Journal of Materials Education Vol. 33 (3-4): 161 - 178 (2011)

HOW TO 'SURVIVE' AFTER GRADUATING IN MATERIALS SCIENCE - IV: WRITING COMPELLING PAPERS

Federico Rosei* and Tudor Johnston

Institut National de la Recherche Scientifique, Énergie, Matériaux et Télécommunications, Université du Québec, 1650 Boul. Lionel Boulet, J3X 1S2 Varennes (QC) Canada;
* email: *rosei@emt.inrs.ca*

ABSTRACT

This article describes our view of how to write compelling papers for Materials Science journals (and hopefully for broader audiences). Most of this discussion also applies to both physics and chemistry journals. We will discuss the usual forms of written scientific communications, including short letters/communications, full papers, comments, perspectives, review articles, book chapters and even books. Besides the 'technical' or 'nuts-and-bolts' aspects of scientific writing, we once again emphasize a fundamental concept that we developed in the previous two articles, namely: *learn to play from the other side.* We remind the reader that anything that matters in the world of science is also peer-reviewed before it is seen by the ultimate readers; therefore, once again, we advise the reader to place him/herself in the mindset of those who are going to evaluate their written work to anticipate their reactions and forestall objections. As a matter of background, we remind the reader that this is the fourth article of a series. It follows the first (in which we described how the graduate course on 'Survival Skills for Scientists' was created at Institut National de la Recherche Scientifique (INRS) in Varennes (QC)), the second (in which we offered basic advice on how to apply the skills and knowledge acquired in graduate school to finding a job and developing a career in the 'real world' of science after graduating) and the third article (in which we described the Peer Review System and how it is used as a form of quality control in modern science).

INTRODUCTION

As pointed out by many illustrious authors before us, the best results that scientists are able to generate in the laboratory do not really 'exist' in any practically useful sense until they are published in a well-recognized venue, usually referred to as a *"peer-reviewed"* journal[1-6]. In addition, due to increasing competition for funds, for resources in general, and for positions/jobs, scientists are now constantly being made aware that they should "publish, or perish". (For general advice on scientific careers, we refer the reader to References 7-13. The total number of these scientific journals and consequently of papers published yearly worldwide has increased steadily over the last few decades (nor has the quality deteriorated

significantly), together with the number of journals and even the number of conferences. This increase means that it is more and more difficult for any individual paper to stand out from the others, and thus it is more and more important that you pay attention to what you have to do to produce publications that can indeed stand out from the others. Hence this paper.

To get to this desired state of refereed publication of a piece of work, the report you write must pass through the first gatekeepers (i.e. the editors), and then through the referees. Your report must sell on its quality and originality as well as on its clarity. Your chance of success will be better (not to mention the quality of the communication) if you take care to appeal to two classes of browsers or readers. At one level, to make the widest impact, you wish to reach people who may have only a superficial knowledge of the field (such as the editor and the browsing reader) and who therefore must, so to speak, be wooed. At the deepest technical level, however, you also need to convince the experts (the referees, the authorities in the field and your critics). They are the ones who know the field well, but they (or rather a subset of them) are also the ones who must first be convinced that your work is worthy (by the standards of the field) to be added to the canon of archived publications.

Before and after this archival peer-reviewed output there lie the more ephemeral but nonetheless vital communications delivered directly to the public in the form of oral presentations, invited talks, seminars and conference posters; these will be discussed in a forthcoming article of this series.

SCIENTIFIC WRITING: GENERALITIES

To be a successful scientist it is not enough to have original ideas, you must also be able to communicate your science and insights to others. You must therefore become a good communicator, and learn how to disseminate your ideas widely. You will have to communicate your results and conclusions effectively in each publication, and to disseminate them broadly by arranging to publish in the journals with the best impact and which will agree to transmit your work to the world. This transmission will not only be most immediately apparent to the specialists in your community but also to a wider audience of scientists from different fields and eventually perhaps even to the layman. This ability to communicate effectively distinguishes at least partly, very good and good scientists from the average or below. The ability to do this can be learned and can always be improved.

Beyond this somewhat obvious view of the public communicator, there is the fact that the scientist who wishes to succeed widely (and don't we all) must be able to communicate on at least two levels. Besides communications to peers (initially through anonymous peer reviewers) via peer-reviewed publications, there are also more restricted (i.e., less public) communications to funding agencies and to various committees (again through peers) for funding and academic recognition. Since most of this communication is written, at arms' length, so to speak, without direct contact with the target audience, doing it effectively is obviously essential to success here.

The purpose of this article on written communication is not to help you to learn the basics of prose writing. (There are many excellent books for that. Our best advice to improve your prose is to read widely, and not just from the scientific literature[14].) Rather, this is the place to discuss how to package and color the messages you want to send, to understand that you will always be sending more than one message at a time, and to understand and control all the messages (both explicit and implicit) that you will be sending.

Your most important underlying message, the one which you cannot avoid sending with each communication, is the one of *who you are*, or at least how you appear to the readership. To transmute a well-known aphorism of the Canadian communication guru Marshall

McLuhan (who famously said, "the medium is the message"), here you should understand that "the message is the messenger", since the underlying message of your science communication is who and what you are. In fact, anything of any length that you write shows the reader to some extent who you are. However, like an actor in a play, if you pay attention, you can also learn to appear to be something more and perhaps rather better than harsh reality. Another aspect that you should learn to keep in mind is that usually you are engaged in *advocacy*. You are not just sending an objective message ("take an impartial look at this"), you are also putting forth your particular point of view ("and this is what it means"). Be aware that your voice will always be in your prose unless you make great effort to remove it. You should make the conscious effort to put on your "objective" spectacles and try to step back from the work and see what kind of a person you would seem to be.

Structuring the explicit text can be done much more effectively if you imagine a rather skeptical reader and then answer the questions, which such a reader might well, come up with. It is even better if, in the text, these questions can be answered before the reader even thinks of them. If successful the feeling will tend to arise naturally in the reader that this author is "really quite intelligent and someone to get to know". This arises because the feeling also implies that "this author thinks like me". (This is harder to do than one might think at first sight, because the most important unanswered questions, the ones that tend to block the reader out are often just those, which you are unlikely to invent for yourself. In lieu of this self-blindness, this is also another area where it is a very good idea to get help from others.)

