HOW TO 'SURVIVE' AFTER GRADUATING IN MATERIALS SCIENCE VI: HOW TO WRITE WINNING PROPOSALS

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HOW TO 'SURVIVE' AFTER GRADUATING IN MATERIALS SCIENCE VI: HOW TO WRITE WINNING PROPOSALS

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ABSTRACT

This article describes our views and advice on how to write winning grant proposals. Hereafter we will discuss the most basic strategies for getting your science funded, starting from fellowships as salary support for junior scientists to grants for faculty members and staff scientists in national laboratories. Besides the 'technical' or 'nuts-and-bolts' aspects of writing projects, we emphasize yet again the fundamental concept that we developed in previous articles, namely: since anything that counts is peer reviewed, *learn to play from the other side.* We therefore advise the reader to place him/herself in the mindset of those who are going to evaluate their written ideas to anticipate their reactions and forestall objections. In terms of context, we also remind the reader that this article is the sixth 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), the third (in which we described the Peer Review System and how it is used as a form of quality control in modern science), the fourth article (in which we gave tips on how to write compelling papers) and the fifth (in which we describe our views on how to give good oral presentations).

INTRODUCTION

After discussing the broad issues of "scientific survival" [1,2] (first developed through a graduate course and then published as a book), followed by more detailed suggestions on how to get a job [3], the intricacies of the peer review system [4], how to write a paper [5] and how to give a talk [6], we now discuss at length how to write a winning proposal [7]. Other points of view on these concepts can be found elsewhere [8,9,10,11,12].

When you begin your evolution towards becoming a more or less independent scientist, in the early years you focus on the work and someone else worries about securing funds to do the work. Since "He who pays the piper calls the tune", the person who has to be convinced

so that you can pursue a given line of research is the one who is "paying the piper" and often this is done quite informally, without even the ritual of a handshake. The skill that you need to develop is how to deal with this person. A useful image is that of a bird in a nest, where the food for the nestlings is brought to the nest by the parents and the essential skill for the nestling is how to convince the parent bird to feed that nestling rather than the competing siblings. Upon leaving the nest the young bird has to become an independent forager and new foraging skills must be rapidly acquired. A useful read to that effect is "Managing Your Boss", a classic from the Harvard Business Review[13] which gives valuable advice on how to appreciate the pressures faced by your boss and help him achieve his objectives.

If you are working in an industrial laboratory, in effect you are remaining in a nest, since the management will generally provide the money you need to do your research. In exchange it will also tell you which projects to tackle, or in other words that money that comes in, comes with strings already attached. For those with a bent for original research, very few industrial laboratories still offer the possibility to carry out basic research at competitive levels, whereas this was not so uncommon thirty or so years ago. Clearly, to accept these restrictions rather than the different ones of an academic life is a choice you make on your own in advance.

Since in "*A Ph.D. is not enough*" [14], Peter Feibelman has already described so eloquently the advantages and disadvantages of working in a *managed* research environment (e.g. industrial or government laboratory), we will not go over the same aspects here. However we do still remark that it is best to decide early on whether the life in an industrial or government suits you, because making a later transition to the life of an independent academic researcher is difficult unless your industrial work has already made you a potential "star" in academia. It is however true that in industry there may be some work which is supported by external funds, in which case you may well be called on to play a role in

the preparation of these grant proposals. Although the procedure varies too much from one research environment to another to discuss the details, the material below on applying for research grants may therefore be of some use even out of academia. Since we suspect that most people who are reading this will probably have opted for the freedom of working in an academic setting, we will from here on concentrate on the aspect of applying for financial support from an academic environment.

Common elements between fellowships and grants.

In the world of academic research, while you are developing your basic research skills, you should also begin to learn how to fund your research by applying for money from various sources in the form of written applications[15]. The sooner you learn how to do this effectively, the better. All scientists compete for access to three essential "items": funds, space and people. For obvious reasons though, without funds you will not be able to secure space nor to have people work with you.

