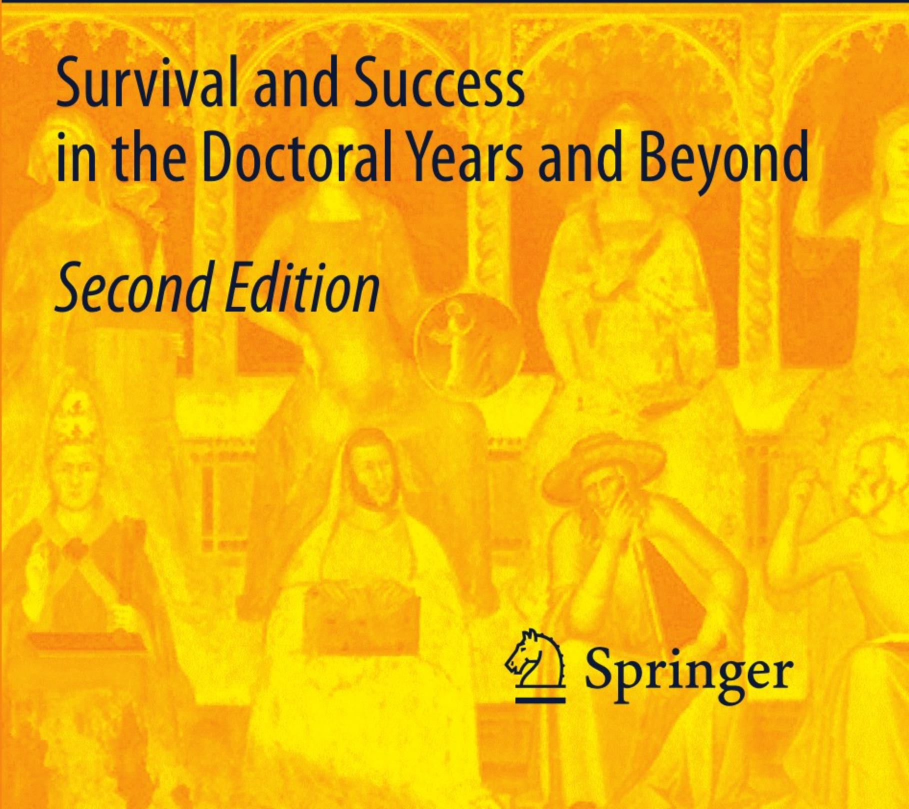
Patricia Gosling · Bart Noordam

Mastering Your PhD

Survival and Success in the Doctoral Years and Beyond

Second Edition



Springer

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Authors' Note

It's been four years since the 2006 publication of the first edition of 'Mastering Your PhD: Survival and Success in the Doctoral Years and Beyond'. In the meantime we've written quite a bit of new material. Some of it appeared as a monthly column on the ScienceCareers.org website, and some of it consists of additional tips and advice we thought would be of value to fledgling PhD students and those who are further along the road. With several new chapters of material and many new insights to help you along the way, we hope you enjoy this second edition. Best of luck on your journey.

September 2010

Patricia Gosling
Bart Noordam

Preface

Why Read a Book About Getting a PhD?

PhD students and their supervisors tend to focus only on the content of the research that leads to the doctoral thesis. All other issues are often taken for granted: how to organize your work, give a presentation, work in a team, cope with your supervisor, and effectively manage your time. When asked, former PhD students usually claim that the general experience of being a graduate student, which includes learning how to solve complex problems and work well with others, were of greater value to their careers than the actual content of their thesis. The goal of this book is to use some of the skills shown to be effective outside the world of academia to help PhD students master all the non-scientific aspects of getting a PhD. Hopefully it will help graduate students get the most out of (and fully enjoy!) their PhD years, as well as offer some much-needed support as they prepare for their post-PhD careers.

Sink or Swim

After hearing about this project, a professor in the UK had this to say: 'This book should not be published. Obtaining your PhD is like swimming across a big lake. Some students cannot swim, so they'll sink. That is the way the academic system selects those who will win. By providing students with a book on how to swim, they will pass and ruin the system.' We can't think of a better endorsement for this book. And we believe, of course, that it is indeed possible to learn to swim and survive the course. In fact, we think that mastering certain skills along the way is just as important as getting across the lake to get the prize (your PhD) on the other side.

The Problem: Saving an Old Master Painting from the Ravages of Time

To help illustrate some of the principles and suggestions we've outlined in this book, we've decided to follow a team of graduate students as they work together on an important project: saving a priceless Old Master painting from further deterioration. The robe of the Virgin Mary in the middle panel of *The Coronation of the Virgin* by Lorenzo Monaco (ca.1414) is currently white. Technical examination has shown, however, that the robe was originally a deep pinkish mauve. A restorer can retouch the painting with red paint, but if the robe is still fading a colour difference will occur, so elucidating the correct composition of the original paint, plus understanding the exact nature of the fading process will be critical for a proper restoration to be carried out.

Isabel, a chemistry PhD student, will be analyzing the chemical composition of the paint. Her challenge will be to use the analytical techniques currently available to study a sample from the painting, typically a tiny sample that is barely visible to the human eye.

Yousef is a PhD student in physics who will be focusing on calculations of the rate of fading of certain paint compositions, as well as the important issue of whether it will be possible to reconstruct the original colour of the painting. Another aspect of Yousef's project will be to develop new analytical techniques for gaining more information from the precious paint samples.

Peter is working on his PhD in art history. His project will include the interpretation of the painting based on its use of colour, particularly when the colour is thought to have a religious or symbolic significance. The use of colour may also be characteristic for this particular artist. The Virgin's white robe, for example, is symbolic of her purity as the mother of Christ, while purple is symbolic of her royal nature as the queen of heaven.

In order to solve the problem of the painting's degradation the team will have to work together and rely on each other's data. Communication, planning, and cooperation will be key to their success. The three are graduate students at the same university, albeit in separate research groups. Isabel has joined a well-established group run by a senior professor. Yousef works for a world-renowned professor in a large group with many PhD students and several Post-docs. Peter works as one of two graduate students for a young assistant professor.

