COMMUNICATE YOUR SCIENCE! ...

WRITING RESEARCH REPORTS

Bernard S. Brown

'Think, work, publish', said Michael Faraday. By this, he meant that a research project is not finished until the findings have been published. This means writing a research report. 'But haven't I published the work already?', you ask. 'I've presented a punchy poster* at a conference, and I've given a talk (with some super seminar slides†) to the rest of the lab.' Alas, posters and talks don't count as 'proper publications'. And you need proper publications in order to make your reputation in research and to get funding for further research.

You may think that writing isn't easy – and you'd be right! Admittedly, there are 'gifted writers' who seem to find writing easy, but these people are exceptions. For most of us, writing is not easy. But research isn't easy either, so why be upset about writing that report? Thankfully, there are some tips that can make it less difficult. There are many books that give advice, and some are listed at the end of this article; I include here five pieces of advice that have worked for me. Here they are: arranged to make up the word **WRITE**:

W – Work up to the task

Perhaps the most difficult part about writing is getting started. Here, it helps to work up to the task – that is, to prepare yourself. This means having some idea of what you are going to write before you sit down in front of that blank sheet of paper or computer screen. One suggestion I have found helpful is Woodford's 'reservoirs' technique. Take five sheets of paper. Label them: Introduction, Materials and Methods, Results, Discussion and References. Write any ideas you have for the report on the appropriate sheet. Write them in any order. Doodle, and draw rough graphs and diagrams. Compile tables of results. Wherever you are, make a note of ideas and transfer them to the sheets later. If you have already presented a poster, then the information it contains could form the basis of a more detailed research report.

Two further suggestions will also help. First, don't be discouraged – it may take a long time to write the report. Your research may have taken many months, so don't be surprised if the writing takes many weeks. Second, although the report will describe your work in a particular order (see later), you don't have to write the report in that order. Write the easiest part first. This will probably be the *Materials and Methods* section. Having prepared yourself, you are ready to begin writing.

R – Rush through the first draft

You sit at your word processor, ready to write. The first sentence comes to you and you type it. The next sentences comes, then the next. Soon, you have a paragraph, and then the whole *Introduction* is written. Naturally, you rest! Later, you return and, to refresh your memory, you read through what you've written. It's awful! So you go through the text again, deleting words here, replacing sentences there, editing for style, content and clarity. Many hours later you have a rewritten *Introduction* – but there's much more to write yet and, already, you feel discouraged. Have you spotted where you went wrong?

Your mistake was to edit as you went along. Don't do it! You should rush through the first draft. By this, I mean you should try to write the entire report in rough form. Don't worry if a particular word is not quite the one you want. Don't worry if your sentences aren't quite grammatical. Don't worry if you've got typographiccal eerors or speling mistakes (!). Let them pass; you are aiming for a rough draft on paper (or on screen). When you have the first draft, you can go through it at your leisure and correct it.

If you can write the first draft at one sitting, then great! However, not everybody can do this. I can't; after a short time at the keyboard my mind starts to wander. I read the previous paragraph. I start editing it. I save it, count the words, play with the mouse pointer, gaze out of the window, have a stretch, get up and walk about, have a cup of coffee, read a magazine, have a snooze... Instead of wasting time like this, it's better to take several short sessions to 'rush through the first draft' and, here, I found that two suggestions in a book by K. Atchity were very useful. The first suggestion is to ration your writing time and set yourself easy targets. You could, for example, decide to spend one hour – no more and no less – on writing. You might decide that, during the hour, you are going to write the *Introduction*, or the first paragraph or the first sentence ... Whatever target you set, it should be one that you can reach within the hour. The hour starts. You switch on your computer and type INTRODUCTION. You have an hour to reach your target, so you need not feel bad if you waste some of it. So spend some of the time thinking, relaxing, doodling. Have a cup of coffee. Then write your first sentence. When the hour is up, stop writing. Whenever I have tried this technique, I have always found that I have reached far more than my target. For example, today, I decided to spend an hour writing the section WORK UP TO THE TASK. I've still got ten minutes left and look how far I've got – I'm nearly at the end of the next section. In ten minutes, I will stop – and have a cup of coffee!

