthermore, LinkedIn offers the opportunity for longer endorsements, in the form of mini-references from previous employers and colleagues, all of which can serve to further demonstrate your skills and expertise. Of course, if you have no endorsements, then it may be wise to either ask a colleague to recommend you, or to simply remove that particular skill from your list.

Exercise: update your LinkedIn profile

Many of you might have a LinkedIn profile, but when was the last time that you updated your information? Set aside a couple of hours to update everything, including a nice profile picture that is professional in appearance, and which ideally comes from the current decade! For those of you that don't have a LinkedIn profile, then sign up for one, and follow the instructions, making sure that you elucidate where appropriate, as there is nothing more unappealing than a half-arsed set of answers. Sadly, uploading publications to LinkedIn can be a bit of chore, and so it is advisable to upload the three to five key papers that best represent you research portfolio. You could also provide a link to other databases, such as ORCID (see section 7.10), where interested readers can further investigate your extended back catalogue.

7.8 YouTube

YouTube [23] is a video-sharing website, where users can post videos, create playlists and interact with other users via liking (and disliking!) posts and posting comments. The central hub of these activities is based around something called a YouTube channel, which is where all of the videos from a certain person or organisation are grouped together. These channels can then be subscribed to, ensuring that as a viewer you are kept up-to-date with the most regular releases from your favourite YouTubers.

As well as being a useful resource for everything ranging from cute cats [24] to instructions on how to build an interior wall [25], YouTube also hosts a number of innovative science channels, which explore different facets of science and which serve as excellent examples of effective science communication in action. Two of the best are MinutePhysics [26] and SciShow [27], both of which have several million subscribers, educating and informing on a variety of scientific topics, from exploring dark matter to presenting biographies on some of humanity's greatest scientists.

If you are thinking of creating your own YouTube channel, then it is important to consider all of the advice that has previously been discussed in this chapter in relation to blogs and podcasts. In addition to this, it is highly recommended that you rope in some friends or colleagues with filming and visual editing experience, as there are many examples of potentially great YouTube videos that are let down by the amateur nature of the filming. In building your list of subscribers it is also important to engage with other YouTube communities, and once you are established to maybe consider doing some guest videos with other successful YouTube vloggers (video bloggers), thereby introducing your work to a new audience.

Exercise: get inspired by video

Go onto YouTube and watch a couple of videos from either the MinutePhysics or SciShow channels (or another of your choice). Then scroll down and read a selection of the comments for the videos and see if you can figure out what it is about the video that people really connected with. If you feel as though you have something to add to the discussion then feel free to post a comment and join in!

7.9 ResearchGate

ResearchGate [28] is a social networking site, which unlike the other examples mentioned so far, has been designed primarily for use by researchers. ResearchGate is used by academics to share their papers, engage in conversations relating to their research, and also to find collaborators for future projects.

After building a profile that outlines your areas of research and expertise (in a similar fashion to that of LinkedIn), you are also able to upload all of your publications, either manually or by using digital object identifiers (DOIs). As with LinkedIn, colleagues can endorse you for specific skills and expertise, and there is also a jobs board, which recommends jobs based on your expertise and portfolio.

In addition to this, you are also able to provide answers to any questions that other researchers may have, either related to your publications or to your field of study in general. ResearchGate also presents you with the opportunity to track your paper's citation rates and to see how many people have viewed and downloaded your paper from the site in recent times. You can also follow other researchers, to ensure that you are kept up to date with their recent activities.

ResearchGate may not have all of the bells and whistles that come with some of the other social media sites, but this is probably a good thing, as there are far fewer things to be distracted by, and almost all of the activities and conversations that you can become involved in are likely to be both relevant and beneficial to your scientific career.

7.10 Others

The social media sites that are discussed above are by no means an exhaustive list, with Professor Andy Miah providing this on his blog post 'The A to Z of social media for academia' [29]. Other platforms that are worth a quick mention include Instagram [30] and Flickr [31], which in essence act as community photo depositaries, as well as Google+ [32], which is a very useful tool for creating and interacting with specific online communities. Google+ has not been the success that many were hoping for, and it is doubtful that its popularity will increase as Google focus on other ventures. Mendeley [33] and Academia.edu [34] are alternatives to ResearchGate in the researcher-only social networking category. Reddit [35] is often referred to as the 'front page of the internet', and is effectively a group of hundreds of thousands of message boards, in which any topic you care to think of is discussed and deliberated. Reddit also has a very particular set of etiquettes, which it is wise to adhere to, although a fantastic introduction to the site is the New Reddit *Journal of Science* [36] section. Finally, Periscope [37] is a social media tool that allows you to live stream and comment on any activity or experiment that you are doing, and also gives any observer the opportunity to ask questions and interact with you in real time.

Whilst not being a social media site as such, ResearcherID [38] is a very useful tool to have in your digital arsenal. It provides you with a unique identification number that you can then assign to your publications and use them to track your work. This is extremely useful if you have used multiple combinations of your name (for example initialisation, or not, of any middle names) throughout your publication back catalogue. As well as linking directly to the bibliography manager EndNote [39] and the scientific citation indexing service Web of Science [40], your ReseracherID can also be synced to ORCID [41], which is an additional personal identification number that can also be applied to grants, to ensure that you always receive credit for your work. Including a link to your ORCID profile is also an effective way of advertising all of your publications in a traditional CV, where space may be limited (figure 7.2).

Another useful digital utensil is IFTT [42], a web-based service that stands for 'If this then that', and which allows you to create your own unique automated combinations or 'recipes', for example tweeting a link to your podcast every time you upload it to your hosting site. This is a great way to ensure that all of your outputs are linked up into a coherent stream, turning your digital footprints into an elegant waltz. Social bookmarking sites such as Diigo [43] and StumbleUpon [44] also allow you to keep tabs on other people's digital footprints, helping you to track resources, comment on threads, and generally keep in touch with a number of varied and appealing communities.

7.11 Digital collaborations

As well as being a fantastic resource for advertising your skill set, finding information, and managing your research portfolio, the internet provides the perfect means for truly international collaboration, via nothing more than a couple of mouse clicks or the touch of a screen. Emails have long since replaced the traditional letter or fax as our communication tool of choice, but there are many other innovative and effective ways with which we can collaborate with other scientists from across the globe.

Video conferencing represents an effective way of having group meetings, with the elimination of unnecessary travel not only benefitting the participants in terms of time and money saved, but also having a positive impact on the environment as well. There are a number of video conferencing facilities available, both free and paid, and as with social media it is probably best to try out a few and see which of them are the most suitable for your needs. Two of the most well-known are Skype [45] and Google Hangouts [46], both of which offer free video conferencing facilities for up to a certain threshold of participants, with screen sharing and other tools also available. Google Hangouts also presents you with the opportunity to record your calls and then directly stream them through your YouTube channel, and allows non-participants to ask questions via a forum.

When hosting or participating in a videoconference, always remember to test the connections beforehand, and make sure that your colleagues have both the relevant accounts and the software that is necessary for them to participate. If there is a large group of active participants, then it might be an idea to communicate via the instant messaging facilities of these conferencing suites instead, as it can be difficult if 15 or 20 people want to talk at once! As with all meetings, it is important to have a strong chair, and to stick to an agenda.

Document sharing facilities, such as Google Docs [47] or Dropbox [48], represent an extremely effective way of collaborating on a document or presentation, allowing you to share and co-edit documents in real time. This means that you can handily create folders for different research projects, and easily share them with other collaborators, giving easy access to the work wherever the internet is available.

7.12 Summary

This chapter has discussed the importance of creating a manageable, informative and attractive digital footprint, offering practical advice and guidelines on how to set up and manage successful blogs, podcasts, and social media profiles.

