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Introduction

One does not need to be terrifically brainy to be a good scientist.
Most people who are in fact scientists could easily have been something else instead.

Long gone are the days when learned gentlemen (and they were almost exclusively men) of science pondered the natural and physical world around them, and discussed the latest discoveries and inventions, often over dinner and a glass of fine wine. Even fifty years ago, science seemed a rather gentler activity than it is today. Then it seems, there was time to take tea and linger in discussions on fascinating topics. Compare this to the frenzied world of research today. In the twenty-first century we not only have to conduct successful, competitive research, but also fund it, publish it, talk about it (often to the public as well as to colleagues), patent it and exploit it – and all this while juggling the pressures of teaching and an ever-growing burden of administration. Anyone who really knows about research could be forgiven for feeling that it's a tough life for scientists – yet those outside still think we take eight week summer vacations!

Of course our 'rose-tinted view' of the scientific past ignores the struggles and challenges facing our scientific forefathers; and science offers the same, and perhaps even greater, challenges and excitement as it always did. Nevertheless, scientists now need a range of new skills, and they need to learn them quickly in order to be successful. Many universities provide courses for graduate students on communication and presentation skills, publishing, obtaining grants and fellowships, ethics and the many other aspects of research. But all too often such courses are squeezed out by the pressures of experimental work or writing a thesis, or are presented at a time when their relevance is not obvious. Even more sadly, many young scientists still have no such training, and the busy schedules of their advisors and mentors means they must acquire the skills of the trade 'by association' – or learn the hard way, by making mistakes. As you move up the career ladder, formal training is less obvious. The new faculty member is faced with the daunting task of applying for their first grant, supervising a group, training young scientists and teaching – each requiring a range of new skills and posing a set of new problems. In the past, such training was provided by 'the mentor' or supervisor, and was comparable to an apprenticeship. Today supervisors and mentors may be separate people. Supervisors have a formal position of directing research, whereas mentors may be an independent colleague who simply provides advice. If you are lucky enough to find a talented and experienced mentor, be grateful and attentive; you can learn more from them than from any book. Sadly now, few senior scientists have the time they would like to spend on either supervising or mentoring their younger charges.

This book cannot (and does not attempt to) cover all of the many issues scientists may have to deal with, nor does it offer solutions to the problems they will face. Hopefully, it may offer some practical advice on the major aspects of scientific life, which are now essential for a successful career.

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Starting out in research

> A novice must stick it out until he discovers whether the rewards and compensation of scientific life are for him commensurate with the disappointments and the toil.

All too often the choice of a scientific career or the decision to take a higher research degree is based on default. Perhaps you have a good Bachelor's or Master's degree, and you found the degree course reasonably enjoyable. After much deliberation, you still have no clear idea of the career you should pursue. Your friends are planning a Ph.D., you have the qualifications and your mentor may be quite persuasive (particularly if the department has to fill its quota award of studentships), so a Ph.D. seems like a reasonable option. The prospects of poor pay, a few horror stories of long hours and the possibility of many months with no results may dampen your enthusiasm, but in the absence of a suitable alternative, a higher degree seems a reasonable, or even an attractive option.

This is clearly not the best way to enter research, which is at best demanding, but rewarding, and at worst demoralising and unrewarding. Nevertheless, some who take this step with little commitment are still 'caught by the bug' and go on to be very successful scientists. Even the many who complete their Ph.D., but decide that research is not the career for them, should have benefited from the breadth and depth of training they receive and skills they acquire – even though they may not recognise it at the time.

Hopefully, many who undertake a Ph.D. do so because they believe that they *want* to do research, and perhaps go on to a career in some aspect of science. Even this is not an easy choice. Undergraduate projects, constrained by time and money, usually aim to teach practical skills and knowledge of the subject, and therefore give little real insight into what research is like. Some people have the fortune and foresight to take summer jobs in labs or spend a year working in a lab, and an increasing number of undergraduate courses now offer a year out working in a lab in industry or academia during the degree. These experiences are invaluable. They can help you decide if you really want to do research (or equally importantly if you do not), and are a huge bonus on your CV when applying for either a higher degree or a job – of any description.

Many universities now offer 'pre-Ph.D. courses', either as an obligatory foundation year of Ph.D. study which is very common in countries such as the USA, the DEA in France, the M.Sc. which combines lectures with a research project, or the more recently developed Master of Research (MRes) now offered by some UK universities. Each of these varies somewhat in the research training available, depending on the university and the nature of the course, but for those uncertain about undertaking a Ph.D., can be invaluable in helping to clinch the decision one way or the other. It will also provide an excellent grounding in research.