To finish the project successfully, the team will have to draw on many skills they hadn't really counted on using including good communication, proper planning, and effective time management.

Zug, Switzerland — Patricia Gosling
Amsterdam — Bart Noordam
September 2010

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Chapter 1
Choosing a Research Group: Pluses and Pitfalls

Nothing great was ever achieved without enthusiasm.
– Ralph Waldo Emerson

Before you even get started on your PhD research, you will have already made a decision that will have a major impact on the success of your project, and perhaps even on your future career: you have chosen to work in a particular research group, under the guidance of a particular thesis advisor or supervisor.

While making this choice, you most likely spent a great deal of time thinking about your research project. You addressed questions such as: do I want to continue the type of research I did for you my senior thesis/Masters degree, or do I want to explore a new field? Do I prefer doing experiments in the lab or do I feel more comfortable with a theoretical approach? No doubt that you've had to think long and hard about all these personal preferences.

However, there is one more success factor for a productive and pleasant research period: the group you're working in. Think of your team as being on an island together in the most basic social unit of scientific research – science's nuclear family – the research group. For the next few years you'll be 'stranded' with this particular group of people – like it or not.

Every research group has its own unique chemistry – its own group dynamics. There are, nonetheless, some patterns to be aware of. It can be helpful to consider which type of group you're likely to be most comfortable in. Sure, you need to choose a group that does the science you want to do, but other factors like the size and nature of the group are also important. Reflect on the others who live on your little research island and what each of them is likely to contribute to the group effort – and your own research.

In this chapter we describe five archetypal research groups, ranging from a small group with a starting (assistant) professor as a supervisor, to a huge group led by a senior (full) professor. We discuss typical advantages and disadvantages of different types of groups. Include these considerations before you make a final choice. If you have already made your decision, you will be ahead of the game by being aware of some of the advantages and pitfalls of the type of group you're working in.

The Start-Up Group

Let's say you've joined a new group headed by a young assistant professor.[1] In this scenario you'll belong to the first generation of PhD students and your advisor will likely be full of energy and

[1] In this chapter we use terminology from the US academic world to describe academic ranks: assistant, associate and full professor. Each country has its own academic system with its own nomenclature. However, the career paths are similar. After completing a post-doctoral fellowship, one starts with a small (sub) group, as an assistant professor (in the US). In about 5 years the group grows in size, and the supervisor is promoted to associate professor. When the group matures and reaches the status of a completely independent

eager for data – data that you will have to acquire. *Caveat emptor*: young thesis advisors have the tendency to design overly ambitious research programmes. Plans may have to be simplified when reality sets in. In such a small group you will have frequent and intensive interactions with your advisor, particularly because his or her career will depend on the success of the first generation of graduate students – you. The lack of experience of assistant professors in supervising students is usually compensated by the enormous amount of time they spend with their small group. Moreover, your advisor will often have fewer teaching and administrative duties. More time, therefore, can be devoted to working in the lab. Full of exciting new ideas, a starting professor often operates more like a more senior partner than a boss. On the down side, there is the pressure to get tenured, and management and interpersonal skills don't come naturally to everyone.

In such a setting it is crucial that you get along well with your advisor, so it's a wise idea to invest in that relationship. If there is no common ground and enthusiasm for your project, your life in the lab is bound to be rocky.

In a start-up group there will probably be just one or two other PhD students or Post-docs. The success of your projects will naturally be intertwined. The equipment and apparatus you'll need to acquire data will probably have to be constructed or set up. Lacking the infrastructure of an existing group, all of you will probably spend a lot of energy in building equipment, designing new models or writing new computer codes. Make a good and fair arrangement with your colleagues on how to share the output once it's time to harvest the data. Agreeing upfront on the order of authors' names on papers, for example, will prevent

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academic group, the supervisor is usually (but not always) granted academic tenure and promoted to full professor.

conflicts once the results start rolling in. Although this issue is relevant in any group, it surfaces often in start-up groups. These groups still lack clear publishing policies, while the output to be shared can be limited for the first generation students.

How can you tell if a new group leader has her act together and if you're likely to make a success of your time there? After all, your young professor has no track record in guiding a group. Although no success is guaranteed, we have two suggestions that might help you to find out. First of all, consider your job application as a selection process that works both ways, the professor looking for the best possible student and you searching for a group that suits you. Second, try to find out how the professor functioned as a Post-doc in previous job. Was she already responsible for setting up new experiments and acting as a professor-to-be, or was she still working like a senior PhD student, acquiring data independently and executing suggestions effectively, but not doing more than that?

The 'Up-and-Running' Group

Around the time an assistant professor has delivered the first generation of PhD students into the world, he is usually promoted to the rank of associate professor. The new associate professor's initial research has made some impact on the scientific community, and as a result, grant money is easier to come by and the group is able to expand. The investments made by the first generation of PhD students are starting to pay off. It may seem much easier for the second generation of students to do good research because the environment is so much more conducive. But usually the more established thesis advisor spends less time on research, since he/she is invited to give more lectures and to attend more conferences. Also, invitations to all kinds of committees are eagerly accepted. How well the associate professor copes with this transition will depend on his organizational skills.

As a graduate student, you will have to work much more with your fellow researchers. Guidance from your thesis advisor will be less frequent (as she may be less in touch with day-to-day activities in the lab) and perhaps less astute than in the start-up group. Accept this reduced interaction with your advisor as a fact of life; after all, the ability to work well independently is a key career skill. Discuss how the two of you can have effective interactions when you *do* get together. You may have to make an appointment with your advisor to discuss progress on your research. This may be tricky as your thesis advisor may not yet be used to scheduling discussions which previously were spontaneous. In such a growing group it is as important to get along with your fellow graduate students as with your advisor. Students nearing the end of their studies can be a great help in kick-starting your research project (provided they have time and are willing). Be honest with them about your needs. In exchange for their help you might offer to help them wrap up any remaining experiments for their thesis.