With so much choice it is very easy to get overwhelmed, and so it is important to remember that it is simply not possible to write a number of successful blogs, run a podcast, have an active presence on every social media site, and also carry out scientific research! The most effective way of building a useful and enjoyable portfolio is to dip your digital footprint into a few of the different media, and to determine which of them are most suitable to your own skills and needs.

Eventually, you should consider entering competitions for your scientific blogs and podcasts, such as the SciWriter [49] competition and The Podcast Awards [50]. You might not think that you have a chance, but as the saying goes 'you have to be in it to win it', and at the very least it will give some more exposure to your output and all of your hard work.

One final comment relates to the issue of personal versus professional posts. Some employers have very strict rules in regards to what you can and cannot publish on certain social media sites, and what disclaimers you must use if you do.

Always remember to read these carefully, and also before you post anything to any platform ask yourself one question: 'am I both willing and able to defend these statements?'

7.13 Further study

The further study in this chapter is designed to help you think further about developing your online presence:

1. **Record a podcast:** if you think that audio is the media for you, then follow the advice given in the section on podcasting above and set up your own podcast. Remember that it is important to plan out in advance roughly what you will be talking about (be warned though, as fully scripted podcasts can sound a little unnatural), and also how you will market the podcast and ultimately develop a community around it.
2. **Join a tweet chat:** find a tweet chat that you think will be interesting and relevant to you, and to which you feel you can contribute. After joining in with a couple of sessions, enquire about hosting one, as normally the role of facilitator is rotated around the more active members of the group.
3. **Create/update your ReseracherID profile:** fill in all of your details, and sync to your relevant publications, then take the time to connect with some colleagues and co-authors, and endorse them for any skills that you think they have, and which you are qualified to comment on. Afterwards have a look at some of the questions that have been posted in your field of expertise and see if you are able to provide any answers, or else engage in the debate. Also, remember to update your ORCID profile, to allow for easy tracking of all past and future publications.
4. **Build a website:** if your digital footprint is starting to feel stretched, then it might be an idea to start thinking about building a personal website, to host all of your output, and to act as a holding page for your research and other interests. There are many examples of free and paid for website builders, and the only way to find out which will work best for you is to get out there and experiment.

Suggested reading

There are many books that aim to teach you how to build a following across different social media platforms, but a couple of great free online resources are the *Social Networking for Scientists* Wiki [51] and *A Scientist's Guide To Social Media* [52] from Science Careers [53]. The *53 Interesting Ways to Communicate Your Research* [54] book also provides a number of tips for communicating your research digitally, put together in a concise and engaging manner. For those of you that are interested in who wrote the first science blog, there is this fantastic *Scientific American* article [55] that goes into considerable depth to determine the answer. Finally, if vlogging is something that you think you might be interested in, then the European Geosciences Union produced an excellent guide [56] in conjunction with Simon Clark, who also hosts an extremely successful science vlog: SimonOxfPhys [57].

References

[1] Ed Yong: http://phenomena.nationalgeographic.com/blog/not-exactly-rocket-science/, accessed 8 July 2016
[2] Alice Bell: www.alicerosebell.com/, accessed 8 July 2016
[3] *Guardian* Blog Network: www.theguardian.com/science/series/science-blog-network, accessed 8 July 2016
[4] *Scientific American* Blogs: http://blogs.scientificamerican.com/, accessed 8 July 2016
[5] Wordpress: www.wordpress.com/, accessed 8 July 2016
[6] Tumblr: www.tumblr.com/, accessed July 8th 2016
[7] Scienceblog: http://scienceblog.com/, accessed 8 July 2016
[8] Brain Bank Blog: http://thebrainbank.scienceblog.com/, accessed 8 July 2016
[9] Free sound effects: www.freesound.org/, accessed 8 July 2016
[10] Audacity: http://audacity.sourceforge.net/, accessed 8 July 2016
[11] SoundCloud: https://soundcloud.com/, accessed 8 July 2016
[12] PodBean: www.podbean.com/, accessed 8 July 2016
[13] iTunes *How to Host Podcasts*: www.apple.com/uk/itunes/podcasts/creatorfaq.html, accessed 8 July 2016
[14] Twitter: https://twitter.com/, accessed 8 July 2016
[15] Mom this is how Twitter works: www.momthisishowtwitterworks.com/, accessed 8 July 2016
[16] Altmetrics: http://altmetrics.org/manifesto/, accessed 8 July 2016
[17] ECRchat: https://ecrchat.wordpress.com/, accessed 8 July 2016
[18] Facebook: www.facebook.com/, accessed 8 July 2016
[19] News from Science Facebook page: www.facebook.com/ScienceNOW?ref=ts, accessed 8 July 2016
[20] *Scientific American* Facebook page: www.facebook.com/ScientificAmerican?ref=search, accessed 8 July 2016
[21] NASA Facebook page: www.facebook.com/NASA?fref=ts, accessed 8 July 2016
[22] LinkedIn: www.linkedin.com/, accessed 8 July 2016
[23] YouTube: www.youtube.com/, accessed 8 July 2016
[24] 10 cutest cats moments: www.youtube.com/watch?v=q1dpQKntj_w, accessed 8 July 2016
[25] How to build an interior wall: www.youtube.com/watch?v=HAD2-ubd42g, accessed 8 July 2016
[26] MinutePhysics YouTube channel: www.youtube.com/user/minutephysics, accessed 8 July 2016
[27] SciShow YouTube channel: www.youtube.com/user/scishow, accessed 8 July 2016
[28] Research Gate: www.researchgate.net/, accessed 8 July 2016
[29] *The A to Z of Social Media for Academia*: http://andymiah.net/a-to-z-of-social-media/, accessed 8 July 2016
[30] Instagram: https://instagram.com/, accessed 8 July 2016
[31] Flickr: www.flickr.com/, accessed 8 July 2016
[32] Google+: https://plus.google.com/, accessed 8 July 2016
[33] Mendeley: www.mendeley.com/, accessed 8 July 2016
[34] Academia.edu: www.academia.edu/, accessed 8 July 2016
[35] Reddit: www.reddit.com/, accessed 8 July 2016
[36] New Reddit *Journal of Science*: www.reddit.com/r/science/, accessed 8 July 2016
[37] Periscope: www.periscope.tv/, accessed 8 July 2016

[38] ResearcherID: www.researcherid.com, accessed 8 July 2016
[39] EndNote: www.myendnoteweb.com/EndNoteWeb.html, accessed 8 July 2016
[40] Web of Science: www.webofscience.com, accessed 8 July 2016
[41] ORCID: http://orcid.org/, accessed 8 July 2016
[42] IFTT: https://ifttt.com/, accessed 8 July 2016
[43] Diigo: www.diigo.com/, accessed 8 July 2016
[44] StumbleUpon: www.stumbleupon.com/, accessed 8 July 2016
[45] Skype: www.skype.com/, accessed 8 July 2016
[46] Google Hangouts: www.google.com/+/learnmore/hangouts/, accessed 8 July 2016
[47] Google Docs: www.google.co.uk/docs/about/, accessed 8 July 2016
[48] Dropbox: www.dropbox.com/, accessed 8 July 2016
[49] SciWriter *Competition*: www.ge.com/world-conference-science-journalists/sciwriter-blogging-competition, accessed 8 July 2016
[50] The Podcast awards: www.podcastawards.com/, accessed 8 July 2016
[51] Social Networking for Scientists: http://socialnetworkingforscientists.wikispaces.com/General, accessed 8 July 2016
[52] *A Scientist's Guide To Social Media*: www.sciencemag.org/careers/features/2014/02/scientists-guide-social-media, accessed 8 July 2016
[53] *Science* magazine *Science Careers*: http://sciencecareers.sciencemag.org/, accessed 8 July 2016
[54] Haynes A 2014 *53 Interesting Ways to Communicate Your Research* (Newmarket: Professional & Higher Partnership)
[55] *Scientific American* Science Blogs - definition, and a history: http://blogs.scientificamerican.com/a-blog-around-the-clock/science-blogs-definition-and-a-history/, accessed 8 July 2016
[56] Vlogging 101: A beginners guide to video blogging: http://blogs.egu.eu/geolog/2016/04/04/vlogging-101-a-beginners-guide-to-video-blogging/, accessed 8 July 2016
[57] SimonOxfPhys: www.youtube.com/user/SimonOxfPhys, accessed 8 July 2016

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Effective Science Communication
A practical guide to surviving as a scientist
Sam Illingworth and Grant Allen

Chapter 8

Science and policy

Science without policy is the pursuit of knowledge. But policy without science is the ambition of ignorance.