Atchity's second suggestion is that you don't stop writing without knowing what you are going to write next. You could stop in the middle of a sentence or at the end of a section – when you know what's coming next. This makes starting again easier. Having reached the end of this section (and the end of my hour) I am now going to stop – but, before I do, I shall write the heading for the next section, and part of the first sentence.

I – IMRAD

The letters IMRAD stand for ... [I then stopped. Later, I started writing again by completing this sentence.] ... Introduction, Materials and Methods, Results and Discussion. They summarize the main parts of a research report. In the *Introduction*, you say 'Why I did it'. You outline the problem, review others people's work, then summarize your main results and conclusions. This tells the reader what your report is about, so he can decide whether to read further. Use the present tense.

In *Materials and Methods* you say 'What I did'. Include details, technical specifications, sources and amounts of the materials used. Describe the methods in sufficient detail so that another scientist could repeat your work. Your descriptions should be 'cookbook recipes' given in the order in which you would carry them out. If a method has already been published (either by you or by somebody else), you need only refer the reader to the previous publication. Use the past tense. In *Results* you say 'What I found'. Include a clear and concise

*Advice on how to produce effective posters was given in: Producing Punchy Posters [Brown, B. S. (1996) *Trends Cell Biol.* 6, 37–39] – the first in the 'Communicate Your Science!' series.

†Advice on how to produce effective slides was given in: Super Seminar Slides [Brown, B. S. (1996) *Trends Cell Biol.* 6, 74–76] – the second in the 'Communicate Your Science!' series.

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outline of the experiments you did and the results they yielded. Present your results in graphs and tables, as well as in the text, but don't repeat text results in a table or graph. Write this section in the past tense and, if possible, let its headings mirror those of *Materials and Methods*. In the *Discussion* you say 'What it means'. State what the results show, whether there are any exceptions, the relationship of your results to previous work, and the conclusions you reached and why you reached them. Use the past tense when referring to your own findings, and the present tense when referring to other people's work.

And that's it. You now have a first draft of the main part of your report. Breathe a sigh of relief, and put the manuscript away for several days. Later, you will return to it with a fresh point of view.

T – TAKE A SECOND LOOK

Now you can do all that editing that you longed so much to do when you were writing the first draft! Go through the text carefully; you will be surprised at how awful some of it will seem on the second reading. Spend plenty of time on this stage – take several sessions if you like, for it is hard and meticulous work. But, editing your first draft is enjoyable too, so take your time and enjoy it. Be satisfied with nothing less then the clearest way of reporting your work.