The Small-but-Established Group

Having been a successful associate professor for several years, an academic scientist will usually be promoted to the position of full professor. With the rank of full professor and the hurdle of tenure cleared, their job is secure. Some professors feel they are finally able to relax after many years of hard work. They may become more interested in the administrative aspects of running a research group, and their interest in academic research may start to fade. They have enough experience to keep a small group going, and still periodically have decent or even great results to publish. When you are enrolled in such a steady but small group, you may have to work extra hard to generate enthusiasm for your project. Although such a group can get you a degree, a valuable asset in your future career outside academia, it is not always the best place to start an academic career.

Interactions with your advisor may be infrequent. Proper planning of appointments with your advisor is crucial under these circumstances. You not only have to plan these meetings but also prepare for them. Make a small agenda of things you want to discuss, and have your results ready in a presentable form. You probably can expect more interaction and support from fellow grad students and Post-docs, even if they work on another subject.

But not all small and established groups fit the description above. Plenty of full professors enjoy doing science so much that they remain deeply involved in the research at all times. They may choose to focus their attention on a small research group with just a couple of PhD students – and try to avoid administrative tasks as much as possible. These small enclaves of pure and intensive research can be wonderful and stimulating places for graduate student work. If you get along well with the professor and your fellow PhD students, you will thrive in this type of intensive environment. Your investment in group interactions will be repaid generously: this can be a fruitful setting to have a productive and enjoyable time as a PhD student.

The Empire

Some successful professors allow their group to expand to immense proportions. Such groups can easily have 10–20 PhD students or more, along with several Post-docs. A good fraction of all PhD students work in such groups. Life for them is usually not bad at all, despite the fact that interactions with their 'famous' professor may be scarce to non-existent. Guidance comes from Post-docs in the group and more senior PhD students.

Not every topic investigated in those large groups will be a winner and some will fail altogether. But the availability of sophisticated instrumentation and a vast skill base should enable you to acquire data quickly. If your project fails, there are other projects you can fall back on. More than in any other group, interaction with your peers will determine your success and the amount of pleasure you get from your PhD research. Since there is a whole army of young researchers, you have the luxury of finding a few fellow students – and more senior scientists – with whom you click. You may even decide to work on a series of projects and share the results. Finally, be prepared for an infrequent interaction with your famous professor. When she/he happens to drop by the lab, be prepared so you get the most out it.

Unfortunately, in some of these empires there may be a highly competitive and cut-throat atmosphere. During your introduction to the group, and certainly before you commit to working there as a PhD student, you should be alert to any lack of camaraderie and spirit of cooperation.

In some European countries, such as Germany, the full professors seem to run such empires. In reality the professor often has a few lieutenants running smaller sub-groups. When you work in such a smaller sub group, the dynamics usually resemble those of a start-up group or an up-and-running group.

The Gardener

Once a good scientist, this late-career researcher's interest has waned. With his vast intellectual resources engaged in pursuits that most people only dabble in, he has developed into an extraordinary gardener (or birdwatcher, or cook). He still maintains a research group – he even managed to get his grant renewed the last time – but any good work that comes out of his lab is a result of the efforts of collaborators who haven't yet discovered that his best years are behind him – or the occasional talented student or Post-doc who has the misfortunate to wander through, not having heard word of his scientific demise.

If you're not sure what you want to do with your life, or have a couple of years to kill, a stint in a lab like this can be just the thing. Just don't expect it to be an easy start of a career in science.

Surviving in a Non-supportive Group

If you haven't yet chosen a research group, it's a good idea to give some thought to which kind of group you're more likely to function best in; how well you get on with your colleagues and advisor will have a big impact on how well you perform during – and after – your PhD project. You need to find a group that does the kind of science you're interested in, but also one that fits your personality.

Unfortunately, that's not a very easy thing for most of us to figure out. So much depends on the particular people in the lab – and, especially, the person who runs it. You may think you're likely to thrive in a small group, only to find yourself very happy in a large one. It's very easy to make a mistake. If you do – and even if you don't – there are likely to be times when you struggle with group chemistry, or when you feel you aren't getting the support you need. Here's how to get the most out of such a situation:

1. *Think positively*. Focus on the support that is available rather than sitting in isolation, frustrated about the support you're not getting or blaming those who should be helping you. Use this time as an opportunity to develop some independence.
2. *Find the help you need*. No member of the group, including your advisor, can solve all your problems and fulfill all your needs. Some colleagues and advisors are better at designing new projects, others at debugging computer codes, still others at editing manuscripts. So search around, and don't limit yourself to your research group; you might be, metaphorically, stranded on an island with these folks, but you do have a cell phone and a fast Internet connection. Don't share prepublication data without your advisors permission, but find the help you need where it exists, whether it's within or from outside your group.
3. *Identify your show-stoppers*. It's not necessary to solve all of your problems in order to make progress, at least not all at once. Set priorities; address the most important issues first. If you notice that you're spending a lot of time on problems that seem pressing but, in a careful analysis, don't seem all that important. Focus only on those problems that really stop you from making progress with your project.

If none of the above suggestions works, and you find yourself envying other students who seem to work in a much more productive and pleasant group, it might cross your mind to change labs. This is a delicate issue that we will not discuss here in full detail. A few tips: double check how much greener the pastures are over there (is it really worth it to change?); identify the procedures at your university (is changing labs common practice, or are you considering doing something that is unheard of?); finally, good diplomacy might make such a move more likely to be successful.

In summary, the type of group you work in can determine, to a large extent, the way you work, as well as the type and frequency of interaction you have with your advisor. Your success will be influenced not only by having a good advisor (or a professor with a famous name), but also by your relationships with the other PhD students and Post-docs in the lab. So try to evaluate the dynamics of the group you're in and identify your allies. Putting some effort into these relationships will help make your research projects effective and pleasant.