Apart from the tactical aims in a given application, it is worth keeping in mind (for almost anything you write) that as indicated above you should try to impress two distinct levels of readers. One is class of reader is the eagle-eyed professional, someone who is perfectly at home in the discipline. It is invaluable if you can persuade a colleague to perform this function — that of the Devil's advocate — *before* your manuscript is submitted. You should also, however, try to communicate through the text with someone who is more like an informed layman, perhaps another scientist not at all in your specialty, or even further away. By the way, most of the top-ranked journals include this sort of intelligibility in publication in their criteria for acceptance. (This is because they are well aware that good scientists like to graze a bit outside their specialty and including this wider circle of readers will increase the journal's citation record and overall impact. All too often, and most frequently for reasons of space, this requirement is often the first to be sacrificed to satisfy more technical requirements raised by referees, who as experts are not usually charged with paying attention to general intelligibility.)

By the way, this two-component audience aspect often applies to more restricted venues. In any specialized committee of your peers (such as those assembled for reviewing applications for funding) there should as a matter of course be an expert or two in your own field, but there will usually be many more who are experts in other fields but who are well qualified to easily understand your work, providing it (or at least the principal points) are simply and clearly explained. (Most members of such committees in any case would like to believe that they are not narrow specialists and can get the gist of most things that they are asked to evaluate.) If you can clearly explain the essentials to these scientists, such people will be much more inclined to accept that you know what you are talking about in the difficult and abstruse sections that they do not really follow. They will feel this that much better if they are finding themselves able to follow something noticeably outside their area of expertise, and thus their opinion of your work will likely be improved considerably. These people also vote on decisions and can sometimes counteract the excessively hostile expert(s). You may even find that the expert(s) will approve of the way that you can summarize the core of your work and infer that you are thinking clearly and are thus less likely to go

astray later in the research. (After all, this may even be true.)

Both for publication and for other texts, the resulting text may be a bit uneven, stylistically speaking. This is to some extent unavoidable, since dense and complicated technical paragraphs with long and complicated sentences (often so because of length limitations) and much technical verbiage are being interspersed from time to time with shorter paragraphs, with short, clear sentences with little technical jargon. If this lack of homogeneity is the price of clarity and of being able to address a wider public, then so be it.

We now turn to discussing some particular aspects of peer-reviewed publication. As we do so, we emphasize that the more senior you become, the larger the fraction of your time that you will spend writing. As your career progresses, you will spend less and less time in the laboratory, and more time directing those who do and more time advocating for the work thus done not only in peer-reviewed papers but also on many other levels. The effort in improving your writing skills for peer publication will be invaluable in the other areas as well, and we will be turning to these areas after we have dealt with peer-reviewed publication. It should also be recalled that the training of future scientists should include training them to communicate effectively.

PUBLICATION STRATEGY: Where to publish? In letters or regular papers?

As we all know, the "normal" means of publication is via the peer-reviewed scientific paper. The shorter publications (Research Notes, Brief Communications and the like) are *either* for more limited topics which are not of the same weight as a regular paper (Brief Notes or the like) or for brief reports but on very important topics (so important as to be in the nature of "breakthroughs") for which rapid publication before a wide audience is deemed essential (usually termed Letters or sometimes Rapid Communications). It is the usual assumption that this urgent short publication will be followed by at least one full paper and one should hope several papers. (All too often, however, this is not the case. One then sees what are almost a series of short publications on a given topic, with few full papers, and often stigmatized as "serial publications".) It is essential that the important short publications are clearly identified as such, and not confused with their humbler cousins. This is relatively easy because of the structure of the refereed literature.

It is worth pointing out that in some disciplines and sub-disciplines (e.g. biology and engineering) in which the authors of this paper are not directly active, short papers and communications are not considered prestigious at all. In fact several biologist and engineer colleagues frown on our appreciation of short publications, noting that in their field *"you either tell the whole story or you're not taken seriously"*. Obviously you should use the strategy appropriate for your field.

For topics which are not extremely new, the work on these more established topics tends to be published in only a few major journals, which thus become the "normal" journals for the field. You should have a very good reason for publish a paper in a journal, which is not much used for the area in which you are working (as evidenced by the references you give). It may happen that the Editor may then say something along the lines of "We notice that only a very small fraction of the related papers to which you refer have appeared in our journal. We think that it would be better for you to submit to one of those other journals."

Since we wish to discuss this hierarchy of journals in a field, we begin by recalling the unit of measure, which is commonly used to order the journals prestige, namely the "impact factor". This term is applied to scientific journals (often by people who have not checked into their source or origin) and we will use it (or simply impact) in a general sense as the effective ranking or rating used to place

journals in a hierarchy of effectiveness in dissemination. For those readers who have not yet taken the trouble to look up "impact factors" of scientific journals, here are a few relevant gleanings from Wikipedia. "The impact factor, often abbreviated IF, is a measure reflecting the average number of citations to articles published in science and social science journals. It is frequently used as a proxy for the relative importance of a journal within its field, with journals with higher impact factors deemed more important than those with lower ones are. The impact factor was devised by Eugene Garfield[15], the founder of the Institute for Scientific Information (ISI), now part of Thomson Reuters. Impact factors are calculated yearly for those journals that are indexed in Thomson Reuters Journal Citation Reports." (It is worth reading the rest of the article for general background as well.)