Until you have some faculty standing or the equivalent, you will usually not be eligible to apply for research grants yourself. However, if you are lucky (or have made yourself explicitly available) you may be asked by your supervisor to write some paragraphs for a grant proposal in which the supervisor is involved. If ever such an opportunity comes your way, you should seize it enthusiastically. It is an excellent way of seeing how the process works and the experience will be useful when you will be applying for your own grants.

Even when you are not yet eligible to apply for research support directly, what you can often do officially is apply for some sort of *fellowship* to support yourself as a scholar. If you can get a Fellowship or two early in your career, when you apply to become a junior professor later on, you will have already established a track record for a possible academic employer showing willingness and perhaps some success in

securing external funds and the practice will make applying for grants somewhat easier. It will certainly give you an edge on competitors who either did not take the trouble to apply for a Fellowship, or were not good enough to receive Fellowships.

Since many aspects of writing a Fellowship application are very similar to the similar aspects in applying for a Research grant, it is convenient to discuss these common elements together. After all, in both cases you are trying to convince a funding agency to give you money to do something that you believe is scientifically important and which you can credibly pursue on the basis of your skills and expertise.

The first rule is to start far earlier than you might think necessary. To begin with, you should naturally start early to give yourself enough time to do a good job and give yourself enough time to present a well-polished proposal. Early in their career most people will significantly underestimate (often by factors of two or three) the time needed for preparing any submission, be it for theses, grant applications, fellowship applications, reports or the like. Ideally, you should write the whole thing out, beginning, say, some two months before the submission deadline and then put the whole thing in a drawer to "cool off" for a week or so (be aware that most universities have an internal deadline at least one week before the official deadline from the funding agency). Then pull it out, read it with a cool and skeptical eye to give it that final polish, run it past a colleague or two and then send it off in plenty of time. Well before even this early date it is necessary to allow sufficient time to gain access to all the relevant information (guide-lines, deadlines etc.). Only then will you be able to plan accurately how to write the proposal and to avoid unpleasant surprises. Following this advice will give you a considerable edge over many of your competitors and thus give you a better chance to succeed. Also spreading out the work in time means avoiding the stress of feverish writing and collating at last minute

"under the gun" and so diminish the overall stress of the whole effort.

As remarked above, the first funding opportunity for a student or post-doctoral associate is a fellowship from some granting agency, so such an application may well be your first. Although most fellowships will only cover your own salary[1]; they nonetheless offer at least two basic advantages:

First, since your supervisor now does not have to cover your salary, more money will be available for your project and to cover other expenses. It is also possible that a generous advisor may actually increase or supplement your salary and use the rest to send you to more conferences and do more things. Thus both you and your advisor will be happier and more productive overall.

Second, if you have a fellowship in hand, you can often pretty much choose where to go to work, as compared with the common case where you are depending on someone else to cover all your expenses including your salary, which means that your choices will naturally be severely limited. (This aspect may not, however, apply to your particular case, since many funding agencies ask you to specify where you are to go at the time of application and they may not offer the possibility to change destinations later. You should be careful to verify just how portable your fellowship will be if you succeed in obtaining it.) Of course, even if your employer chooses to accept you without knowing at the time whether you are bringing a Fellowship with you, if the Fellowship is later accorded, you will have your employer's respect and gratitude and are likely to be tangibly rewarded by the employer. It is therefore always an asset in your application to be able to state that you have applied for Fellowship support. At least it shows initiative and consideration for the position of your potential employer.

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[1]There are a few exceptions, including the following: (i) Marie Curie Individual Fellowships offered by the European Union, which also offer a small travel budget; (ii) NATO fellowships offer relocation benefits; (iii) Humboldt fellowships offer various benefits.

All this said, sometimes unfortunately, the timing will just not work out. Most funding agencies accept applications for fellowships only once or twice per year and this coarse timing may not coincide with your personal schedule in looking for a job. There is no simple way around this, except to emphasize that, for any application, whether for Fellowships or Grants, you should always be well aware of the relevant deadlines, and should do as much advance planning as possible so as to avoid unpleasant situations later on.