– Grant Allen

8.1 Introduction

I decided to quote myself to start off this chapter. The quote appears to imply that science can do very well on its own (thank you very much) but that policy without science is lost. However, another interpretation is that while science can reveal an understanding about the universe and the human beings that inhabit some infinitesimal corner of it, that understanding is useless if it does not induce positive change in the people that are discovering it. Change is indefatigable, necessary, and inevitable; after all, the passage of time is measured and defined by discrete events. Yet how change manifests itself in our everyday lives is very much the result of guiding policy, defined for us by 'policy makers', whether they be regulators, lawmakers, governments, managers, CEOs or Vice Chancellors. Policy defines modern civilization, the rule of law and the impacts we have on our planet. Whether we like it or not, policy defines our world and a greater part of our lives than we probably truly realize. However, 'good' policy, or perhaps rather 'optimal' policy, is that which is informed by knowledge, coupled with the policy makers' ability to understand this knowledge and to use it to make predictions about the potential impacts that the policy may have.

This is where science comes in. Without informed policy, we are at the mercy of arbitrary or subjective guidance from groups or individuals that may not be experts, or who may be biased by independent or narrow viewpoints. Science provides the evidence base, the wisdom, and the predictive capacity for policy makers to make the best possible choices within the constraints of the political climate of the day, a climate which is itself a function of the science and policy that defines our expectations, aspirations, the way we think, and the way in which we live our lives.

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However, the route that this important information takes in getting to the policy makers is not always as optimal as it could, and perhaps should, be.

This chapter is concerned with that pathway—the route by which science informs and influences policy. We shall explore some of the established and recognized ways that science is used in decision-making in the modern world, and how you can make your scientific voice heard. Policy is often made by building consensus, and while other voices may have opposing views it is important that we each take a role in putting forward the best-informed, evidence-based facts and opinions to those that need—and want—to hear it. Expert guidance and opinion, especially from independent academics, is much valued by policy makers. But that guidance is only useful if it is heard and received in a form that can be understood, whilst retaining accuracy and honesty.

8.2 How science informs policy

There are manifold direct and indirect ways that science and knowledge are taken into the consciousness of government, lawmakers and policy makers. Indirect pathways are typically less tangible and may be subject to bias. These may include personal opinion formed over time based on reading articles, watching TV documentaries, interacting with social media, and the voices of organized lobby groups with a specific agenda. Such pathways clearly have a role and can be powerful. However, communicating science through these more passive media is dealt with in other chapters in this book. Here we will concern ourselves with more direct pathways, such as submitting parliamentary evidence and guidance for best practice.

The examples we shall present are by no means exhaustive. The pathways by which science is used in policy are many, and are at times indirect and untraceable. Policies that draw on scientific evidence can apply at international, national and local levels, with impacts on anything from multinational industries to individuals. We shall offer some general advice and some example in-roads into national policy here to help you think about how science is seen, heard and used by policy makers; and therefore to be mindful of what you can do to influence decision-making more generally.

Two excellent examples of modern-world policy direction influenced by scientific evidence are those associated with the regulation of the tobacco industry, and the conflicting priorities between slowing (or mitigating) climate change and sustainable economic growth.

In the early twentieth century, smoking was not widely known to be hazardous to human health, with some doctors actually, and of course incorrectly, hailing its many health benefits. As such, the industry was not regulated in the way that it is today. However, taking the United Kingdom as an example, the route by which the tobacco industry has been constrained by policy decisions such as restrictions on advertising, restriction on smoking indoors in public places, increases in taxation, and public health campaigns, has been (arguably) slow. This is widely observed to be due to the conflict between personal freedoms, the influence of well-funded lobby groups, economic impact (with both negative and positive aspects), and the now-obvious science of negative public health impact. Over time, the accumulated evidence of health impacts and a growing consensus by health professionals has led to the policy climate we see today. Very few people on the planet are unaware of the risks, and those that choose to smoke are actively or indirectly discouraged by higher taxation, less prominent advertising and easily accessible public health information and advice. However, this policy success, if measured in terms of the proportion of people smoking in the western world, was absolutely the result of concerted efforts by scientists to provide unequivocal evidence to policy makers that there were significant public health impacts. These scientists provided policy makers with the information from which to make decisions about the best policies to balance health, economic and personal freedom considerations in the face of pressure from lobby groups.

In the case of climate change policy, the debate on the correct weight of policy (nationally and internationally) to mitigate or reduce the effects of climate change remains far from one-sided. While a very large consensus of climate scientists makes it clear that human-induced climate change is real and happening, a significant number of policy makers, as well as a very small proportion of scientists, claim that there is no such thing as climate change, that any change is not induced by human activity, or else maintain that the policy response to it is not justified if it negatively impacts on specific industries or national economies. Luckily, the balance of opinion among policy makers and governments is that steps do need to be taken to tackle this very real problem. As such, national and international agencies and organizations such as the United Nations International Panel of Climate Change (IPCC) are carefully providing and updating the evidence base and predictive capacity in a form that is readily accessible and useful to policy makers. Furthermore, policy makers are integrated into this process through the United Nations Framework Convention on Climate Change (UNFCCC), who facilitate international and legally binding responses to climate change—perhaps most markedly through the negotiation of national greenhouse gas emissions targets. This allows policy makers to make informed collective decisions to mitigate or reduce specific tangible risks and the causes of them, and to form domestic policy to best meet agreed targets.

The enormous but effective organization of science for this purpose through groups of experts like those comprising the IPCC, which collates the very best evidence available from across the world, clearly represents a gold standard and a concerted (and costly) effort. The bottom-up approach by which carefully chosen experts scour the peer-reviewed literature for evidence, review it, and summarize and present it in an accessible form, makes for a system that does not simply pay attention to the loudest voice in someone's ear. Moreover, the IPCC reports provide a regular review that highlight remaining sources of scientific uncertainty, which then sets a forward agenda for individual scientists to respond to, seek funding to explore, and consequently better inform on. Clearly, such a global challenge demands a global response and the global participation of scientists. But the fact remains that policy decisions need to be made on the best available evidence to hand. And without a structure like the IPCC, policy makers would be awash in a cacophony of individual research papers and individual academics, each with their own favourite climate impact and research interest, and vocal counter claims and agendas from lobby groups and a few maverick (to be over-kind) scientists. There is still some way to go to fully predict and understand this complex field of Earth system science, and how it will undoubtedly affect human beings going forward in a world with a rising population. And in a changing environment (physical, political and economic), it will be an evidence base that may always require regular updating. However, the pathways to policy in this arena exist and have been well organized. No policy maker can strongly argue that they are not as well informed as science (and scientists) can possibly make them.

For many other fields of science, the organization of science-policy pathways is much less formal, and individual scientists may need to be proactive in personally bringing their evidence and outputs to the attention of policy makers. In the following section, we shall explore some of the ways in which this can be done.