Returning to our main topic, of the "normal" journals in which work in your field often appears, there will be some order of preference (other things being equal) and this is often given by the ranking of impact factor of those journals. Within this hierarchy, while no journal editor ever wants to publish papers with errors or with material, which is not, truly original, some of the higher-ranking journals may have an additional level of excellence required. In effect, although they find no errors in a particular submission, although it appears original and although the field is indeed one, which they frequently publish, that is not enough; in effect the journal may say, "This material is not quite of the high standards we set ourselves, so perhaps you should go elsewhere". Of course, for the top journals the editor will find this easier to say this more directly, "While there's nothing wrong with this work, it just does not have the wide impact for which this high-impact journal is being reserved." Naturally, since the prestige of publishing in that journal with higher impact than another, is a key point, the authors often contest this assertion negative opinion rather vigorously. Of course, the discussion of this point this then delays the eventual acceptance or rejection. However, as is often the case when it is the higher-ranked journals which are involved, the speed of publication is really something to which only lip service is paid, since reaching the right public with maximum impact (plus the perceived publication prestige in the authors' résumés) is what is really being sought by the authors. When the journal was first established, speed to publication was a primary objective of the authors, but later, when the journal has acquired sufficient prestige, publication as such and not speed becomes the dominant objective of the authors.

When the prestige of the journal is the dominant aspect, publication in one of the journals in the area of the research, becomes a game in which each set of authors aims at publishing in the highest-ranking of these journals. The game begins by making the initial choice of which journal in which to publish. This often comes down to estimating (1) the level of the work being submitted and (2) the level of the highest-level journal for which acceptance is probable. Aim too high and you may lose much time in the refereeing process and still not achieve publication in the high-status journal you have chosen; aim too low and you have an easy publication in a lower-ranking (and presumably less prestigious) journal than the work should have merited. Remember, however, that as far as eventual citations are concerned, if the work is sufficiently important the citations will come in the end (unless the journal is completely obscure). The citations may arrive more slowly if the work appears in a lower-ranking journal than might have other-wise been the case, but the work will usually be recognized by posterity. Merit will out, in time, particularly in today's era of instant searches. In the end, the permanent difference in the choice of journal is mainly the perceived prestige of the journal as a citation in your curriculum vitae.

Of course there are also a few very high-status journals which publish exclusively letters or short contributions by other names of very high quality. Examples of these include, for physicists, *Applied Physics Letters* and *Physical Review Letters*; for chemists *Chem. Comm*.,

Nanometers and *Angewandte Chemie*; for materials scientists *Advanced Materials*. (Scientists from other fields are asked to kindly excuse our incomplete listing.) Some other journals publish both regular papers and communications in the same volume, examples being the *Journal of the American Chemical Society* (better known as *JACS*), and *Physical Review A* through *E*. (In these *Physical Review* journals the elite short papers are styled Rapid Communications, but some cynics cruelly term them "failed *Physical Review Letters*".) Notable materials science journals that mostly publish full papers are *J. Mater. Res.*, *J. Mater. Sci.* and *Mater. Lett*.

Standing above and apart from these more specialized journals are *Nature* and *Science*, arguably the two most prestigious scientific journals in the world, and ones that cover most of science. These both have a section devoted to Letters (*Nature*) and to Reports (*Science*), and a shorter section devoted to Articles, which tend to be longer contributions that report major advances in a given field (each issue only contains one or two of them, on average). They also have a section on very short communications, *Briefs* (*Nature*) and *Brevia* (*Science*) which are one page in length or less. The latter are the most selective and prestigious sections in *Nature* and *Science*. The acceptance ratio for Nature's Brief Communications section is in fact roughly 5%, much lower than the Letters section. While *Nature* used to be a single journal, it is now actually the flagship publication of the Nature Publishing Group, which includes other prestigious journals such as *Nature Materials*, *Nature Chemistry*, *Nature Physics*, *Nature Photonics* and *Nature Nanotechnology*, all of which may be of interest to a Materials Scientist.

Generally speaking, in many (but not all, see the remark above on biology and engineering) disciplines, Letter journals tend to be more selective, and therefore it is more difficult to publish in them. Precisely because it is more difficult, almost everybody would like to get published in a letter journal – the added difficulty and selectivity carry extra prestige and are often associated with a higher quality. The necessity of rapid publication is now often slighted in the weighting of the likely impact and novelty of the publication. In fact, with appeals, corrections, and the like, it is not rare to have some publications in letter journals actually take longer to see the light of day than the average time for publication in the associated regular journals.

A prestigious Letter journal generally offers the advantage that your work, if published, will be read more broadly because of the valued *imprimatur* of a highly selective journal (and thus, one can hope, become one more frequently cited). In the scientific arena, everybody fights for exposure of this kind. Being in the spotlight is almost everybody's dream and peer recognition largely determines your success. (It is precisely because of this prestige that authors will contest unfavorable reviews more vigorously and it is this, which leads, as remarked above, to considerable increase in publication delay due to the time consumed in the back-and-forth salvos of a war with a referee.)

The tendency to write short contributions is not at all surprising, from another point of view than prestige alone. Most scientists, and especially important and famous ones, tend to be incredibly busy, and therefore, as consumers of science literature, are often unlikely to read long papers unless advised to do so by a colleague. Since many famous scientists also desperately want recognition from other famous scientists, they will often try to write short papers in the very best journals with the highest impact factors, so that a larger audience will read them; and so on.

The best approach to this in our opinion is likely to be to describe one sparklingly new idea in each Letter/Communication, and then to expand on it in a subsequent full paper with gorgeous detail and pithy expositions of the key points. After you have managed the arduous task of publishing a first Letter, the follow-up full paper has almost no chance of being actually rejected if the proper journal is chosen

as venue, although the details may be subject to considerable revision. This allows you to remind (in effect) everyone that you just published a Letter, and most importantly, to include all the experimental or theoretical details and background nuances that simply could not fit into the ultra-compact Letter format, but which are vital to publish if your work is to be thoroughly understood and appreciated. This is particularly true if someone wants to reproduce your data or perform calculations based on your experimental results. If you do not get the initial letter accepted in the best letter journal you may either recycle the letter for a somewhat lower-rank journal, or you may just absorb the letter material in the full journal paper. (A cynic might say that the top scientists read only Letters, while the full papers are read by the workers in the trenches, since they need to know the details.)