One of the tricky aspects of obtaining a fellowship is gaining the necessary knowledge about the scholarship programs that are offered, their deadlines, and finding out if you are eligible. Federico: as a graduate student, I spent a significant amount of time looking into such opportunities. Without any specific guidance, it was already clear that fellowships = opportunities in a scientist's early career.

In today's modern, global world, it is not very difficult to find this type of information. A lot of it is contained in ads that are listed in monthly publications, like Nature, Science, Physics World, Physics Today, Materials Research Bulletin, Chemical and Engineering News and so on (scientists from other disciplines will hopefully excuse us for not knowing the equivalent publications in their fields). Information on other programs can be found for example by browsing the internet, or through personal connections. Even after the student/postdoctoral phase it is worth spending a significant fraction of your time performing these searches, not because they will be of immediate use to you, but because this might be useful to your students or to someone else you might know.

Applications for either a Fellowship or for a general-purpose Grant have sections that resemble each other greatly, in that you will have to describe the salient features of your research, either since you began or over some period specified in the Grant Application rules. You will usually be asked for a summary of your best work and its impact. You will also be required to describe a research plan of some sort. It helps a great deal for all this if you have a well-developed CV with such elements, especially if you up-date it regularly. It is a matter for reflective judgment just how much "hype" you should put into the description of your work and plans. Too much and you appear as a callow, shrill and insecure salesperson for your science, too little and you may appear not to have a high opinion of your own work. Here is where consultation with a mentor or a trusted colleague can be extremely valuable. We discuss Fellowships first, then Grants, since that is the likely order for you to be encountering them, at least on your own behalf.

FELLOWSHIPS

A small fraction of the top students and post-doctoral fellows may receive direct personal funding in the form of a fellowship, or scholarship; in other words the funds are awarded directly to the person, rather than the advisor. This funding usually covers most or all of the person's salary and sometimes also some extras for travel and perhaps supplies for experimental laboratory projects.

Since they afford considerable independence, the competition for such fellowships tends to be severe, and usually only the top students and post-docs are able to win them. Salaries awarded through fellowships are often more generous than the ones offered by supervisors from their research grants, partly because they are meant to reward the very best to advertise that aspect. This is another reason why they are sought after so much. Also, long after the Fellowship money is gone, the presence of the "Prestigious Name" Fellowship in your CV is a permanent benefit.

When you apply for your first fellowship as a student, for example for an M.Sc. or Ph.D. scholarship, since your experience in research is usually limited, a great importance and weight are given to your academic performance, i.e. your grades. At later stages in your career other criteria (e.g. your publication record) become

dominant. Typically you are also expected to supply a (fairly detailed) project in your application. Since you will usually not have the necessary research funds under your control, in most cases you will have to 'negotiate' this project with a prospective supervisor, in view of the current overall research program and agree on a compatible research program.

Now, applying for a fellowship may well represent your very first contact with a funding agency. As such, if successful, it will help you build your track record with respect to funding and is therefore to be considered as an important and very useful exercise. As you will find later when you come to apply for other research project support, the basic rules are still those that we have put forward here: (1) apply in good time, (2) apply often, (3) keep on applying and (4) don't become despondent when you are rejected (it happens to all of us). At this point one should recall the well-known Grook of Piet Hein (a Dane who has written a lot in English, but who is not as widely known as he should be):

THE ROAD TO WISDOM

Well, it's plain and simple to express:
Err and err and err again,
but less and less and less.

Your lack of success is not a matter of public record, so remember that after a rejection, it is really only your bruised ego that requires toughening. As in any sport the ball won't go in the goal if you don't shoot, and it takes many shots to get one goal. You must learn that this heartache of a rejection is part of the "cost of doing business" (at least until you get your Nobel prize).

GRANT APPLICATIONS.