E – EXTRA TOPICS

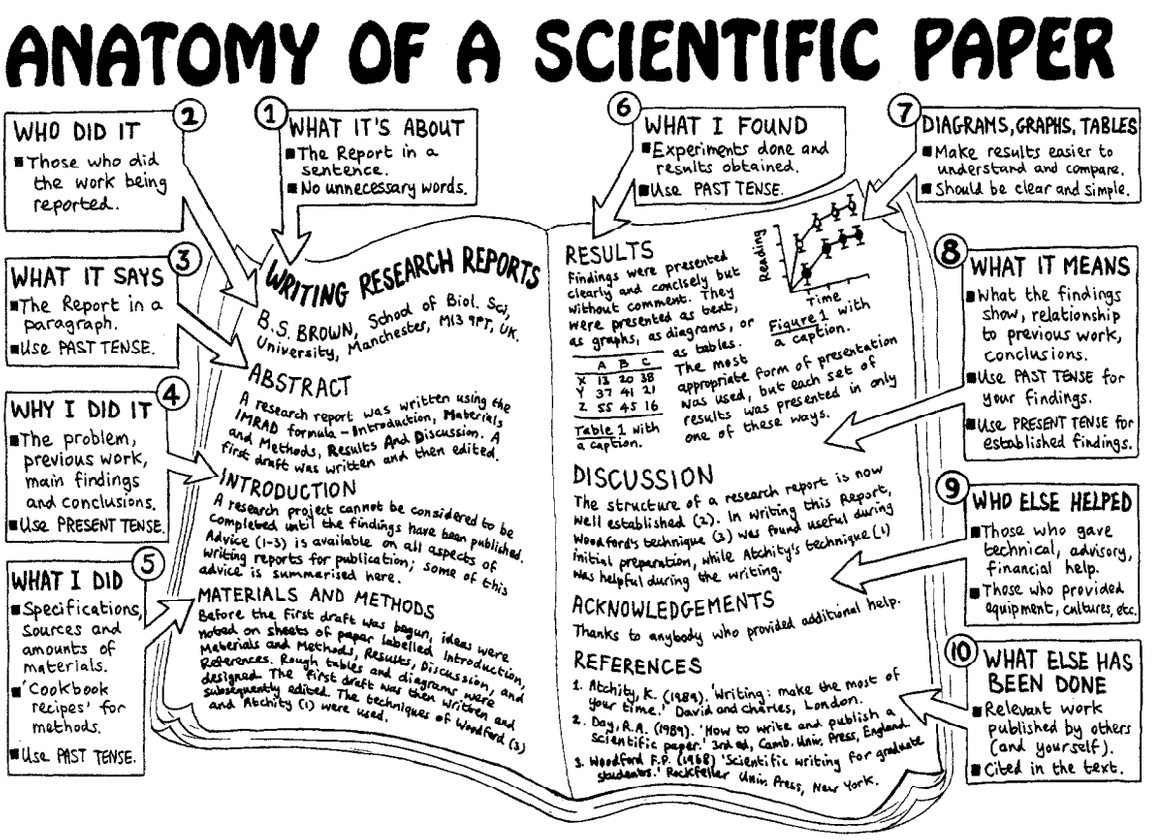
There are some extra topics, not included in the IMRAD formula, that you should consider. They are (in alphabetical order): A title, By-line, Concise summary, Diagrams, Extra help and Former work. The *title* should be brief and informative. It tells the reader 'What it's about' and so should summarize the subject of the report in the minimum number of words. The *by-line* lists the names and addresses of the people who did the work. Your name will be there, of course, and also the name of anybody who made a major contribution to the work. The journal you publish in may list the authors either alphabetically or in order of importance to the work. The *concise summary* or abstract is your report in miniature. It states (in about 250 words) the object and scope of the work, the methods, the main results and the main conclusions. It should be understandable without reference to the paper. Write it in the past tense. The *diagrams* (also graphs and tables) can summarize complex information. The diagrams can be more complicated than those used in posters or slides because readers can spend time considering them. *Extra help* (acknowledgements) should include the names of others who contributed – for example, those who gave technical assistance, special equipment or bacterial cultures and sources of funding. *Former work* (References) is a list of journal citations of other relevant published work. You should compile this list while you are writing the report: every time you refer to the work of others, make sure you have the details on file. The details you need are: authors, year, journal title, journal volume and number, page numbers and title of article. Include these details in the bibliography at the end of the report and refer to them in the text. Journals differ in how they present this information, so you should find out what happens in the journal that you are hoping will publish your report.

After all this is done, send the required number of copies, together with a covering letter, to the editor of the journal. Sit back and wait. If the work is good, and the paper has been written well and clearly, publication will follow!

Here's where to find more help:

ATCHITY, K. (1989) *Writing: make the most of your time*, David & Charles, Newton Abbot

BRISTOE, M. H. (1990) *A Researcher's Guide to Scientific and Medical Illustrations*,



pp. 43–56 and 75–122, Springer-Verlag
DAY, R. A. (1989) *How to Write and Publish a Scientific Paper* (3rd edn), Cambridge University Press
DIXON, B. (1973) Sciwrite, *Chem. Br.* 9, 70–72
EBEL, H. F., BLIEFERT, C. and RUSSEY, W. E. (1987) *The Art of Scientific Writing*, VCH
LINDSAY, D. (1984) *A Guide to Scientific Writing – a Manual for Students and Research Workers*, Longman
PATON, A. (1976) How I write a paper, *Br. Med. J.* 6, 1115–1117
SHORTLAND, M. and GREGORY, J. (1991) *Communicating Science: a Handbook*, Longman
SIMMONDS, D. and REYNOLDS, L. (1994) *Data Presentation and Visual Literacy in Medicine and Science*, pp. 69–73 and 105–121, Butterworth–Heinemann
STRUNK, W., Jr, and WHITE, E. B. (1979) *The Elements of Style* (3rd edn), Collier Macmillan
WAINWRIGHT, G. R. (1993) *Successful Business Writing in a Week*, Hodder & Stoughton
WOODFORD, F. P. (1968) in *Scientific Writing for Graduate Students* (Woodford, F. P., ed.), p.18, Rockefeller University Press