On the other hand, you may not want to go through the quasi-political hassle of writing a Letter and arguing its way past the best letter journals with their guard-dog referees. You may therefore decide to bypass the Letter-submission wars and publish directly in a long paper where the degree of hostility is usually lower. (However, this depends on the journal. As an example, *Advanced Functional Materials* and the Full Paper section in *JACS* are quite competitive).

Clearly, like the choice of journal in which to publish either the letter or the paper, the balance between the two is partly based on your own estimation of how important the work is and partly on your own taste for battle. It is a good idea to evaluate very carefully your personal motives in making those choices. You should also remember that, while you as an established researcher may feel detached about not pushing a particular piece of research to the Letter journal standard, by doing this, you may be denying your graduate student a legitimate shot at a good start in their publishing career. Ethically speaking, given work of equal merit, one should probably push more for the work in which a student is the first author.

CUMULATIVE PUBLICATION PROFILE

By the way, when you are on your way to accumulating papers in your profile, having gone through the process of where and how to publish several (or even many) times, some words on accumulating a profile with several or even many papers are now in order. As a general career strategy, it is best on the one hand, to publish as many glittering Letters as you can. For the rest, the regular papers, it is better to publish a few good meaty papers rather than many average papers of modest length. As a diagnostic for this symptom, if people tend say of your work, “Have you seen X’s last paper on the “whatsit” effect?”, you are publishing too many contributions so small that they risk being lost in the literature “noise”. (A good analogy is maritime radar, where the noisy echo from the waves is called “sea clutter”. If the boats you try to see are too small, they will be lost in the “sea clutter”.)

(The tendency we are advocating is that of the famous German mathematician Gauss (who did not have to apply for research grant money), who had as his motto (on his seal): *Pauca sed matura* (“Few, but ripe”). Since you are not certain to be as talented as the legendary Gauss, you should not go to the extent he did. In fact, many of his results were found in his drawers after his death, because he felt that he had not yet polished them well enough. The real meaning of some of his Latin notes has not yet been decrypted.).

Publishing papers, which are each of impressive weight (in terms of contents, importance, originality and significance), will improve your signal-to-noise ratio, as well as your citation rate and your overall impact (of course it will also reduce somewhat the raw number of publications and might bring harassment from the strict publication counters). Psychologically it will also have a positive effect, since it will make you feel good about yourself and proud of your work. You would like to publish without having to say later (to yourself) something like, “This was a bit thin for a publication; it should have been tucked into another paper.” In the

long run, you want to be able to look proudly at your publication list, rather than to view it as a collection of papers whose sole purpose was to advance your career. (However, to be realistic, your name may well be part of a group publication for a somewhat "political" reason, for a conference or some other occasion; a certain number of these are often an unavoidable aspect of working as a group or team.)

Graduate students often tend to fall into what we call the "short list" syndrome. It takes them a while to publish their papers, and they feel uneasy about having a short publication list, so they would, at least at the outset, publish more small papers. This is understandable, since the length of this list may be a determining factor in a student's ability to find a job after graduation. This is especially true if you want to secure a place in basic research. However, students tend to forget that, in the long run, it is the quality of their work – even their very early work to some extent – which will largely determine their success in science. All in all, if someone has a few lightweight publications at the start of their career, it will not hurt them in the long run, if the lighter-weight "fluff" publications are phased out as the career gets up to cruising speed and you can better control your destiny.

Having settled the strategy for your paper in the sense of what form to use and where to submit the work, the actual writing still has to be done.

WRITING THE SCIENTIFIC PAPER: THE BASICS.

A full scientific paper should report new knowledge in a given area of science, typically in the form of data (collected either experimentally or through theoretical calculations or, occasionally, both, always accompanied by a thorough description of the methods used), their analysis and interpretation. (All this is also implicit in a Letter, but only the basics needed to understand the essential results are actually presented in the Letter.) This means that the authors should have studied the literature in depth and have made sure that their data and/or interpretation is new with respect to what has been previously published, and all this should be done well before writing up the manuscript and submitting it for publication. (Of course, sometimes the writing process itself uncovers an area requiring additional investigation.)

The best way to start writing a paper, as pointed out by Whitesides (and others)[2] is to draft an extended and detailed outline. Besides helping you structure the manuscript itself, this can actually be very useful in planning your research. The outline should contain the key parts described hereafter in this section and should be progressively rewritten with an increasing level of detail, until it is quite easy to turn it into a "story". (The concept is similar to writing a computer program by outlining the modules and their links and then filling the detailed items in each module.)

An essential point that most people tend to forget during the elaboration of the modules is that each paper as a whole should *"tell a story"*. In fact every type of scientific communication you engage in, whether written or oral, should tell a coherent story, though "how" you tell it obviously varies depending on the venue and other aspects.

The normal paper will typically follow the structure described below (although there may be variations depending on the journal, which also reflects the "culture" of the specific field of research).

An *introductory section* should provide a suitable context, describing what the paper is about and why the topic is important, what has been done before and how the authors propose to address one or more of the remaining problems of the field. This includes performing a thorough literature search on prior art, with an appropriate reference list.[1] The literature search is in fact the starting point of any scientific project (not just its write up once the data are collected and analyzed).

A *methodology section* should describe all the theoretical and experimental techniques that

were used to perform this work. This should contain enough details on the novelties in approach and in apparatus, together with the parameters used, so that a reader who has access to similar techniques and equipment would be able to reproduce the work without too much difficulty. None of the useful results should be presented in this section, since, in order to avoid confusion they should be only in their proper section. In a real sense, this is more like the documentation of the details required by the reader to accept that the methodology is sound. If there are novel aspects here then they are naturally given in useful detail for those who might wish to emulate the work. (Sometimes this is aspect is to be placed by the journal in a separated section on "Methods" or the like.)

The *Results and Discussion* forms the intellectual core of the paper. (A minor variant is that some journals require you to keep the *"Results"* and *"Discussion"* sections separate.) The best way to present results and to discuss them is to prepare excellent figures and then to use them as the 'core' of the story you are telling, in a manner, which might well resemble the presentation, one would give as a talk or a poster. (Poster presentations are very useful trial runs to help you tailor the presentation by practicing various presentation approaches on one or two "clients" at a time and checking their reactions.)