Those who go on to study for a Ph.D. are sometimes surprised that, having obtained satisfactory results during their B.Sc. or Master's projects (which may even have contributed to a publication), they struggle for many months with their Ph.D. project. This mainly reflects the very different nature of short-term projects undertaken during Bachelor's or Master's degrees, which, if the supervisor is skilled, will be designed to yield data and will often form part of a larger, ongoing project. The difference when you get to a Ph.D. is, or at least should be, that you will be tackling a much 'bigger' project (i.e. a significant scientific question) and one that will be yours. If your Ph.D. project addresses an important and novel project (which is after all what research is *really* about), it may take many months of developing methods and protocols, optimising conditions, frustrating times of dead-ends and failures. This is disheartening, especially if you have tasted some success in a smaller project. But when you do get a positive result, or perhaps even a major finding, it will (hopefully) all be worthwhile. If you are not elated by getting *that result* – and knowing that you are probably the first person to see it – then research is almost certainly not for you. The more time and effort you put in, the greater the reward when you see the data for the first time. Then you can start to build on the findings, present them to others in your lab, department and the wider scientific community, and hopefully see your name in print – knowing that the work is yours rather than just a contribution you have made to someone else's project. These real highs and lows of research are rarely experienced in short-term projects.

CHOOSING WHICH PH.D.

For many aspiring young scientists, success and enthusiasm are dependent not so much on the project they choose, but on where and with whom they work. Students all too often select their area of research on the basis of an undergraduate project or dissertation which they have particularly enjoyed. You may have strong preferences for certain areas of research (or dislike of others), but these are often based on the skills and enthusiasm of a tutor or teacher rather than on an intrinsic interest in, or on the importance of a specific subject area. Such choices can become ever-more limited with movement up the career structure, and lead to a growing reluctance to leave an area of expertise. It is sometimes unfortunate that a single, short research project can dictate the whole scientific career of the rather narrow-minded or ill-advised young scientist.

In reality, the subject area should not matter that much (within a broad subject area of science such as biology or chemistry or physics). The decision of what project to work on (at any stage in a scientist's career) should be based on whether the project is an important one: i.e. does it address interesting and important questions rather than somewhat trivial ones; does it aim to *understand* or *simply* describe scientific phenomena (the latter are often referred to rather disparagingly as 'stamp collecting', but of course have value); and, importantly, is it feasible? Some of the most exciting projects are *unfortunately* intractable – they are simply too complicated to be solved. This may be obvious even at the outset. If so, they should be avoided. Perhaps the most important way to select a good Ph.D. project is to find the right supervisor, university and department.

LOCATION

As with buying a home, the decision of which Ph.D. project is very dependent on location. Mobility and varied experience are very important in research training and careers. It is quite acceptable to stay in the same institution for an undergraduate and post-graduate degree (provided of course that it is respected and well-resourced), but if this is the case the next stage (see Chapter 7) should really involve geographical movement (if possible abroad). However, personal constraints on movement (such as family commitments) are recognised and taken into account in later appointments. In choosing a university or research institution and department, several factors need to be taken into account, but perhaps most importantly those of reputation and standing in the field. In the UK this is readily determined by checking the Research Assessment Exercise, RAE score (Grade 4 is good, Grade 5 is excellent). Similar 'league tables' of research excellence exist in most countries, but it is important to consider the subject area in which you want to work. It is no good getting into a mediocre biology department in a university noted for its excellence in history and theology. All universities and research institutes worldwide now have excellent websites, providing detailed information of ongoing research, facilities and training for graduate students.

The nature of the Ph.D. has changed significantly over the past decade. Previously the 'apprenticeship' system prevailed, where one or two students worked side by side with a supervisor who devoted time and effort to training their students in all aspects of science. While this is still the aim, in reality most supervisors who are successful in research have several Ph.D. students, as well as other research staff to look after, and many other pressures on their time. Because of this, it is important to look at the training which may be available in the department. Are courses available specifically for graduate students? Will there be tutors or advisers to help if problems arise, or, if your supervisor is not available, is there a healthy population of graduate students to interact with? Have graduate students in the department in the past completed their Ph.D.s successfully (and on time) and secured good positions thereafter? If you cannot find this out by asking your current tutors or by searching for information, ask when you visit – any reasonable prospective supervisor will be impressed by your foresight. Although the system has changed significantly, choosing the right supervisor is just as important now as it always has been.

CHOOSING YOUR PH.D. SUPERVISOR

Of course you need to feel that you will be able to get on reasonably well with the person you will have to work quite closely with for a number of years. You must be able to communicate with them, to respect them and to feel that they will treat students fairly, even if you know they will be pushing you to work long hours and setting seemingly unattainable deadlines and goals. But ultimately they must be good scientists, ideally with an impressive record of publication, training graduate students and securing necessary funding. Selecting a newly appointed member of staff (perhaps as their first Ph.D. student) can be somewhat of a risk. But this may be balanced by the time and enthusiasm they are likely to expend.