Chapter 2
Getting Started

Don't judge each day by the harvest you reap, but by the seeds you plant.
– Robert Louis Stevenson

Your first day in the lab. Undoubtedly you are experiencing a range of emotions from excitement to curiosity to anxiety. You'll be working in this lab and with this group of people, as well as with your supervisor, for several years. This is Day One of a long commitment, so it's important to get off on the right foot. Perhaps you're so anxious to get started and prove your scientific mettle to others, that you decide to do an experiment on your first day in the lab, but this would be unwise to say the least. Give yourself a few days to get orientated, meet the people in your group, meet with your supervisor, and get to know the layout of the university, its facilities and its graduate student services. You will probably have been assigned a lab bench and a desk. In your first days in the lab, rather than jumping in with your first set of experiments, spend some time outfitting your working space with the equipment and materials you'll need. Make your desk a comfortable and personal place to work – you'll be spending a lot of time there. You may also need to register for a university e-mail account and fill in forms for the departmental secretary, etc. Make sure you take care of all these administrative tasks before you get bogged down in your experiments in the lab. The following are some suggestions to make your first few days as a graduate student as smooth as possible and to help you get off to a good start. We discuss some of these issues in greater detail in subsequent chapters, but this brief sketch is meant to give you an idea of some important things to think about early on.

Become Familiar with Your Research Department

Use your first days as a graduate student to familiarize yourself with the inner workings of your department. If you haven't already done so, introduce yourself to the department chairperson, as well as to secretaries, technicians, lab assistants, librarians, and other key personnel. This is not the time to be shy. Make a point of introducing yourself right at the start so that people are not still wondering six months from now if you're a grad student, an undergrad, a Post-doc or a lab technician. Be courteous and open-minded when meeting people for the first time. The people with whom you'll be working will be important to you in more ways than you might realize and first impressions count. You won't be able to work effectively unless you've familiarized yourself with your surroundings and met the key people around you, so be sure not to lock yourself up in the lab all day. Open up, mingle with your colleagues and make the effort to understand the ins and outs of your department. If you need information about the department or the university, ask senior graduate students and staff members. Be sure to introduce yourself to people who will be vital to your research such as those who are responsible for ordering research materials and equipment, operating technical equipment, and maintaining lab safety. Make sure too, to familiarize yourself with lab safety and evacuation procedures. Know where to go to for help when you need it. Perhaps most importantly, try to identify someone who might make a good mentor (a senior graduate student in your group or in a similar group is an excellent choice). This individual can help show you the ropes and provide valuable professional guidance throughout your tenure as a grad student.

Formulate a Working Plan and Set Up a Schedule

Before you even start that first experiment, you should establish a working plan and set up a reasonable schedule for yourself in which to complete the tasks in your working plan. It is best to do this with the help of your supervisor to be sure that you are working on the same goals. Divide your project into manageable phases and have a timeline for each phase. Be sure to set scheduled time off for yourself, because you can't work all the time. Once you've established your goals in conjunction with your supervisor and roughed out a timeline, keeping to your schedule is important (see Chap. 3 for a thorough discussion of goal setting and time management).

Maintain a Proper Lab Notebook

This may seem obvious, but it can't be stated often enough that a major factor in your research success lies in your ability to keep good records of your experiments. Don't fall into the trap of thinking that only a neat lab notebook is a good notebook. Tidy tables of data are not enough. You must write everything down, including everything that worked and – especially – what didn't work. Don't be afraid to jot down random musings or thoughts in the margins. Forget about being neat. Meticulousness and completeness are more important attributes of a good lab notebook than perfect handwriting and tables drawn with a straight-edge. Make this a daily habit. Avoid rushing into an experiment without first writing down all the parameters (and, no, you won't remember all the details when the experiment is over). If you keep a proper record right from the beginning, making sense of your experimental data (and the logic behind your experimental designs) will be a lot easier.

Establish Good Reference Keeping Practices

As you carry out your research, you will need to keep a working bibliography: a list of publications you actually use as references for your research project. Start compiling this bibliography from day one and build it up as your work progresses. This will take away a huge part of the workload when you finally reach the stage of writing up reports, research papers – and your thesis. Once you have sufficient data for a preliminary report, get into the writing habit by writing up your work and submitting it to workshops or conferences. Presenting a paper at a conference or departmental meeting is good practice for graduate students. Establishing a track record through these types of presentations will help your career. Of course, every scientist's goal is to be published in high-impact journals. But that's something you can worry about further down the road. For now, the important thing will be to stay focused and to keep good records of your work in the lab and in the library.

Dealing with Initial Ups and Downs

Life is filled with ups and downs and this is no less true than in your life as a graduate student. Experienced scientists know that research can be frustrating at times and not always go according to your well-made plans. Inexperienced scientists have a harder time managing their expectations and frustrations. So expect to go through periods of stress and anxiety, whether due to work, study, or personal matters. Taking a little time off to relieve stress when the pressure gets too high is always a good idea. Don't feel guilty about having to take a break from time to time – you'll come back refreshed and ready to get on with your work. Most likely you've moved away from familiar surroundings in order to attend graduate school, leaving friends and perhaps family behind. Take the time to build a social network and your own informal support groups. These could consist of people from your research team or just a group of peers, older colleagues or anybody you get along with. You'll need these people to share problems with and to go to for moral support when you need it most. Whatever you do, don't make the mistake of keeping problems to yourself. Everyone hits a difficult patch at some point in their graduate student years, so having problems is nothing to be ashamed of. Unresolved problems will not go away on their own. If you don't resolve them they will keep you awake at night until you are so ground down by stress and anxiety that it will be hard to find your way back on the right path. Find someone understanding to talk to when things get too much to handle on your own. Lastly, while graduate student life can be gruelling, take time out to have fun. There's more to life than the inside of a lab.

Chapter 3
Setting Goals and Objectives

Give me a lever long enough and a fulcrum on which to place it, and I shall move the world.