The *Conclusions* are naturally the last part (of the main paper, i.e., except for appendices). Actually, we prefer to call it *Conclusions and Perspectives* to make clear distinctions between present summary conclusions and the possibilities for future work. The *Conclusions* are redundant in that what they will have been said piecemeal in the Results, the real function here is to summarize for the browser who has not read the *results* what the results actually mean. As to future work, you should weigh carefully the choices between (a) revealing some of your research plans prematurely and exposing them to rapid competitors and (b) in effect putting your intellectual stamp on concepts, which you will not be able to attack yourself in the near future.

"PLAY FROM THE OTHER SIDE" (like a hostile referee) while writing the paper

Now that the order of presentation is determined, the next thing to consider is how to do the actual writing. To reduce the amount of rewriting you will have to do, you need to pay close attention to what you are doing. When writing a paper you should be very critical about your work, your approach, your results and the way you are presenting them. The best way to do this is to do what we have repeatedly denoted by the phrase "Play from the other side". First, ask yourself all the time, how would you rate this paper if you were to review it as an anonymous and ruthless referee? Would it meet the standards of the journal where you wish to submit it? Would it have a fair chance of being accepted? You need to answer these questions honestly and objectively and then make the appropriate changes to your paper. It is even a good idea to pose the questions as they would be put by a hostile referee. As we have already remarked, many small points of clarification in a paper are actually inserted to forestall pointed questions by a referee. (In effect, you answer the question before it is asked.) Of course, being objective about your own work as if you were a referee is the tricky part here, but doing this is a lot easier if you have done some refereeing yourself.

Any of the scientists who have been even modestly successful will admit that their ability to write papers improved tremendously after the first few chores of difficult refereeing have been done. After that it is much easier to put on your "referee's hat" to see the flaws in your own work and in its presentation. For this reason you should be generous about acting as a referee; you will get as much benefit as the service you render to the journal and to the scientific community. (Besides, it looks good on your CV.) Thus, if you are a student or postdoc and your supervisor is doing a lot of refereeing, offer to help. Most will be grateful for the offer; but once you are experienced enough to contribute usefully, it is a good idea to make sure if feasible that it is you who sends the report in to the journal (or is at least given

credit to the journal for assistance) and thus gets added to their list of referees. (If you do a sufficiently good job of refereeing, you may eventually be asked to become an Editorial Board member or Associate Editor and this is a very useful addition to your CV.)

If you do this exercise of serious self-evaluation each time you write a paper, it will generally save you a lot of time and frustration later (and even more so for the toughest journals). A good paper has to be thought through exhaustively and should convince you more than 100% when you submit it. One measure of when you have done enough self-evaluation is how you feel when you contemplate another re-write. If you are exhausted and cannot stand the sight of it any more, you are probably incapable of improving it and further work may well make it worse[1]. At that point, you are definitely ready to submit, because it is unlikely that you can make any more useful contributions. As we have said above, another important piece of advice is to ask some colleagues (e.g. your mentor if you have one) to read the final manuscript critically for you before submission. (If you are good, enough terms you may do this even if you have had them look at an early draft. Do not wear your friends out!) This "internal" review is important, and since it is informal and usually constructive, it is likely to save you a lot of time and frustration. If you can, you should also try to have a final review by a friendly expert (for content) and by someone less than expert (for clarity).

When junior colleagues are first authors, one should try to have them produce at least the first draft of the paper; after all they will have to learn eventually, so you are not doing them a favor by doing too much of the "spade work". A strategy, which often works, is to sit down together and write the outline, and then send the student to write the paper from that. Of course, this approach will not be as efficient as if you wrote it all yourself, especially while they are learning, but a very important part of the education to which the student (or a post-doc) is entitled is some training in writing good papers.

CHECK THE BROWSING SEQUENCE: Title, abstract, introduction, conclusions and references

The remarks here apply to both a letter and to a full-length paper, since in terms of overall structure, there is not a huge basic difference between them, except in the length and the degree of detail. The sequence given in the title above is important because it gives the *browsing sequence*, by which we mean the sequence in which a paper is usually scanned by a browsing scientist to be flagged for possible detailed reading. Since a very busy scientist nowadays may not be able to go through the literature more than once or twice a month, and sometimes even less (sad, but all too true), to be flagged for reading your paper will have to elicit a "yes" at each browsing step or the browser will move on to the next paper.

In more detail, then, in browsing through journals, the reader will first skim through the titles. If the *title* attracts enough attention to warrant going further, the next step is to read the *abstract*, then the *introduction*, then the *conclusions*, and (perhaps) finally one checks the *references*. (The references are often checked before the body of the paper to see if you have cited the reader's work, and to see if your knowledge of the literature is adequate.) The body of the paper will only be attacked if these preliminary indications are promising enough to make the reader think that it is worthwhile. (However if there is a particularly striking *picture*, one that may "leap off the page" even for the casual browser, you should give it a chance to do its work by making sure that all the essential information is inside the frame of the picture and not buried in the caption or in a distant part of the text.) Although you are not writing your papers exclusively to captivate and please super–busy scientists, if you do not pass this browsing sequence of checkpoints, your paper will be read only by the small set of people who read everything on the particular topics they care about. You should want to do better than that.

The situation resembles that of a store window full of merchandise trying to lure a customer inside. This includes the name of the store and what it sells, any indication of a special sale, window displays, perhaps a display inside the store and finally the merchandise itself. Another way to look at is from the point of view of the literature browser. In effect, the title should answer the implicit question in the browser's mind for each component of the *browsing sequence*: "Should I stop to look at this paper in more detail?" Unless most of the *browsing sequence* "boxes" (*title, abstract, introduction, conclusions*) look as if they are ticked "yes", your paper may not be looked at further in depth.