8.3 What you can do to inform policy

This section gives just a few examples of how your work may influence policy. In practice there are many ways this can happen. You may be identified by specific agencies or individuals who have heard about your work in a specific field, and as a result of this you may be asked to provide advice in the form of expert reviews of government-commissioned reports, written by civil servants or other academics and think tanks. Or you may be invited to tender for contracts to provide such reports yourself. To raise your visibility in such circles, your academic track record would need to speak for itself whilst you simultaneously seek to network through science advisory groups, such as those which exist in many national science funding councils. Often, direct invitations to participate in this manner are passed through word of mouth between existing expert networks, or by recommendations from other academics who may cite your academic track record as a reason to solicit advice from you, and to draw on your specialist expertise.

Such ‘top-down’ invitations would normally come a little way into your academic career after you have established yourself in your field. With this in mind, there are more proactive routes through which you can provide input whilst simultaneously raising your profile in policy circles earlier in your career. For example, the UK Parliament forms select committees composed of, and chaired by, Members of Parliament, tasked with gathering evidence for debate on policy matters of national interest prior to legislation, and examining the impacts of legislation after they have been introduced. These committees regularly issue open calls for evidence, to which anyone can provide input. Most democratic governments (at both a local and national level) work in similar ways—they consult the public and experts for guidance to inform debate and decision-making. We shall explore an example of such a consultation in the exercise below.

Exercise: find opportunities to provide evidence to policy makers

This exercise will help you to research the routes that exist for ‘bottom-up’ (proactive) provision of expert advice to policy makers.

Examine the webpages of your parliament’s select committees and look for open calls for evidence. A list of current open calls for the UK Parliament is provided in [1].

Pick one of the open (or historic) calls and follow the guidance for preparing evidence. It doesn’t matter if there are no open calls relevant to your field, but it may help to look for previous calls that are.

Have a look at previous committee reports and learn about how the evidence has shaped the narrative of the report and any resulting debate. Think about how your expertise could inform that narrative and how you would best present it to policy makers.

Should you submit evidence to such a committee, it is important to approach your writing in the same way you would any academic narraitive, i.e. by structuring it with an introductory summary (analogous to an abstract), a body of text citing appropriate references in the context of the policy being discussed, and a conclusion, avoiding the use of technical language. Evidence submissions may necessarily require you to extrapolate from your knowledge to form an opinion or a conclusion on the policy in question. As with any piece of scientific writing, it is therefore important to be clear where you are stating your personal opinions, and what comprises the evidence informing that opinion.

A parliamentary committee may then reference your evidence in its report or in debate, and you may even be invited to be interviewed by the committee. This may seem daunting. However, think about the positive impact that you can then have on changing the course of debate and policy. Consider the impact agenda discussed in chapter 3. The use of your science in policy, and the traceability of it through citable policy pathways such as this are an incredibly important aspect of both your work and your future ability to secure funding for your research. It shows that you know how to translate science into impact, inform public and political debate, and bring about change.

Another simple way that you can provide direct input to policy makers is by registering your expertise with your national parliamentary library. Parliamentary libraries are a service to Members of Parliament (or congress, assembly, etc), and their librarians do a lot more than simply run a book-lending service. Much like civil servants in government departments, parliamentary librarians provide an information connection service to elected representatives with specific questions. This may be in response to a question raised in parliament, or by a member of the public or lobby group. Parliamentary libraries often collate research briefings for parliamentarians on specific subjects of topical debate [2]. To do this, library researchers will consult the published literature, including peer-reviewed academic journals, and also consult an in-house database of experts, who may be contacted for advice. You can register your expertise in your field with this database by contacting parliamentary libraries, such that you may be asked for input or advice in response to requests for information from Members of Parliament. This may even result in you being put in direct contact with them.

Parliamentary offices offer all sorts of other services to policy makers, Members of Parliament and civil servants. For example, the UK Parliamentary and Science Committee publish a quarterly magazine provided to all members [3]. You can subscribe to it yourself. This magazine, like many of its international analogues, openly solicits ideas from academics for articles. You can suggest a topic for an article to an editor, explaining why it is relevant and topical to policy makers and you may be invited to submit an article for publication. Note that you are not likely to receive remuneration for such work; like so much in academia it is a labour of love. However, I did this in 2013 [4], and immediately received a request—from a parliamentarian that had read my article—to review an influential government report on the impacts of hydraulic fracturing in the UK on greenhouse gas emission targets. This is an excellent way to raise your profile in policy circles as a new academic with an emerging track record.

8.4 Summary

This chapter has provided examples of some of the routes by which scientific evidence is used by policy makers, as well as some concrete routes for how you can contribute to the process proactively as a scientist.

Almost universally, the people charged with making decisions and setting policy welcome input from experts, and crave evidence to help them make informed judgments for the benefit of everyone. No one likes to make a bad decision.

However, except for global ‘grand challenges’ or matters of high national importance and public interest, the organization of science into policy is typically bottom-up, and relies on the proactivity of individuals or the widening of existing expert networks. You can raise your visibility by getting involved in evidence requests and by talking to those in existing networks, while simultaneously developing your track record of expertise and underpinning research. Keep an eye out for opportunities, register and subscribe to email alerts and policy publications, and ultimately, help to make a difference.

8.5 Further study

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

1. **Read a policy report:** visit the UK Parliament’s Recent Select Committee publications [5] and read one of the recent reports on a topic that is related to your field of research. You will find that these documents provide an excellent summary of the topic and its policy implications, and they will give you a good idea of the kind of evidence that is both submitted and referred to in such reports.
2. **Join the library:** subscribe to the email alerts from the UK Commons Library and its research service [2]. Even if you are not based in the UK, these emails will keep you up-to-date with parliamentary debates, reports and calls-for-evidence in any subject area that you wish to specify.
3. **Read a POSTnote:** The Parliamentary Office of Science and Technology (POST) provides balanced and accessible overviews [6] of research from across the sciences that are used to brief UK Members of Parliament. They provide excellent summaries of many different topics, and are worth reading to both broaden your knowledge and also look for areas that require further evidence.

Suggested reading

The Science of Science Policy: a Handbook [7] provides an overview of the current state of the science of science policy from three angles: theoretical, empirical, and policy in practice. The authors offer perspectives from the broader social science, behavioural science, and policy communities in this evolving arena. The text also delivers insights about the critical questions that create a demand for a science of science policy.

Using Science as Evidence in Public Policy [8] encourages scientists to think differently about the use of scientific evidence in policy making. It investigates why scientific evidence is important to policy making and argues that an extensive body of research on knowledge utilization has not led to any widely accepted explanation of what it means to use science in public policy. This book, which is also available as a free online report [9] would be of special interest to scientists who want to see their research used in policy making, offering guidance on what is required beyond producing quality research, translating results into more understandable terms, and brokering the results through intermediaries, such as think tanks, lobbyists, and advocacy groups.

The UN Climate Change Newsroom [10] provides examples of UN-commissioned scientific reports and expert committees. Reading such reports and understanding how they are informed will help you to understand the pathways by which expert knowledge is drawn into policy-relevant documentation.

Finally, *Merchants of Doubt* [11] is a general interest read and cautionary tale about how poor science can negatively influence policy debate and hinder policy trajectory, and explores in depth the tobacco and climate change examples we highlighted in section 8.2.