As remarked above (and is nonetheless being repeated here once more to emphasize the importance of this point), give yourself adequate time to prepare your Grant Application. Also, sometimes you will need collaborators (likely from other universities,

research laboratories and industry). This may require approvals from the hierarchy in those other institutions and may take even more precious time. All this is much easier to accomplish if there is not undue time pressure.

Contrary to most young scientists' expectations (a lot of people just consider it a boring exercise), writing the science part of a Grant Application (the part that is most fun to do) is not enormously different from writing a scientific article, except that the particular packaging and arrangement is that required by the granting agency. (Pay close attention to their rules on format and the like!) The main difference, in general, is that when you write the article or abstract or summary, you already know the results, while in the grant you are indicating what you hope they will be (in some cases you might have sufficient preliminary results that you are not predicting or hoping much, in fact).

One of the things that you must remember for a Grant Application is that it will of course be looked at by experts (essentially referees) who will either write reports or be members of the evaluation committee. It is clearly vital that these experts be convinced and all the important points must be clearly and concisely made for these experts, naturally without insulting their intelligence. However, as remarked above, you should also remember that there will usually be on the committee some quasi-experts, people who have some knowledge of the field, but not an expert's knowledge. (They are, however, probably the experts in other fields being considered by the committee.) It is very important to convince these people as well (remember that in the committee they likely outnumber the actual experts in your field) by summarizing the important stuff to them, usually in a carefully crafted summary sentence or two. These must be of exemplary clarity, and usually appear at one end or the other of the most technical sections. (It is quite permissible to use cunning phrases to set these sentences apart, phrases such as, "in non-scientific terms one can say" or "a popular version of the foregoing might be".) The impression that you

would like to leave with these readers is that they pretty well figured it out all on their own, without their being too aware of the subtle help you are providing. If this is done well enough, these readers will almost begin to feel as if they really understand the essential points on their own, as if they invented (or "would have invented") the basic concept themselves. This pseudo-glow of discovery will favor their opinion of the project. If you succeed they will become your partisans as a result.

Often you will also be asked for a popular summary, perhaps for a possible press release. Your chances of ever seeing this as a press release are of course very slight, but you should nonetheless seize the opportunity to explain to the same quasi-experts the overall thrust of what you are doing with a minimum of jargon. If you can be clear here then the reader will be more inclined to give you the benefit of the doubt on the more complex stuff. The point is that in this popular summary you are taking advantage of the fact that you will not be viewed as talking down to the committee (whom you do not want to offend) but in effect around them to the public. This effort will stand you in good stead in other circumstances, when you have to explain what you are doing in a very limited time on other occasions (for example to inexpert visitors).

There is a dilemma which often occurs in deciding how to present the project's chance of success. Although the funding agency's aim is to invest the taxpayer's money on the best projects, it is really not very reasonable for them to expect (as they seem to do) that scientists will actually discover *exactly* what they propose to do in their grant proposals. After all, scientific *research* (as opposed to *development*) is about doing something really *new*. When you set out on a new project, to some extent you actually expect and hope to be surprised, and in many ways you welcome the unexpected. If you already knew what you are going to discover, it would hardly be research at all! (In development work on the other hand you are trying to do something better or faster or more cheaply than it has been done before,

so the doubt is not whether it can be done but whether it is advantageous to do it the way that you propose.)

You may well be asked to outline the prospects of success, i.e., as a result of success here what might be now done better in other contexts, or even what may be done for the first time. Even if this is not specifically asked for, it is a good idea to devote a final sentence or two to the glorious prospects when and if success is attained. In the same vein one should not be shy about spelling out what may be done if the essential research project goals are obtained before the end of the funding period.