The *first* lesson from all this is that, when you submit a paper for publication, you should make sure that the *title* you choose is appropriate and captivating. It should be as short as you can make it, since longer titles are somewhat of a turn–off. (A superb title for review of some work on how frogs' eyes automatically track motion was "What the Frog's Eye Tells the Frog's Brain." That is a title that is difficult to beat.) Remember that your title does not have to have too much detail, because that you can put into your abstract.

Your *abstract* should also be short, clearly written, and should contain the main points of your paper. Your *introduction* (really the first paragraph if you can manage it) should place your work in its proper context, and give a broad view of why this field is important, and where it is leading. It should not repeat information known to the reader from the title. Your *conclusions* are also important, because they may be the only thing most of your readers will remember. The *conclusions* may make the difference as to whether the paper is marked for a high-priority read, as something to come back to when there is more time, or is merely to be copied into a running bibliography for the next paper the browser may be writing. Ideally, the concluding / summary section as well as the actual conclusions, should also point to new perspectives and directions of research. Finally, of course, in the references, you should make sure that you are citing all the relevant literature, and if possible, even more. Remember, being generous in citing other people's work is very unlikely to do you any harm. (After all, some people may look at your paper simply to see "what it says about my work".)

Remember again that you are "telling a story". After reading your Introduction (and perhaps Methods section), the reader, if properly engaged now wants to come to the "juicy core" of your story. This is where your most important Figures come in. You need to "package" your data in well prepared, easy-to-read and captivating Figures. If your work revolves around some kind of microscopy technique, which produces colorful images that are easy to understand, you are obviously at an advantage with respect to someone who plots a graph that is not simple to read for a non-expert. Either way, you need to prepare those figures in the best possible way, then to tell your story around them. Many figures are crippled by the fact that some essential detail (such as usefully clear labels (not just A, B or C) for curves or objects) are hidden in the captions or buried in text, which is not right next to the Figure. Often this is done because it is "easy", such as coloring the curves and having no useful labels in the frame. A good figure is worst place to be lazy and the best place to add some showmanship.

Letters are so short that, paradoxically, they require a lot of re-writing to get it right and yet keep it compact. The actual effort can easily exceed that of a full-length paper where space requirements are not as restrictive. The tricky micro-decisions for letters are often whether or not to drop a detail because keeping it might mean compressing it to incomprehensibility. With full papers one can readily arrange to have dense patches for the expert and simple elucidating paragraphs to bring the less specialized reader up to speed on what is going on; doing this in a Letter is much harder.

Full papers should include all the follow-up details, figures, data and in-depth discussions

that cannot fit into a Letter. You have not really told the whole story until you publish the full paper, so it is something to be taken seriously at least once for each major line of research, rather than publishing many skimpy letters without the necessary follow-up details. There often is a separate section for Methods, for an exhaustive description of the experimental and/or theoretical methodology used to obtain the results. This is partly for those who just want to verify that you did it correctly, and partly for those who want to pay you the compliment of using your methods. (Of course, people who use your method(s) should provide more citations to your work for the bean counters who check these things.) Usually there is no page limit for a full paper (well, sometimes you may be asked to split it into two parts); this however should not be taken as an indication not to write concisely. There is no need for being as concise as to confuse the reader, however, it is important not to overdo compactness in a paper.

THE ORDER IN WHICH YOU WRITE

After this discussion on the structure, here are a few tips on the order in which you should write your manuscript (which is not the order in which the sections appear in the paper):

(i). The *introduction.* You should really start writing the introduction before you even start working on the project. This may sound unusual, nevertheless it is very important. When you choose (or are assigned a project), you should already know what is likely to be important and significant about it, what has been done before you begin the work and what you are setting out to do. This is essentially the real reason for your introduction, and, if you write it before starting the actual work, it can guide you later. (In effect, your initial summary, which is essentially, "Why I am doing this work", later becomes "Why you should read this paper".) This also means that you can already write down the essential bibliography of what the patent office would call "prior art". If your results eventually take you in a different direction, all you have to do is go back to rewrite a bit of the *introduction* once you have finished collecting all the data.

(ii). You should write the *methodology*, in extensive detail (to be edited and shortened later if needed) *while you are carrying out the project*. This is the best way to ensure that you record properly *all* your experimental and/or theoretical parameters, approaches and subtleties. It is easy to forget some details on the way to doing a project of several years, and writing this section up as you go will save you time and frustration later.

(iii). For the *results*, once your experiments and/or calculations are done, you need to thoroughly analyze and interpret your data, then package it into Figures in such a way as to *tell your story* around them (see discussion above). (Sometimes you may even find that there is something missing, and if you are prudent (and perhaps lucky), you may be able to fill this lack yourself. If not, address this as a topic for future work, but do not just sweep it under the rug or ignore it. You do not want to leave it for a hostile referee!) This section is called Results, or sometimes Results and Discussion depending on the journal guidelines. The results section is really, what you need to set the stage for discussing your pretty pictures. Remember to make the key figures leap off the page at the reader they are often your real crescendos.

(iv). After preparing the sections above you now write the *conclusions* and *perspectives*, then the *abstract* and, finally, the *title*. (After having done all this you may well have to re-write the *introduction*.) Recalling the discussion above, remember above all to write and structure all these elements of the paper in a captivating way, so as to draw the reader in.

(v). You then write the *acknowledgements* (see below), then the cover letter (further down below) and finally submit.

ACKNOWLEDGEMENTS

This section serves at minimum to express gratitude to all the funding sources that sponsored the work. (It can actually be useful, sometimes, to read the acknowledgements in other people's papers as they occasionally report new funding opportunities) This same section is where you also thank anyone who contributed something, which was not yet quite enough to be listed as an author. Both are a must. Funding agencies usually state clearly in their guidelines that their support must be acknowledged. The authorship / acknowledgement issue can be delicate because of potential ethical abuses. (It often happens that people who did not contribute much are listed as authors (perhaps for political/economic reasons), and it sometimes happens that people who contributed quite a lot find themselves slighted (in their opinion) because they are only thanked but do not appear as co-authors.) Welcome to the political process!