– Archimedes

As you work your way through the settling in process, take some time (a few days if necessary) to write down your short- and long-term goals and objectives. We know that your ultimate objective is to write your thesis and obtain your doctorate, but that goal is years away, so you'll need to break things down into smaller steps. By breaking down the different stages of your doctoral studies into manageable steps and committing them to paper, you'll not only avoid becoming overwhelmed by the tasks ahead of you, and you'll have a set of measurable and realistic goals towards which to work.

One of the best ways to identify your goals is to start by writing down an action plan. This type of activity usually involves the following steps:

1. *Clarify your goals and objectives*. First look at the big picture and then break things down into shorter time segments.

What do you want to have accomplished by the end of the first six months of graduate study? The first year? Sketch these goals out broadly, as they are likely to change over time. Now, write down your objectives for the next three months, and then fine tune these for over the next month. Now that you've written your goals down, ask yourself two things: are my goals measurable? How will I know when I've achieved my goal(s)?

2. *Write down a list of actions*. Now it's time to think about all the things you need to do to achieve your goals. What limitations and constraints do you have in terms of time, know-how, equipment, material, etc? Write down as many actions as you can that will help you achieve your goals.
3. *Prioritize*. Take a good look at your list. Prioritize the actionable points so that you do first what is most efficient and what will most likely assist you in achieving your goals.
4. *Organize your actions into a plan*. Actions that are set into a time framework make up a plan. Make sure your plan is workable. Can you do the actions you have set up for yourself in the time frame you've allotted? Make sure you've ordered your actions into a logical sequence.
5. *Monitor and measure your progress*. On a regular basis you will have to monitor your plan and make adjustments if necessary. It's important to remain flexible and re-state your goals from time to time as necessary and as you gain more experience with your project (for more details on how to do this, see Chap. 6: Monthly Progress Monitor)

In the business world, some people prefer to follow the SMART method when establishing – and achieving – their goals:

- **S**pecific
- **M**easurable

- **A**ttainable
- **R**ealistic
- **T**ime-related

In other words, there is no point in setting a goal that you can't measure, can't attain, or isn't realistic. If, for example you are not physically fit, the goal of climbing mount Kilimanjaro next week is specific and measurable, but unlikely to be either attainable or realistic in the time frame you have allowed yourself.

Effective Time Management

Once you've identified your short-term and long-term objectives, managing your time effectively will be key to keeping to your plan and attaining the goals you've identified. Most of us are familiar with that desperate feeling that time is slipping through our fingers, or that we don't have enough hours in the day to do all the things we need to do. Often that feeling of a lack of time has more to do with poor time management skills than with an actual lack of time. We all have the same 24 hours in every day. How we make use of them differs widely among individuals and good time management is a major factor in successfully completing the goals you have set for yourself.

One useful tool in effective time management is to keep a record of your activities. You will be keeping a lab notebook of your experiments, of course, but it is also helpful to keep a written record on a daily, or weekly basis, of *all* your activities. This will help you analyse how you actually spend your time. The first time you start writing down all the things you do in a day, you may be shocked to discover how much time you actually waste.

You may also be unaware that your energy levels vary throughout the day and night. In fact, the majority of people function at different levels of effectiveness at different times. Most people know whether or not they are a ‘morning person’ or a ‘night owl,’ but do you know at which times of the day or evening that your energy dips or peaks? Your productivity may vary depending on the amount of sugar in your blood, the length of time since you last took a break, routine distractions, stress, discomfort, or a range of other factors. Identifying your peak energy periods will help you to use this time more wisely, doing the things that count. By identifying your energy dips, you’ll know when it’s time to switch tasks, eat something to give you energy, or take a break for some fresh air.

Record Your Daily Activities

Keeping a record of your activities for several days will give you a better understanding of how you spend your time – and when you perform at your best. Without modifying your normal routine or behaviour, write down all the things you do (as you do them) in the course of an entire day. Record your daily activities like this every day for a week. Every time you change activities, whether its reading e-mail, working in the lab, making coffee, sleeping, eating lunch, reading in the library, or attending meetings, note down when you do this and how you feel.

Learning from the Record

Once you have noted the way you use your time every day for a week, go back and analyse what you have recorded. It is not unusual to discover that you spend a huge amount of time doing activities that are low down on your list of priorities! (See the 80-20 rule below). You may also discover that you have more energy during some parts of the day, and feel a bit listless and tired during others. Much of this variation in energy level depends on the breaks you take, the time and amount you eat, and the quality of your nutritional intake. Your written record will give you a basis for experimenting with these variables. Have you discovered that you have lots of energy in the morning and feel tired in mid-afternoon? Then get into the lab early and do your important thinking and/or experiments at this time. Use your low-energy time in the afternoon for more routine work such as searching the literature or writing up your notes. An even better solution to beat these periods of low-energy are to get out of the lab and go for a brisk walk in the fresh air.

Another useful tool for helping you get everything done is to draw up a to-do list. This can be done daily or weekly, whatever works best for you. A to-do list is a list of all the tasks that you need to carry out to reach the goal you have set for yourself. Once you've written your list, you can prioritize these tasks into order of importance.

There are people who make lists and people who don't. Perhaps you've never thought of yourself as a 'list' person before, but to-do lists are essential when you need to carry out a number of different tasks or different sorts of task, or when you have made a number of commitments that need to be attended to simultaneously (multi-tasking). Don't make the mistake of thinking that you can juggle all of this information in your head. If you find that you are caught out time and again because you have forgotten to do something, then you definitely need to keep a to-do list.

While to-do lists are a very simple tool, they are also extremely powerful, both as a method of organizing yourself and as a way of reducing stress. Often problems may seem overwhelming, especially if they're left to rattle around in your head; or you may feel you have a huge number of demands on your time. This may leave you feeling out of control, and overburdened with work. Writing things down in a list (and crossing the things off the list that you've accomplished) can help to relieve these feelings.