Ask to speak to other students in the potential supervisor's lab to determine what the supervisor is like to work with. Are they enthusiastic and supportive, even when the results all seem to be negative? Do they try to ensure that their graduate students get the right training and experience to complete their Ph.D. on time, or will they keep them working in the lab long after the end of their course? Ask about the completion rates and the subsequent careers of past students, and check their publication record by a literature search. Determine if there is a good structure in the lab. For example, are there experienced post-docs who can advise on a day to day basis, and skilled technicians to help the naïve graduate student? Is the lab well funded, does it look organised and have the right equipment?

Personality and attitude to research and graduate training is important in selecting a supervisor, but if you really want to succeed in research, the supervisor's scientific achievements and reputation are of prime concern. If he or she is successful it is likely that their graduate students will also do well. Many of the world's leading scientists started out in some of the very best labs, and a significant number of Nobel Prize winners were at some stage supervised or mentored by a Nobel Laureate. The very best scientists will almost always provide the best trainers – even if they are not always the easiest people to get on with.

Reaching the right choice of a Ph.D. project or supervisor (which of course depends on each individual) may seem a daunting task. There is now a great deal of information and advice around, but if you are uncertain, there are courses which help that choice to be made, e.g. the extended Ph.D. in which the first year involves rotation between labs on several projects as is common in the US, the four year Ph.D. in the UK and some other countries or the MRes which operates a similar system. Each of these provides experience of different labs, projects and supervisors before the final choice is made for a Ph.D.

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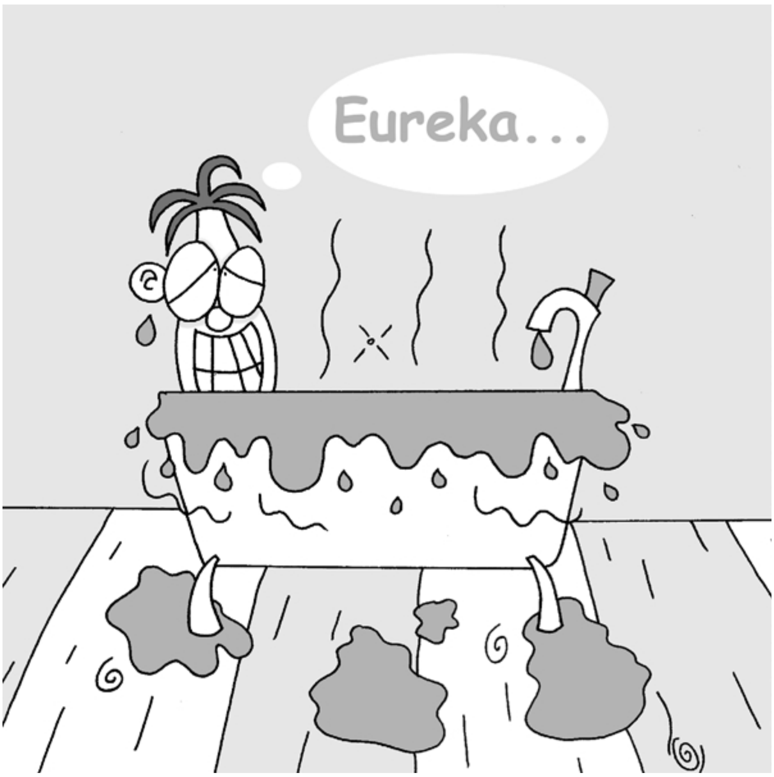

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3

Getting down to research

It is psychologically important to get results, even if they are not original.

The early phase of research can be somewhat bewildering and varies considerably between countries, institutions and labs. In some institutions, the first year or so is spent on taught courses, with only short lab projects, to be followed by a gradual introduction to the research project. At the other extreme, the student is launched into their own research project on day 1 and expected to produce some results by day 3. Both approaches are valid, have benefits and disadvantages, and each poses challenges and frustrations. For any new research project there always seems to be too much to take in at once: new colleagues, new techniques, numerous papers to read – most of which seem unintelligible or at best irrelevant – talks to attend and, most importantly, results to obtain. There is so much to do and learn, but as soon as you are in the lab, try to do an experiment.

LIFE IN THE LAB

The lab is not just a physical structure, but also a group of people each acting and interacting in different and specific ways. No two lab structures are identical because they are determined by the personalities and activities of the staff, the size of the lab (people, funding and space), the type of work being undertaken and the style of the lab head. You need to know about the physical structure, the individuals, what they do, i.e. ‘how the lab works’.

In most cases, active labs will include senior scientists (usually holding a faculty position in universities or senior scientists in research institutes or industry). One of these will be the lab head, but there may be