THE COVER LETTER

Once the publication is properly written and has been approved of by all co-authors, it is time to submit. While we have already discussed the general factors, which influence the choice of journal, to go further here, would require considerable detail for each field, so we leave this "as an exercise for the reader".

There is one crucial document, which must still be produced and sent: the cover letter. For most journals this is just a formality – a couple of paragraphs indicating who the authors are (including of course the corresponding author), what is the title and the text guaranteeing that the manuscript is being submitted on an exclusive basis.

However, this document should be taken a little more seriously for the medium-level journals and especially for upper-tier journals. In such cases it is important to describe why the authors are choosing this specific journal and to spend time to highlight the originality, significance and importance of the work itself. If the journal is one of the select few where this work is usually published (easily checked via the reference list), this should be emphasized. Very often the cover letter is the very first document that the editor reads upon opening your submission, and it may therefore play a very important role in determining its ultimate acceptance or rejection so its importance is not to be underestimated (For instance it may make it more difficult for the editor to use the response that "your work is not really suitable for our journal" or "we note that our journal is rarely cited in this work").

In addition to the basics just discussed, some journals encourage authors to suggest a list of possible reviewers[16] and this list is generally attached to the cover letter. Whenever possible, you should try to use this to your advantage, by suggesting people who are well known in the field and who are likely to provide a fair assessment of your work, but who, of course, are not among those with whom you have had a relation (collaboration or the like) which would provide a conflict of interest. (Since it based on your interactions with them to date; the choice can be a bit tricky, of course. As peer review is anonymous, you will probably never know if someone you think is fair and friendly may be unexpectedly severe in your absence.)

This is also the document in which you may request the exclusion of specific reviewers whom you think might have a specific conflict of interest (such as being in direct competition) in assessing your work. In general you do not have to be very detailed here, since the editor really does not want to know the details and is in any case very unlikely to overrule your expressed wishes in this context.

REVIEW ARTICLES

While at the outset of one's career one is very unlikely to be asked to provide a review article, eventually that day may well come. Invitations to write reviews are usually issued to senior scientists who have an established reputation in

the field. These people are however usually very busy, so they often turn down such invitations or ask their younger collaborators to co-author the review with them. This state of affairs often opens opportunities for younger scientists to write or at least participate in writing a review, if only to compile and organize the list of references. If a review is done properly this is an excellent scientific exercise which will make you intimately familiar with the literature and hopefully draw attention to your ideas and perspectives as well as attract many citations. In addition, if you have a good idea for a review article you can always write a proposal and submit it to an editor, hoping that they will agree for you to write the review.

A good review article should of course give a broad overview of a field, or at least part of a field. Shorter review articles are often referred to as Feature Articles or Mini Reviews. Normally a review does not contain original results, however it reports an original viewpoint on the main discoveries of the field and where it is heading (or should be heading) according to its authors. If done well, it is a fairly monumental task, and a useful contribution to the literature and may hence garner a respectable number of citations. It is best pursued, in our view, coupled with writing another significant piece of work such as a PhD dissertation or a grant proposal so as to take advantage of the common bibliography, introductory paragraphs and several discussions. (Not many of us can expect to follow the illustrious example of Nobel Laureate astrophysicist Subrahmanyan Chandrasekhar as recalled in a special number of *Physics Today* (December 2010, pp 38 – 53. He would make titanic contributions in a field for a few years, write a landmark monograph book and then go on to something else, repeating whole cycle eight times in his life! The first cycle was the one for which the Nobel prize was awarded.)

A review should not be simply a list of what has been done presumably in a usefully organized manner (although many bad ones do merely that), but rather should help draw broader conclusions by comparing and cross-referencing the key results of the literature, trying to point the reader towards new directions and opportunities. This last is never easy and usually requires considerable experience (more than you are likely to have in the early years). However as a junior author, the discussions on this with the senior author may be invaluable (particularly the undiplomatic parts, which may well, not make the final cut).

HIGHLIGHTS AND PERSPECTIVES

Some journals (e.g. *Science*, *Nature* journals, *Small*, *Angewandte Chemie*, etc.) also publish fairly short commentary papers whose purpose is to highlight an emerging new field. These are usually called “Highlights”, or “Perspectives” and are only a few pages in length. In some sense they are like mini-reviews, since they describe the key results and future potential of an emerging field where little has been published so far. They are usually written upon invitation from the editor, however if you have a good idea on a Highlight you can always propose it to the editor in the form of a synopsis and hope that they will consider it for publication.

In some cases the “Perspective” is a direct (positive) comment intended to highlight another paper that appears in the same issue of the journal, which was chosen by the editorial team for the spotlight. The author of this Perspective, in most instances, is one of the referees of the journal itself who participated in reviewing said paper. For the two papers to come out together in the same issue/volume, the timing has to be perfect. Therefore, from the point of view of editor it makes sense to ask one of the referees of the manuscript (who should be a well known and respected scientist in the same field) to write the Perspective as this person is already intimately familiar with the paper itself and is in a unique position to describe its importance to the community.

RESPONDING TO REFEREES.

Several weeks after submission (hopefully weeks rather than months although this can happen too!) you will receive a message from the editor with an acceptance or rejection notice, also including comments from one or more referees (see our previous article on the peer review system). In a good majority of cases, the referees will request some revision, either minor (if you are lucky and have done a good job to begin with) or major. In some cases they will recommend outright rejection (in which case you are unlikely to win publication), but more often you will get mixed reviews (often the case when you receive two or three reports) with comments and requests that might even to some extent contradict each other. At this point then you can either withdraw your paper (if it is rejected you do not really need to formally withdraw) and submit it elsewhere or revise it and prepare a response to the referees.

Responding to negative comments from referees is a delicate matter, especially when their comments were not only substantially negative but also somewhat hostile. If the comments are entirely hostile it is actually possible to discredit the referee in the eyes of the editor by diplomatically pointing it out in a separate letter, and asking to have an additional opinion by a different referee. If the hostility is more veiled, it is much harder to respond effectively.