Preparing a To-Do List

The solution to feeling overwhelmed is simple: Write down the tasks you need to do, and if they are large, break them down into their component elements. If these still seem too large too handle, break them down again. Do this until you have listed everything that you have to do. Once you have done this, run through your list and allocate priorities: A (very important) to F (unimportant). If too many tasks have a high priority, run through the list again and demote the less important ones. Once you have done this, rewrite the list in order of priority. When you are finished you will have a precise plan that you can use to eliminate the problems you face, one step at a time. You will be able to tackle all of these things in order of importance. This process will allow you to separate the important tasks from the many time-consuming trivial ones.

Multi-tasking: Is It for You?

Multi-tasking is the ability to do more than one thing at a time, such as talking on the phone while reading your e-mail, or eating lunch and reading the newspaper while recording data from an experiment. The more tasks we juggle in an attempt to make the most of the time we have, however, the less efficient we become at performing any one task. And the more time you take to return

to an interrupted task, the harder it is to remember where it was that you left off. Studies have shown that multi-tasking can greatly increase your levels of stress, so you'll have to decide whether it's the right approach for you. Some people are natural multi-taskers, others prefer to do one thing at time. Many people feel that multi-tasking, while a good idea in theory, diminishes their productivity and makes them work harder in order to feel that they're keeping up with all the things they're supposed to do. Increases in technology have made it harder than ever to avoid multi-tasking, so you might want to try to slow down a bit and work on one task at a time to see how this effects you work – and your mood. Your concentration and productivity will most likely increase and you will probably stop feeling like you're running in a million directions at once.

The 80/20 Rule

Attributed to the Italian economist Vilfredo Pareto, the original concept of the 80/20 rule states that the relationship between input and output is rarely, if ever, proportional. When applied to your work, it means that only 20% of your efforts produce 80% of the results. Learning to identify the 20% that produces the majority of your results is the key to making the most effective use of your time. While simplistic in its conception, putting the 80-20 rule into practice is somewhat more difficult. So how do you recognize the crucial 20%?

1. *Take a look at the people around you*. Twenty percent of your colleagues probably give you 80% of the support you need. They are your true advocates. Take the time to learn from their example and to cultivate supportive relationships with them.
2. *Take a close look at your work*. Ask yourself, Which 20% of my work should I be focusing on?

Am I Focusing on the 80% or the 20%?

Let's look at the above statements in a bit more detail. The following are some indications of whether or not you're spending your time as you should.

You're focusing on the 80% if the following statements are true:

- You're working on tasks other people want you to do, but you yourself have little or no stake in them.
- You're frequently working on tasks considered 'urgent.'
- You're spending time on tasks you are not particularly good at.
- Completing some activities is taking much more time than you expected.
- You find yourself complaining all the time about how little you seem to be accomplishing
- compared to the effort you put in.

You're focusing on the effective 20%, however, if:

- You're engaged in activities that advance your overall goals in the lab.
- You're working on tasks that you may not like, but you're doing them knowing they relate to the bigger picture.
- You're asking for help with tasks you are not good at doing yourself.
- You feel a sense of accomplishment.

Implementing the 80/20 Rule

All of this may sound hopelessly simplistic, so if you're particularly sceptical, try applying the 80/20 principle for a few days just to see what happens. An increased awareness of the way you work and the time you spend on a variety of activities will help you learn to make use of this remarkably effective principle. You will feel that you have more time, that you are able to focus on what is essential and that you can reduce the amount of time you spend on meaningless tasks or those that won't help you reach your goals.

Saving an old master painting: Yousef establishes a set of goals

Not one to waste any time, Yousef decides to start off on the right foot by establishing some goals and objectives for himself during the first week in the lab. Some of these goals are non-research related, such as familiarizing himself with the department and the library and setting up his work space. Even though he's anxious to do his first experiment in the lab, he takes the time to write down some goals for his research. First, he needs to do some background reading as he knows very little about the chemistry and physical properties of paint pigments. Even though he is a physics student, he also wants to read up a bit on art history, so he can put the project into context and make it easier to talk to Peter with whom he is collaborating. He sketches out in his notebook his goals for the first month, and then for the three month, and six month mark, and then creates a realistic action plan for himself in the given time frame. Since he will be using a relatively new technique for studying paint samples (secondary ion mass spectrometry, or SIMS), Yousef has made one of his goals to do a thorough literature search on this technique. He also maps out an initial set of experiments, and highlights any possible pitfalls. Yousef is pleased that he now has a plan to work with and goes out for a coffee. In the hallway he runs into his supervisor and Yousef realizes that he has not discussed his plans with him at all. So he tells his supervisor about his ideas and asks for a brief meeting to be sure that his plans are in line with his supervisor's own ideas and vision. After some minor modifications they agree on the plan and Yousef communicates to his teammates the things he wants to work on in the coming months.

Chapter 4
How to Think Like a Scientist

Science is a way of thinking much more than it is a body of knowledge.
– Carl Sagan

By the time you've made it to graduate school, you should be well acquainted with the principles of the scientific method. Most likely the concepts have been drilled into you ever since high school biology class. Even so, we felt it wouldn't be a bad idea to review some of the principles here, as they will form the core of your work in the lab.

Over the years, well-meaning friends and family members have probably asked this deceptively simple question: 'So what does a scientist do anyway?' or 'Tell me about your research.' You may or may not have a ready answer depending on who is doing the asking and how much explaining you want to do. But imagine you are sitting around the dinner table and have been asked this question by a family member or friend, someone who knows nothing about scientists or the scientific method. How would you respond in a way that was clear and made sense to the non-scientist?

Perhaps the simplest and most accurate answer you could formulate is that scientists observe and measure the world around them. They gather information or data based on their observations, and when they think they have enough to answer the questions they have asked, they try to make sense of what it all means.

During this process, most scientists use a reductionist approach. Let's say one scientist is studying a complex chemical reaction, another is investigating the foraging behaviour of the ring-tailed lemur, and a third is researching the ocean currents around Tierra del Fuego. In order to make sense of these very complicated phenomena, each of these scientists must break down the particular problem into simple components. These four components are usually given as follows:

- Observation
- Constructing a hypothesis
- Carrying out experiments to test the hypothesis
- Formulating a theory

These four steps, taken together, are what is commonly known as the scientific method. If carried out correctly, the ultimate goal of the scientific method is to construct an accurate representation of the physical world. You may already have learned about the scientific method at some point in your career as a student of science, and while it may all seem very theoretical, it will be important to keep these steps in mind as you go about your own research.