In this connection, if you have been considering the future, it is not uncommon for an experienced researcher to know at least some of the desired results already (perhaps via some preliminary unpublished results) even when writing a grant proposal on a topic that is supposedly new. Neils Bohr once remarked that "Prediction is difficult, especially about the future." However there is a way to reduce the risk of prediction somewhat. If you can do it, it is an excellent strategy for a sufficiently productive scientist not to publish all the results immediately, but to keep some (good) results in the drawer. If you are in this happy position, when you come to write your next big grant proposal, you can then describe with reasonable certainty some useful fraction of what is going to happen, and you can even produce some preliminary results (in effect looking at them in your desk drawer), to give the impression that what you are proposing is promising and feasible. That way it will be much easier to obtain the grant, since your proposal will look more convincing and realistic. (Of course it will also be much easier to report on it once you are finished.) You must, however, be careful and emphasize that what you are proposing is "new" (by which you mean that it has never been reported before). At the same time, you must make sure that nobody is competing on the same topic, because you certainly do not want to be actually scooped by someone else on results that you have already but are holding in reserve. Most scientists early in their career

tend to feel, however, that they must put it all "in the shop window" to make the best paper immediately. This strategy of keeping something in hand for the next proposal is thus unlikely to be useful early in one's career.

Many funding agencies also ask you to describe what are the "benefits" or "added value" to your country, should the project be funded. This can be a tricky section, depending on the research climate in which the funding agency is operating. When funds are tight governments tend to look for quick payoffs, leaning towards more applied research (on the grounds that basic research does not carry enough "added value", or return on investment on the time scale relevant to a politician's re-election). This section may thus prove to be the most difficult one in the grant, especially if you are setting out to do something fundamental rather than applied. There is no easy way out of problem, and what can be said here should be taken very seriously and will require your best thought, even if you do not address this aspect directly. You must find the right balance between "promising the moon" and being demolished by experts who know better. Discuss your ideas with some colleagues and try to be creative. If there are only long-term benefits, be honest about it. In academic research, the most tangible benefit of a given project is usually its contribution to the training of "highly qualified personnel", who are then expected to join the workforce and make a difference with the specialized training they have received. Emphasizing this aspect is always a good idea.

The funding agency to whom you are applying will usually ask you to report on your results periodically and often (for a project grant that is not continued for many years) a final report on how you spent the taxpayer's money at the end of your grant. A successful grant application has usually offered a road map for the research and what will be required in a report is how the journey went, how far you progressed, and any extra unlooked-for windfalls. Many funding agencies are flexible, but even they are usually

happier if you tell them that you managed to do what you had envisaged or promised in your original proposal (in fact, paradoxically, some funding agencies are not flexible at all).

What, how and why?

A good proposal should address three important questions, namely **what** research will be done it, **how** will it be carried out and **why** should it be done? Usually most projects adequately address the first two (**what** and **how**), which are somewhat easy, however, most applicants come short of answering the why. This is also often seen in job interviews, when asking candidates for faculty positions to describe their proposed research program. The **why** is crucial because it serves to demonstrate the originality and novelty of the ideas. Since this is a frequent weakness exhibited by a great majority of applicants, we suggest to devote significant time and effort to this aspect, as it can often make the difference between boosting or undermining the chances for success.

Two types of proposal "philosophies": emphasis on the project or emphasis on the track record.

By and large, funding agencies rely on two different proposal philosophies. In one case, the emphasis is on the project, i.e. funding the best ideas with potential for the highest impact. The National Science Foundation in the USA would fall under this category. In the other case, significant weighting is given to the track record of the applicant(s), which counts for at least as much, if not more, than the proposal itself. The Australian Research Council in Australia and the Natural Sciences and Engineering Research Council of Canada fall under this second category. All in all, both philosophies have merits and disadvantages and require superior writing skills. These aspects, whenever possible, should be taken into account when deciding which country or research system best suits your views and abilities.

CONCLUSIONS

Writing a winning grant proposal is becoming significantly more difficult, due to reduced available funding which in turn leads to lower success rates. We advise to plan for a project and start writing it well before the deadline; to emphasize the novelty and originality of the ideas behind the proposal; and to have colleagues review it internally and provide constructive criticism before submission, so as to forestall potential objections from referees (play chess!).

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