References

[1] UK Parliament *Open Call for Evidence*: www.parliament.uk/business/committees/inquiries-a-z/current-open-calls-for-evidence/, accessed 8 July 2016

[2] UK Commons Library and its research service: www.parliament.uk/commons-library, accessed 8 July 2016

[3] www.scienceinparliament.org.uk/

[4] www.scienceinparliament.org.uk/wp-content/uploads/2013/12/sip70-1.pdf pp 41–5

[5] UK Select Committee *Recent publications*: www.parliament.uk/business/publications/committees/recent-reports/, accessed 8 July 2016

[6] POSTnotes: www.parliament.uk/postnotes, accessed 8 July 2016

[7] Lane J *et al* (eds) 2011 *The Science of Science Policy: A Handbook* (Palo Alto, CA: Stanford University Press)

[8] Prewitt K, Schwandt T A and Straf M L (ed) 2012 *Using science as evidence in public policy* (Washington DC: National Academies Press)

[9] *Using Science as Evidence in Public Policy*: www.ametsoc.org/ams/assets/File/NRC%20-%202012%20-%20Using%20Science%20as%20Evidence%20in%20Public%20Policy.pdf, accessed 8 July 2016

[10] The UN Climate Change Newsroom: http://newsroom.unfccc.int/, accessed 8 July 2016

[11] Conway E M and Oreskes N 2012 *Merchants of Doubt* (New York: Bloomsbury)

Chapter 9

Other essential research skills

You have no responsibility to live up to what other people think you ought to accomplish.

– Richard Feynman

9.1 Introduction

There is much more to research than simply performing experiments, writing grant proposals and communicating your findings to a variety of audiences. In order to be a successful scientist you need to be able to balance a number of different tasks, whilst developing your skills and expertise in both specialist and more generalised fields. This chapter will outline some of these skills and discuss why they are important for you to consider in your scientific career.

It is also important that you are realistic. A report from the Royal Society [1] shows that the majority of people who undertake a PhD will end up in a career outside of academia. It is therefore vital to develop other key skills that will help you to both get a job, and to excel in it. Being a scientist means that you have a number of key transferable skills that make you a genuine asset, but it is important that you advertise these skills effectively, and that you take every opportunity presented to you to enable you to develop them further. It is also imperative to point out that pursuing a career outside of academia does not mean that you have 'failed' or 'turned your back on science'. There are in fact many careers outside of academia that are still connected to science, and where you will almost certainly be paid more and have better working hours.

It is vital that you keep track of all of the events, activities and training programmes that you participate in, as these will serve as excellent exemplars when writing your résumé, or for personal development reviews, etc. Vitae [2] offer an excellent online planner [3] for recording your professional and career development. Your institution might well have a license for its use, but if not then it is available for a small annual fee, which is definitely worth it, as it is a great resource

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for not only keeping track of your achievements, but also mapping out an action plan for areas that need further development.

As scientists we have a responsibility to not only ensure that we effectively communicate our research to a variety of audiences, but also to make sure that the manner in which we conduct and disseminate our research is ethical, and based on sound scientific values. We are part of a long line of practitioners, and as such we have an obligation to respect the legacy that has been left to us, and to help to pave the way for the future generation of scientists that are yet to come. It is important that we never lose sight of the fact that we are part of a very privileged few, and that in order to make the most of the opportunities that have been afforded to us, we must ensure that we conduct ourselves in a manner that is beneficial to the rest of society.

9.2 Time management

Procrastination is the bête noir of any researcher, whether via the obvious and immediate temptations of social media, or the more subtle distractions of spending too much time pursuing a project that is of no long-term benefit. However, there are a number of basic things that you can do in order to maximise your time efficiently:

1. **Know when you work best:** probably the most effective way to manage your time is to determine when in the day you are at your most effective, and to try and do the bulk of your important work in this time. For example, if you know that you work best as soon as you get into work, then ignore the temptation to check your emails and instead get to work on finishing that research paper that has a looming deadline!
2. **Know where you work best:** another important aspect for you to consider is that you select the correct environment for the task that you are doing. For example, if you work in a busy office, then it might be conducive for bouncing ideas around about a new scientific study, but if you want to read some papers then it would probably be more beneficial to head to a quieter room, such as at home, or in a library.
3. **Avoid meetings:** avoiding unnecessary meetings is a sure-fire way to manage your time effectively. Make sure that any meetings that you organise are absolutely essential, and if you do find yourself bogged down with meetings then try and get hold of the agenda beforehand and simply accomplish the tasks that are being discussed. That way you can circumnavigate the need for a meeting in the first instance.
4. **Learn to say no:** sometimes we are all guilty of saying yes to one too many people. However, it is important to remember that if you take on too many things, then you run the risk of doing none of them very well at all. It is perfectly okay to say no to people, 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. Of course, if you do say no then make sure that it is clear that you are available for future consideration (but again, only if that's what you actually want!).

5. **Manage your calendar:** try to include daily tasks and deadlines in your calendar, including dates for follow-up and evaluation where necessary. As you accomplish these tasks, delete them from your calendar to give you the satisfaction of a digital checklist.

Another extremely useful tool in time management is the STING acronym, shown in figure 9.1.

When you are setting out to accomplish an important project, this acronym is extremely versatile and efficient. Begin by selecting an appropriate task, and time how long you plan on taking to complete it, e.g. ‘in the next two hours I am going to write 500 words of the introduction to this paper’. Whilst you are doing this task, ignore everything else (turn off your phone and deactivate your email if necessary),

Select a task

Time yourself

Ignore everything else

No breaks

Give yourself a reward

Figure 9.1. The STING acronym for time management.

and allow yourself only toilet breaks until it is finished. Once it is finished give yourself a reward. This can be anything you like, from a slice of cake to checking yourself to check your emails. The most important aspect of applying this acronym is in the selection of the task; make sure that you choose something that is substantial, yet ultimately achievable within a sensible timeframe.

One final time management technique is to consider the importance–urgency matrix shown in figure 9.2. If you have a number of tasks to accomplish, then take a couple of minutes to plot out where they lie on the matrix, as this will help you to determine the order in which you should attempt to tackle them: those in Q1 need to be dealt with immediately, followed by those in Q2, whilst those in Q3 can either be delegated or pushed back, and those in Q4 can probably be dropped altogether.

9.3 Networking

One of the best ways to get ahead in the world of scientific research is through effective networking. Whilst it is a skill that does not come easily to many of us, it is a vital tool that you can hone with practice. There are always plenty of opportunities to network, be it 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 with starting up a conversation. So here are some tips that should help you to become a consummate expert in the field:

1. **Don't be afraid**: this might seem like quite a glib piece of advice, but it is also the most important. Many early career researchers struggle to engage with more senior scientists, as they have put them on a pedestal that they do not wish to approach. Remember that these eminent scientists are still human, and that they

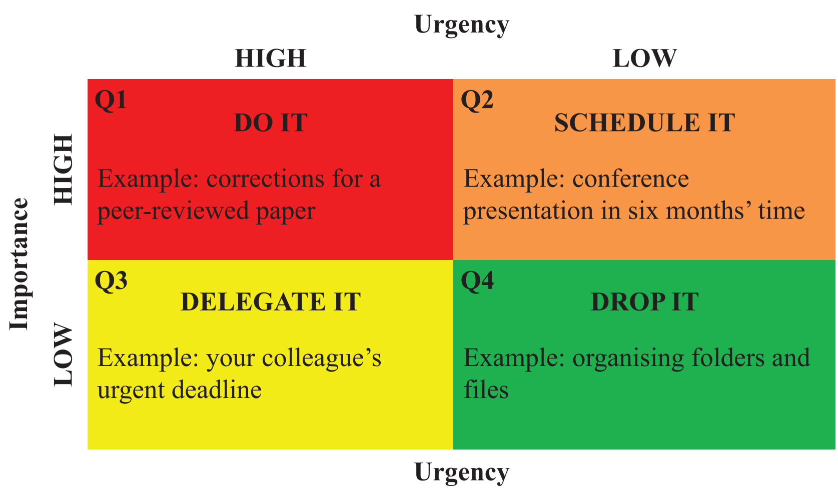

Figure 9.2. The importance–urgency matrix.

were once in your position too! Many of them will relish the opportunity to speak to eager and passionate young researchers, but you'll never know unless you try.