Learning on the Web

Fergus Doherty

Previous articles in *trends in* CELL BIOLOGY have highlighted the growing relevance of the Internet, and in particular the World Wide Web, to the cell biologist as a research tool. Indeed, the Internet is becoming as important a research tool as any conventional laboratory instrument. The value of the Internet lies in the huge wealth of linked information it contains, readily accessible via a desktop computer. These features also make the Web an attractive resource for learning, especially in the rapidly advancing life sciences. At its most extreme, the Internet can provide the platform for 'virtual courses', where students participate entirely via their desktop computer. Even without going totally 'virtual', the Internet can provide a rich and valuable learning environment for anyone interested in the life sciences.

Computers and learning in the life sciences

Since the introduction of the first viable and affordable personal computers, educators have explored the possibilities of computer-aided learning (CAL). However, it is only in recent years, with the appearance of powerful desktop computers with user-friendly interfaces, capable of handling complex graphics, animations, video and sound (multimedia) that CAL has really taken off. The computer environment offers the student self-paced interactive learning. Modern desktop computers can now display three-dimensional (3D) representations of complex structures such as cells and macromolecules, aiding understanding of topics that can be difficult when taught by conventional methods. Software for producing tailor-made CAL packages has become easier to use (e.g. Authorware, Hypercard, ToolBook), allowing academics to produce their own packages. Commercial publishers are also increasingly entering the field. However, CAL material of this kind suffers from several disadvantages. As research progresses, material can quickly become out of date, necessitating frequent updates. In addition, the rapid advances in knowledge mean that teachers and researchers are necessarily specialized and find it difficult to keep up with current knowledge. Finally, academic institutions have limited funds to invest in expensive commercial software. Many of these problems can be overcome by using the Internet as a resource for learning.

Learning and the Web

HyperText Markup Language (HTML), the technology that underpins the Web, enables the display of multimedia items over the Internet. HTML also includes clickable links to other 'pages', which may be physically located anywhere on the Internet. These features make the Web a valuable learning environment. Teachers can easily build up a learning environment composed of material produced in-house, together with resources from the wider scientific community. For example, a simple, student 'Home Page' can be created that includes course timetables and course descriptions produced in-house. A series of lectures in a timetable page can then be linked to any relevant learning material on the Web. Many teachers produce lecture outlines as documents, slides or overheads prepared on computer. These can easily be converted to HTML documents, either with a simple text editor or with one of the many free or shareware utilities available. Electronic lecture notes of this kind can then provide the framework for links to animations, graphics and relevant information elsewhere on the Web. The 'Home Page' approach is relatively simple and provides the student with an easy way to use the Web, reducing the risk of being 'lost in hyperspace'.

More advanced pages can be created by extending the facilities of HTML with external programs or scripts. An example of this is John Maber's (Leeds, UK) glycolysis tutor (see Box 1), which takes the student through the glycolytic pathway via a series of choices and prompts. Combining external routines with the forms feature of HTML allowed David Davies at Birmingham (UK) to create Web-based self-assessments for students (Box 1). External helper applications can also be used to extend the functionality of HTML. Links can point to files that are opened by applications available to the user. I have used this approach to display 3D protein representations – using Brookhaven data base files and the molecular visualization program RasMac (Box 1).

The Web provides a more open environment for the student than 'traditional' CAL, which is often focused to teach a particular point. Access to the Web allows the student to explore freely the growing amount of information that is published on the Internet. Increasingly, scientific journals are appearing on the Web, and the Internet seems likely to become an important medium for scientific publication, perhaps the 'first stop' for any researcher or student.

As well as subject-specific pages, the Web can provide more general features for education. Local Usenet news groups for students and staff can be created to promote discussions about the course (e.g. see the author's pages, Box 1). This interactive approach has been taken even further

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