Because scientists may be unduly influenced by personal and cultural beliefs and assumptions, which may alter their perceptions and interpretations of the natural world, the scientific method, if rigorously followed, can be considered an attempt to minimize bias on the part of the scientist. That doesn't mean, however, that the scientific method is without pitfalls.

Common Errors in Using the Scientific Method

Not Proving the Hypothesis by Experiment

Perhaps the most fundamental error a scientist can make is to mistake the hypothesis for an explanation of a phenomenon *without* having performed any experimental tests to verify the hypothesis. Sometimes what we think of as common sense, logic, or intuition tempts us into believing that no experimental proof is necessary to prove the hypothesis because the answer seems so obvious from the start. Consider a classic mistake made by the philosopher, Aristotle, who many people consider to be the father of the scientific method. He emphatically stated that women have fewer teeth than men (probably to support his argument that men were superior). He never actually tried to prove this fact; he just used this misconception as a way to prove what everybody in ancient Greece accepted at face value anyway (that men are superior to women!). Now we all know that adult men and women have the exact same number of teeth – so don't fall into the same trap as Aristotle. Use properly designed experiments to prove your hypothesis, rather than rely on 'obvious' assumptions.

Discounting Data That Don't Support the Hypothesis

Another common mistake is to ignore data that do not support your hypothesis. In the ideal situation, the scientist is open to the possibility that the hypothesis is either correct or incorrect. If, for example, the researcher has a strong belief that the hypothesis is true or false, before collecting any experimental data, there may be a psychological tendency to find something 'wrong' with any data that does not support the researcher's expectations. It's hard to get rid of all our biases at once. The important point to keep in mind is that you need to treat all data the same way.

A third type of common mistake occurs when systematic errors are either over- or underestimated. For example, many discoveries were missed by researchers whose data pointed to a new phenomenon, but the data were mistakenly attributed to 'experimental noise.' Conversely, data that is part of the normal variation of the experimental process was taken as evidence for a new discovery.

How can this tendency towards bias be reduced? An important check on bias is to promote open communication among the members of a scientific field in the form of publications and conferences. In this way, the biases of individuals will most likely be cancelled out as other scientists try to reproduce their results. In time, a consensus may develop in the research community as to which experimental data has withstood the test of time.

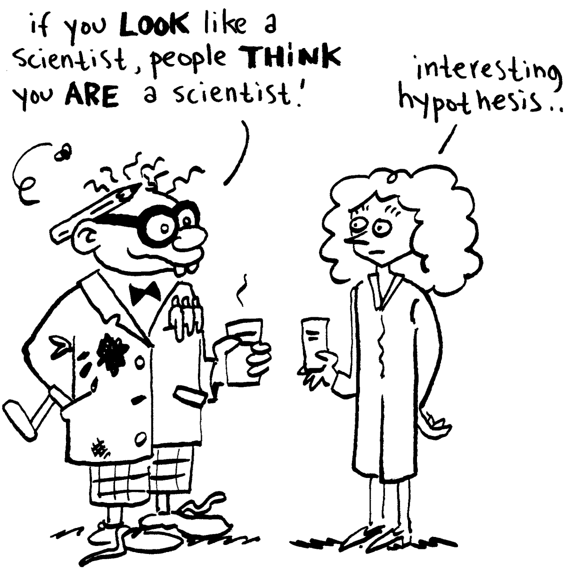
Fact, Theory, Hypothesis – What's the Difference Anyway?

These terms are not interchangeable, even though they are often treated that way in popular usage. For a scientist, each of these terms has a specific definition:

A *fact* is a thing that is known to be true. Fire burns wood into ash. Water is solid (frozen) at temperatures below zero.

A *theory* is a conceptual framework that can be used to explain existing observations and predict new ones. For example, the path the sun follows as it crosses the sky can be explained by the theory of gravity.

A *hypothesis* is a working assumption. Usually this assumption is formulated *before* experiments are carried out to test it. If the hypothesis holds up against existing and newly obtained data, the scientist may formulate it as a theory.



Is There Ever a Time When the Scientific Method Is Not Applicable?

A frequent criticism of the scientific method is that it cannot accommodate anything that has not already been proved. This argument points out that many things thought to be impossible in the past are now everyday realities (such as flight, for example: Two hundred years ago it was believed impossible for humans to fly in the air). This criticism, however, is based on a misunderstanding of the scientific method. When a hypothesis passes the test, it is adopted as a theory, which can correctly explain a range of phenomena. This theory, however, can always be falsified by new experimental evidence. But it is not necessary for the hypothesis to have been previously proved for the scientific method to work.

Ockham's Razor

In the fourteenth century, William of Ockham proposed the principle of Ockham's Razor, which he stated as: *Pluralitas non est ponenda sine neccesitate*. This can be translated as: Entities should not be multiplied unnecessarily. In other words, 'keep it simple'.

Suppose, for example, you have two theories that predict the same thing. In this instance, the principle of Ockham's Razor can come in handy. Here are two sample theories that describe the same phenomenon:

1. The tides on earth are influenced by the position of the moon.
2. The tides on earth are influenced by the position of the moon, which is determined by the force of powerful extraterrestrial beings.

Both theories make identical predictions, but Ockham's Razor would discount the second theory as containing unnecessary information. The simpler theory works just as well. Ockham's Razor does *not* guarantee, however, that the simplest theory will be correct, it merely establishes priorities.

A Final Comment

Biases aside, the scientific method is the best approach we have to accurately answer questions about the physical world in which we live. Without the scientific method, we might still believe in the idea of spontaneous generation (that flies, for example, are ‘born’ out of rotten meat), a theory that was disproved by Françesco Redi and Louis Pasteur in an ingenious experiment using the principles of the scientific method. As a result of his experiments Pasteur concluded that there is no life force in air, and organisms do not arise by spontaneous generation [from rotten meat] in this manner. ‘Life is a germ, and a germ is Life. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment.’