2. **Be yourself:** you shouldn't worry about how you come across. All of us get nervous at times, and this is even more pronounced when we are trying to be someone that we are not. 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). Just because there may be people present with more experience than you does not mean that your opinions are any less valid.
3. **Don't hog conversations:** Oftentimes, well-known scientists will have a raft of people waiting to talk to them. If this is the case, then simply go and talk to someone else and come back to them later; there is nothing worse than people who linger whilst eavesdropping in on a conversation. Similarly, if other people are starting to linger, then either bring them into the conversation or move on. There are always other people that you can talk to.
4. **Try not to be too blunt:** networking sessions are an excellent opportunity for seeking out potential employment. 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, is preferable to asking someone if they can employ you before you have even been properly introduced.
5. ***Always* carry business cards:** that way you can continue the conversation later, and the person you are talking to is also able to pass on your details to other colleagues.

Another thing to remember is that you can always ask 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.

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 going to an event with some friends or colleagues, then remember 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 as part of a team, whether in a large international consortium or as a member of a small local group, is an important part of any researcher's day-to-day life. Learning how to work as an effective member of a team, and realising that there is a multitude of different roles that can be played depending on the situation is a valuable lesson.

There are many different resources available that aim to determine which type of team player you are, for example the Belbin Team Inventory [4] splits the number of roles into nine distinct characters, including implementer, evaluator and coordinator. The Belbin Team Inventory is also explicit in its assumption that most people will veer towards more than one of these characters, and it is of course only one such indicator of personality and character traits.

However, despite what any of these inventories and tests might say, the person who knows best what kind of team player you are is you. It might be that you are the kind of person that 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. That is why working as part of a team is such a necessary part of scientific research. It is arrogant to assume that you will be able to do everything by yourself, and long gone are the days when review panels looked favourably on solo papers and lone grant applications. These days, internationalisation and collaboration are the key to being a successful researcher, and it is important that as well as developing these collaborations you learn how to contribute to them in an effective and considerate manner.

The most important thing to remember when working as part of a team is that not everybody is the same. It seems like such an obvious thing, but the majority of disagreements when working as part of a group are because people either assume that other members of the group will behave the same as they do, or expect them to do so. The truth is that everybody is different, and what works for you might not work for someone else. So if you are the kind of person that 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 ago. Similarly, if you are the kind of person who gets everything done weeks in advance, don't apply unneeded pressure to people who work to the same absolute deadline, but at different speeds. As with any relationship, working as part of a team is all about compromise and respect. Remember that there is a greater aim that you are working towards, and that if your ego takes a bit of a battering along the way then so be it. If you remain professional, committed and polite throughout then you will find working as part of a team to be more enjoyable, and you will also probably be invited to be part of one on a more regular basis!

9.5 Objective reflection

As scientists we are taught to inherently reflect upon our practices. For example, we may perform an experiment and then adjust certain variables or aspects of the methodology based on the initial findings and relative successes of the process. This is something that the majority of scientists do on a fairly regular basis, but how often do you take the time to formally reflect on your practices in general?

Reflection is an incredibly useful aspect of the learning cycle, and it is a necessary step in the formation and cementing of knowledge. Yet it is something that is often overlooked and neglected, especially when compared to other aspects of learning such as knowledge retention and experimentation.

Figure 9.3 is an adaptation of Gibb's reflective cycle, which is a very useful model to help in the process of reflection.

The value of reflective learning extends far beyond adjusting your experimental setup, or readjusting your analysis for a set of results. It is a practice that will not only help to shape your research, but that will also help you to evaluate your career path. For example, reflecting on where you aim to be in the next three to five years, and how you are working towards specific milestones will help you to focus on what you need to achieve and how you will go about doing so.

9.6 Mentoring

Mentoring is an excellent way of identifying areas for improvement and benefiting from the expertise of specialists, who are already well versed in their respective fields. As the American motivational speaker Robert Kiyosaki puts it:

> 'If you want to go somewhere, it is best to find someone who has already been there.'

Many research institutes and universities offer formal mentoring schemes, especially to early career researchers and new members of staff. Whilst these can be a great opportunity to find out more about your research institute, there is always the chance that you will be assigned someone with whom you have very little in common. In order to counteract this, and for those of you who are not part of a formalised mentoring scheme, it is recommended that you also establish your own independent network of informal mentors.

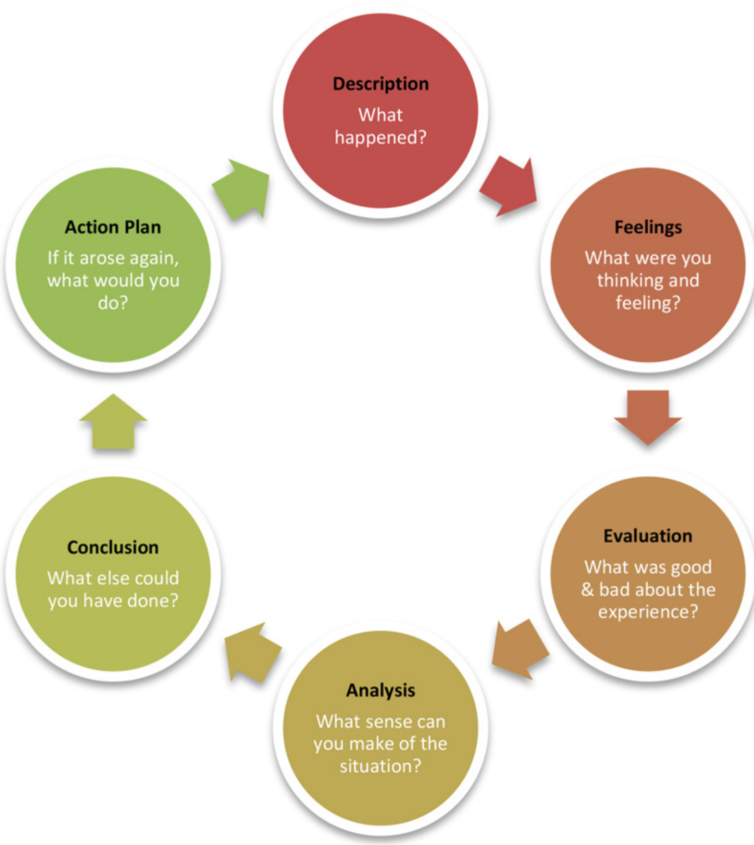

Figure 9.3. Gibb's cycle of reflection. Adapted from [5].

Your network of informal mentors might be very diverse, and may not even be at your own research institute, but effectively they should form a body of people who you can meet up with on an irregular basis, whilst you exchange knowledge over a coffee (or something stronger). They should be people that you get on with, and with whom you share a mutual level of respect and understanding, but they needn't be in a senior position to you. What is important is that they have a level of expertise in a particular field that you have identified as something that is lacking in your own professional development.

As well as finding suitable mentors, it is also important for your development to find people that you can mentor. Again, this can be done in a very informal manner, but it is something that you will ultimately benefit from, as by passing on your own knowledge you help to cement the understanding in your own thought processes. In addition to this you are completing the knowledge cycle, and are helping to feed back into the scientific system of which you are an integral part.