The best response in any case should always be cool and diplomatic, avoiding vehemence, which may become shrillness. One should freely acknowledge any valid points the referee has made (even going so far as to thank the referee for the help in improving the paper) and show that you are making an effort to improve your manuscript based on his/her comments, yet still defending your ideas where this is required. An ultimate tactic for specific points of disagreement is to summarize both positions and leave it to the reader to judge. (This has the advantage of getting your point of view into print in spite of the referee, and of making you look very fair-minded, yet confident, in leaving the final judgment to history.)

We cannot say too often that if the referee proves obdurate, you should maintain a polite tone always. If the editor thinks that you are being reasonable and conciliatory and the referee a little shrill, you may well win in the end. (After all, the final decision is the editor's, the referees being really advisors, without the direct powers of actual judges.) In the same vein, if the referee says something particularly unpleasant, the very best advice is to not fire off a joyously hostile response in the heat of the moment. Do nothing at all for several days and let yourself cool down. Heated answers will never help. Have an arms-length colleague look at your response for excesses before you sent it in. If this is done properly, the editor might in the end side with you as an open-minded and reasonable person (perhaps being afflicted by a vociferous extremist), and either invite an additional reviewer or just discard the negative reviewer's views.

COMMENTS AND REPLIES.

Certain journals make space for a comment-rebuttal exchange on previously published papers. These consist of a "Comment" on the original paper from some critics, usually followed by a "Reply" from the authors of the original paper, who usually wish to defend their viewpoint. Comments and Replies can be useful additions to the literature, especially if they are constructive and bring new insights. It is wise to write both of them diplomatically rather than use a confrontational tone because typical readers will not be interested in a petty dispute – they will want to learn something new. Writing a Comment once in a while is a useful exercise, however we encourage you to take this initiative with caution. (It is more likely to win you enemies rather than friends. Tudor: 'As an exception to this, one of my longest collaborations arose from a Comment and Reply, which led to a useful new result.')

BOOK CHAPTERS AND BOOKS.

Publishers nowadays are continuously on the hunt to sign up scientists for the arduous task of

writing a book (especially on new "hot" topics). One of us (Tudor) has co-authored a very successful book on Plasma Physics a while back. The other (Federico) has been frequently solicited to write books on "Nano" (broadly speaking) by a number of publishers and has (so far) resisted the temptation. (Tudor: 'This sort of thing is much better done with two authors, each of whom is prepared to take on the work when the other is temporarily saturated with the effort of the detailed corrections and re-writing. However increasing the number of authors may bring one into the domain of the instabilities of games with more than two players.')

Writing a book (including Survival Skills for Scientists, which we co-authored and which turned out to be a great success) is a monumental task, which takes up a huge amount of time, energy and effort. While it may be financially justified in certain cases (for example if you are the main instructor of a large undergraduate course and there is no adequate textbook to cover the course's material) it is usually not worth the effort it requires. It rarely brings much "glory" (in the form of scientific impact, e.g. citations) and usually does not yield a substantial financial return either. (The exception being a book for a large undergraduate course, in which case, if there is no credible alternative, you might actually make a lot of money from it.)

Writing book chapters represents a similar endeavor, although the effort is much smaller and thus may be justified on occasion. Similarly to the exercise of writing a book, it is to be considered as a service to the community. In some ways it is akin to writing a review article, although the purpose of the book and its book chapters will be mostly educational, whereas the audience and readership of review articles consists mostly of your peers.

Forthcoming article in this series.

The next article in this series will deal specifically with how to give an oral presentation (including short conference talks, poster presentations, invited talks, plenary talks, as well as departmental seminars and colloquia and even public lectures).

ACKNOWLEDGEMENTS

F.R. is grateful to the Canada Research Chairs program for partial salary support. F.R. also acknowledges the Institute for Advanced Studies of the University of Western Australia for support through a Senior Gledden Visiting Fellowship (2009) and a Professor At Large award (2010, 2011) which made it possible to organize the "Survival Skills" Workshop at UWA in May 2009 and October 2010 and the Masterclass on "Writing Compelling Science Papers" in May 2010. F.R. thanks Professors Jason DeJong (University of California, Davis) and Kevin Plaxco (University of California, Santa Barbara) for helpful discussions and for sharing their group's guidelines on how to write a paper.

REFERENCES

1. F. Rosei, T.W. Johnston, *Survival Skills for Scientists*. Imperial College Press (July 2006).
2. G.W. Whitesides, *Adv. Mater*. **16**, 1375 (2004).
3. F. Rosei and T.W. Johnston, *J. Mater. Ed*. **32**, 163 (2010).
4. For those who are not yet familiar with these terms, this means literature for which publication is obtained only through the filter of judgement by their peers in research science (usually through an anonymous review process).
5. B.H. Thyer, Successful Publishing in Scholarly Journals (Sage Publications Inc., 1994).
6. K.W. Plaxco, The art of writing science, Protein Science 19, 2261 (2010).
7. J. Longuski, The Seven Secrets of How to

Think Like a Rocket Scientist. Copernicus Books, New York 2007.

8. P.J. Feibelman, A Ph.D. Is Not Enough: A Guide to Survival in Science (Perseus Publishing 1993).
9. C.J. Sindermann, Winning the games scientists play (Perseus Publishing 2001).
10. G. Schatz, Jeff's View on science and scientists (Elsevier 2006).
11. J.T. Yang, An Outline of Scientific Writing (World Scientific 1995).
12. F. Rosei, A. Pignolet, T.W. Johnston, *J. Mater. Ed*. **31**, 65 (2009).
13. F. Rosei, T.W. Johnston, *J. Mater. Ed.* **31**, 293 (2009).
14. R. Rhodes, *How to Write, Quill*, William Morrow, New York (1995).
15. E. Garfield, New tools for navigating the Materials Science literature, *J. Mater. Ed.* **16**, 327 (1994).
16. D. Grimm, Peer review: Suggesting or Excluding reviewers can help get your paper published, *Science* **309**, 1974 (2005).

This page intentionally left blank