9.7 Career planning

As mentioned in the introduction to this chapter, the majority of people who undertake a PhD will end up in a career outside of academia, and given the limited availability of government funding, and the increasing numbers of research students this seems to be a trend that will only increase in the years to come. There are two things that are important to note at this point: 1) pursuing a career outside of academia is in no way a failure and 2) you need to have a very clear plan of exactly what it is that you want to do.

If you enjoy doing scientific research, then there are still plenty of careers that you can pursue outside of academia. For example, you could go and work for a large research institute or government agency such as the Environment Agency [6] or the Met Office [7], in the UK. Alternatively you could go and work for an instrument manufacturer or a manufacturing company. Many of these jobs will allow you to conduct scientific research, and also present you with opportunities to publish papers and attend conferences, but often with the bonus of a full-time contract and a sense of security that is often absent from any non-faculty position within academia.

If you have decided that research is absolutely not for you, then there are still plenty of options for you to pursue. However, you need to think carefully about how you can sell your unique skill set to a different audience, and how your experiences will help you to gain employment and then excel in your new career. For example, writing a thesis demonstrates that you have excellent written communication and time management skills, whilst analysing data and setting up experiments exemplifies your problem solving skills. Presenting your research at a conference typifies your outstanding oral communication skills, whereas supervising undergraduates expresses your aptitude for teamwork and leadership.

There are many jobs outside of research that would benefit greatly from your unique skill set, with this excellent resource from The Versatile PhD [8] providing a list of alternative careers and the potential routes into them. If you feel as though you have an aptitude for communicating your research to a varied audience, then one career you should certainly consider going into is teaching, which as a profession is crying out for qualified science teachers, particularly those in physics, maths, chemistry and computing. In the UK, the Department for Education [9] offer a number of bursaries and financial support for teacher training, including large tax-free sums to help sweeten the deal.

If you do decide to stay in academia, then you need to be savvy. As the number of PhD students increases year-on-year, at a rate greater than the increase in government spending on research, there is bound to be a pinch. Many excellent researchers are thus forced to find employment via a series of fixed-term contracts, that offer less job security than the traditionally permanent positions available to faculty members of academic staff. Therefore you need to make sure that you stand out from the crowd, and that you have the CV and the expertise that enable you to do this. You also need to be realistic, as getting a permanent academic position is probably the most difficult that it has ever been. Be open to all possibilities, and be sensitive to the fact that you may need to go abroad in order to gain experience. Never pass up any networking or knowledge exchange opportunities, as you do not know what they might lead to. Above all though, have faith in your own ability. If you truly believe that this is the career that you wish to pursue, and that you can make genuine contributions to the field then the right opportunity will present itself. You just need to be patient in waiting for it, and when it does come you need to make sure that you are ready to grab it with two hands, as it may not come again.

Exercise: write a five-year plan

Having a five-year plan will help you to focus your career objectives, and will also be of great benefit in terms of your research interests, grant applications and potential publications. Taking the time now to plan out your research for the next five years will also help to ensure that you maximise your opportunities, and should highlight what areas you need to focus on, which skills you need to develop further, and also what avenues you should not be devoting your limited time to.

After writing your five-year plan, ask a more senior colleague 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 and an inspirational tool to help focus your work into achieving the career that you are aiming for.

9.8 Open science

The phrase Science 2.0 has many different definitions and interpretations, but it can essentially be thought of as a way of conducting science that utilises collaborative and open approaches, which are sensitive and aware of the opportunities and practicalities afforded by Web 2.0 technology (World Wide Web sites that are based on user-generated content and that promote connectivity).

A 2015 survey and consultation by the European Commission [10] into the use of Science 2.0 found that many scientists preferred to use an alternative name, and that instead they would prefer the term ‘open science’. Open science can be thought of as an umbrella term (see figure 9.4) that incorporates a number of movements, including (but not limited to): open access (OA), open data, open research, and citizen science. What each of these movements has in common is that they are dedicated to making science more freely accessible and understandable to as large an audience as possible. However, it is undoubtedly the OA movement that has garnered the most publicity.

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 always the case. If you are reading this as a scientist at the outset of your scientific career, then you may be surprised to find out that it costs (often large sums of) money to read online research articles. 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, jobs, or

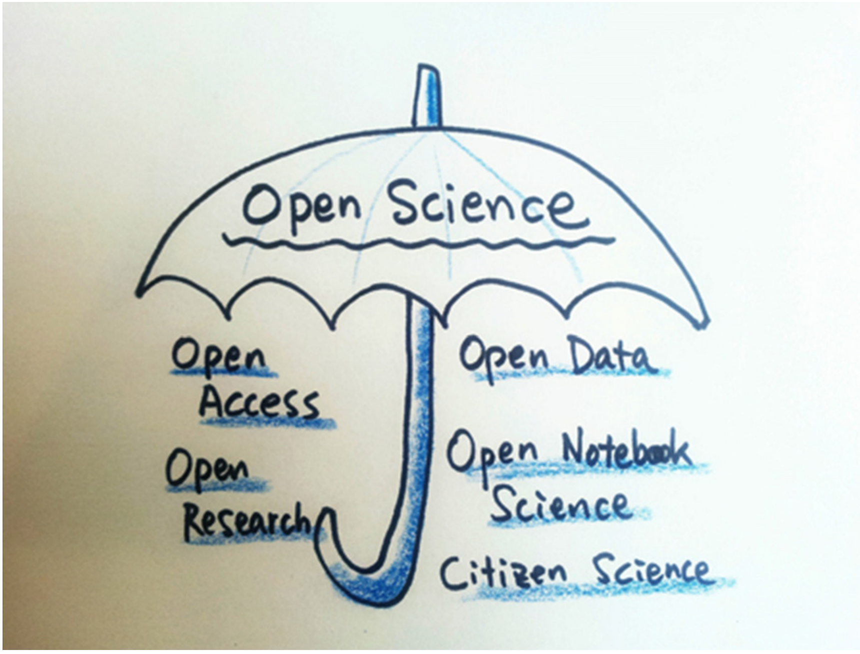

Figure 9.4. The open science umbrella (Image credit: Open Science CC BY 2.0)

infrastructure (as an example, in 2009, Clemson University in the US, an institute with fewer than 17 000 students, spent an astonishing $1.3 million on journal subscriptions [11] to the publishing magnate Elsevier alone).

Over the past 30 years, journal prices have out-priced inflation by over 250%, but it wasn't always like this. In the past journals existed for two reasons: as an affordable option for scientists to publish their work in (as opposed to the more expensive option of personally published books), and as a place where members of the general public and the wider scientific community could find out about advances in science. Sadly, in recent times many journals seem to have lost their way on both counts, hence the need to open it up again, via OA.

The beginning of the modern OA movement can be traced back to 4 July 1971, when Michael Hart launched Project Gutenberg [12], a volunteer 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 free, digital-only journals were launched, amongst them *Psycoloquy* [13] by Stevan Harnad and *The Public-Access Computer Systems Review* [14] by Charles W Bailey Jr.

Since then, the OA movement has grown considerably, although it is important to note that publishing articles so that they are free for all is itself not without expense. Despite the lack of print and mailing costs, 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 to be found.

One alternative, known as the gold route to OA, is to make the author(s) of the article pay for the right to have their research accessible by all. Many journals already require an article processing charge (APC) to be paid before publication, and so some journals have simply elected to add an additional charge if the author wants to make their journal open to the general public.

The other main alternative is the green route to OA, which involves the author placing their journal in a central repository, which is then made available to all. 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 circumnavigated by uploading final 'accepted for publication' drafts of the article.

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. The Research Councils UK (RCUK), for example, has a policy that supports both the gold and the green routes to OA, though it has a preference for immediate 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 currently for any articles published in closed access journals, express permission is 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 right to free access. At the moment many governments have a centralised pot, which they allocate to their different research institutes. However, issues arise when one considers the limitations that this imposes on poorer countries, institutes, research disciplines, and independent researchers. There is also the minefield of determining who gets how much and why. It is for these reasons that many are pushing for '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 modus operandi of almost all publishing companies.

The sad truth of the matter is that many of the more traditional journals are now run as big-business, money-making machines, safe in the knowledge that they can get away with charging large fees, because scientists are still desperate to publish in places with a 'high impact' (see chapter 2). However, if enough scientists rise up and move away from these restrictive journals, and migrate towards those with an OA policy, then the impact factors will soon follow suit (in fact, there is already evidence [15] that publishing in an OA journal will result in more citations for your research). Only then can we begin to reinstate knowledge as a basic human right available to all, rather than as an expensive luxury doled out to the privileged few who can afford it.

9.9 Integrity

Integrity is the keystone in the set of ethics by which scientists lay out their stock. A 2015 report [16] by Science Europe sums this up perfectly in the following extract:

> '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 can quite frankly be no science. Even with peer-review systems, research panels and academic scrutiny, so much of our discipline is reliant upon science being conducted in a fair and honest manner. The temptations for fabricating the perfect results may be great, but the potential damage that this can cause to not only your reputation but also that of the field in which you operate, mean that the negatives vastly outweigh the positives. Sadly, it is a risk that a very small number of scientists are willing to take, and to their actions we must be vigilant, whilst making sure that in our own practices we are absolutely above reproach.

As scientists, it is not just the fabrication of results that we must stay clear of; we must also ensure that we conduct our research in an ethical way that is respectful of the needs and rights of others. It goes without saying that any research that you conduct should stand up to the ethical guidelines laid out by your research institute, especially if it involves a possible invasion of privacy. These ethical procedures are no longer the sole preserve of medical scientists 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 a built-up area, or using satellite imagery to record the geology of privately owned land.

As well as respecting and adhering to the rights of the general populous, it is vital that as scientists we respect our fellow researchers. Whilst multiple groups working on a similar problem is a healthy way in which to conduct research, it is important to realise the serious implications that can result from plagiarism, something which is becoming easier to perpetrate given the globalization of science brought about by the digital age. Seeking permission and dispensing appropriate acknowledgment are essential ingredients for building a fertile and fair playing field. If you are at any point in doubt about crossing a line, then either contact the scientist whose research you are working from, or consider how you would feel if your own work had been abused in a similarly anonymous manner. We owe it to each other, as scientists, to make sure that everyone is given a slice of cake proportional to what they have legitimately earned.

9.10 Summary

This chapter has discussed a number of the additional skills that are required in order to be an effective and responsible scientist. Practical advice and activities have been provided, which should help you to be more proactive in building a unique skill set, which will in turn be a valuable asset whether you decide to stay in academia or pursue a career outside of it. Whatever your career choice, it is important that you plan ahead, and that in doing so you identify any areas in your expertise that require strengthening or are missing entirely. After identifying these areas for potential growth you should actively seek out ways to improve them, via either training opportunities, professional development activities, or formal/informal mentoring sessions. It is vital to remember that no matter how considerate or helpful your line manager or supervisor is, the only person that is ultimately responsible for your career is you. Make sure that you plan ahead, that you take all of the necessary steps, and that you work on developing the contacts that will help you to maximise your true potential.

As scientists it is also important to remember that we are representatives not just for our research institutes and fields of research but also for science in general. In conducting our research, it is important that we approach all situations with great integrity and consider the wider ethical implications of our work. By thinking about how to ensure the greatest number of people have access to your work, you will not only be improving your effectiveness as a communicator, you will be improving your standing as a true citizen of science.

9.11 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 the fact that you need help in writing grants or publications, etc. Identify a colleague with whom you get along, and ask them if they could provide you with some advice in this area. 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 expertise in this area.
2. **Attend a course:** your university or 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 most useful for you if and when you move on from your current employers.
3. **Get some experience:** if you have decided that a career in academic research is not for you, then try and find opportunities to gain some experience in the alternative career that you have identified. For example, if you want to go into teaching then go and volunteer at a local school, or similarly if you are thinking about going to work for a business, then think about linking up with an appropriate company to do some knowledge exchange. As well as looking good on your CV, this will also help you to determine if this is definitely the correct career path for you.
4. **Investigate OA:** find out the approach to OA that is adopted by both your research group and your institute. If there is an OA group then ask if you can go along and attend a couple of the sessions, and if not then you should think

about setting one up yourself. Without ensuring that our science reaches the greatest number of people as easily as possible we will not only be doing a disservice to the rest of society, we will also be partly responsible for the stagnation of further growth and development in our research fields.

Suggested reading

There are many web-based platforms that offer useful career planning tools for scientists and researchers, with the Vitae *Researcher Careers* [17] website 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 [18].

If you want to find out more about the open science movement, then Leonelli *et al* [19] and Tennant *et al* [20] present nice introductions, including discussions of required changes in research culture, whilst Masum *et al* [21] presents 10 simple rules for effectively cultivating open science.

References

[1] Taylor M, Martin B and Wilsdon J 2010 *The Scientific Century: Securing Our Future Prosperity* (London: Royal Society)

[2] Vitae: www.vitae.ac.uk/, accessed 8 July 2016

[3] Vitae *RDF Planner*: https://rdfplanner.vitae.ac.uk/, accessed 8 July 2016

[4] Belbin *Team Inventory*: www.belbin.com/, accessed 8 July 2016

[5] Gibbs G 1988 *Learning by Doing: A Guide to Teaching and Learning Methods* (Oxford: Further Education Unit, Oxford Polytechnic)

[6] UK Environment Agency: www.gov.uk/government/organisations/environment-agency, accessed 8 July 2016

[7] UK Met Office: www.metoffice.gov.uk/, accessed 8 July 2016

[8] Alternative (non-academic) careers: https://versatilephd.com/phd-career-finder/, accessed 8 July 2016

[9] UK Teaching bursaries: https://getintoteaching.education.gov.uk/bursaries-and-funding

[10] European Commission 2015 Validation of the results of the public consultation on Science 2.0: Science in Transition https://scienceintransition.files.wordpress.com/2014/10/science_2_0_final_report.pdf

[11] Elsevier journals—some facts: https://gowers.wordpress.com/2014/04/24/elsevier-journals-some-facts/, accessed 8 July 2016

[12] *Project Gutenberg*: www.gutenberg.org/, accessed 8 July 2016

[13] *Psycoloquy*: www.cogsci.ecs.soton.ac.uk/cgi/psyc/newpsy

[14] *The Public-Access Computer Systems Review*: https://journals.tdl.org/pacsr/index.php/pacsr, accessed 8 July 2016

[15] Eysenbach G 2006 Citation advantage of open access articles *PLoS Biol* **4.5** e157

[16] Seven reasons to care about integrity in research: www.scienceeurope.org/uploads/PublicDocumentsAndSpeeches/WGs_docs/20150617_Seven%20Reasons_web2_Final.pdf

[17] Vitae *Researcher Careers*: www.vitae.ac.uk/researcher-careers, accessed 8 July 2016

[18] Institute of Physics *Early Career Researchers + Career Changers*: www.iop.org/careers/researcher--career-change/page_64175.html, accessed 8 July 2016

[19] Leonelli S, Spichtinger D and Prainsack B 2015 Sticks and carrots: encouraging open science at its source *Geo: Geogr. Environ.* **2.1** 12–6

[20] Tennant J P *et al* 2016 The academic, economic and societal impacts of open access: an evidence-based review *F1000 Research* **5** 632

[21] Masum H *et al* 2013 Ten simple rules for cultivating open science and collaborative R&D *PLoS Comput. Biol.* **9.9** e1003244