Saving an old master painting: Isabel forms hypotheses about the whitish, transparent inclusions in the red paint

To prepare for her work in the lab, Isabel has been doing a lot of reading in the library on the chemistry of paintings and some of the problems that paintings display after several centuries of being exposed to light, air, humidity and extremes of temperature. In her reading she has discovered that some degradation can be the result of the formation of lead-soap aggregates of certain pigments, including red lead-containing paints. These lead-soap aggregates can expand and remineralize, changing their chemical composition. Because of some other evidence found on the painting, such as the break up of the overlying paint layer and whitish opaque material protruding through the surface of the painting, Isabel hypothesizes that aggregates have formed and have remineralized to lead carbonate, a remineralization product. If this is the case, she hypothesizes further that the red lead reacted with fatty acids released by the ageing of the oil binding medium. In order to prove her hypotheses, she elects to analyse the paint sample with a number of imaging techniques including FTIR, SEM/EDX and SIMS, selecting the appropriate technique to determine whether lead-soap aggregates have indeed formed, if they have subsequently remineralized and if this remineralization product is indeed lead carbonate.

Chapter 5
Designing Good Experiments

There must be no barriers for freedom of inquiry. There is no place for dogma in science. The scientist is free, and must be free to ask any question, to doubt any assertion, to seek for any evidence, to correct any errors.

– Robert Oppenheimer

In the last chapter we talked about what it means to 'think like a scientist' and how to successfully apply the scientific method to your work. A critical feature of this process is testing your hypothesis with experiments. Good experimental design for each and every experiment you conduct will greatly enhance your chances for success in the lab. Even if you obtain a negative result, a well-designed experiment will give you confidence in your work and the reliability of your data.

Designing a suitable experiment to test a hypothesis takes ingenuity and skill. Whether your experiment requires sophisticated equipment or not, there are a number of features that are common to all well-designed experiments:

1. *Discrimination between different hypotheses*. A well-designed experiment should be able to discriminate between two hypotheses. In a poorly designed experiment, you may obtain results that support more than one hypothesis. If you carry out an experiment and discover that this is the case, then it's time to start over.
2. *Replicating your results*. When you carry out your experiment several times, are you able to replicate your results? If not, there is a serious flaw in your experimental design.
3. *Controls of variables*. Experiments must be well controlled against each of the variables tested. It is important to eliminate the possibility that other factors in the overall experimental set up are producing the effect you observe, rather than the factor you are interested in studying.
4. *Methods of measurement*. Your method of measurement must be reproducible from day to day, between different researchers in the same laboratory, and between different laboratories. Many scientists do not consider a result to be valid unless a different researcher has reproduced the same results. Maintaining the accuracy of your instrumentation and exercising quality control in your laboratory practices are critical.
5. *Blinding*. In the last chapter we talked about experimenter bias. It is possible for researchers to unconsciously 'fiddle' their data to get the result they hoped to get. In order to avoid this type of unconscious bias, it may be desirable to carry out experiments in which you don't know, for example, which compound is being tested in which laboratory rats, or which chemical reaction is taking place in a particular reaction vessel. This method is routinely use in clinical trials of drugs in which both the doctor and the patient are unaware of the treatment they are receiving. These so-called double-blind studies

are meant to avoid any bias on the part of doctors and patients as to the efficacy of a drug. The placebo effect has been well established.

6. *Accuracy and precision*. In almost any type of experiment, you will most likely have to measure something (the rate of a chemical reaction, the glucose level in blood, the orientation of molecules in reactive scattering). Therefore, it is critical that you know both the *accuracy* and the *precision* of your measuring device. Measuring the length of a fruit fly, for example, with a yardstick would not be very accurate, although it would probably be quite precise. These two terms are not synonymous and it is important to understand the difference. *Accuracy* means the ability of a method to give

a true measurement on average. *Precision* is a measure of the method's reproducibility. Your method of measurement should be both accurate and precise (have a low standard deviation). Sometimes one of these factors is more important than the other. If you are measuring changes over time of a particular quantity, it will be more important to have a precise method of measurement than an accurate one. Accuracy and precision are important factors in your experimental design as they will determine the reliability of your data. They will also determine the number of significant figures you can use in reporting your results.

Good Science and Good Experimental Design Go Hand in Hand

In order to assist you in designing good experiments, we suggest you follow these three steps:

1. *Define your objectives*. What is it that you are trying to test in this particular experiment (which question are you trying to answer)?
2. *Plan your strategy*. How will you achieve this objective? What is the size and scope of your experiment, and how many times will you try to repeat it?
3. *Experimental details*. Sketch out the details of your experiment. Which tools and equipment do you need? How much time will your experiment take (1 h, 1 day, 1 month?)

If you are a biologist who is carrying out experiments in a population of plants or animals, or a clinician doing a clinical trial with human patients, a statistician would tell you to think about the statistical tests you will need to perform to analyse your data. This will help you plan your experiment from the start. For example, you will need to know beforehand how large your study population needs to be to give you enough statistical power for your analyses.

Once you have identified your objectives and formulated a hypothesis, you need to define the variables you will use for testing your hypothesis. A well-designed experiment should have only one independent variable. If you change more than one variable at a time per experiment, you will not know which variable is causing the effect you observe. Keep in mind that some variables are linked and influence each other to create the same effect. Initially, try to choose variables that you think act independently of each other.

Make a list of answers to the questions you have. This can be a list of statements describing how or why you think the observed things act as they do. These questions should be stated in terms of the variables you have identified. Normally, you should formulate one hypothesis for each question you have. And you must do at least one experiment to test each hypothesis.

Design Experiments to Test Your Hypothesis

The next step is to design an experiment to test each hypothesis. In order to do that, you'll need to make a list of the things you will need to do to answer each question. The list you create will be your experimental procedure. This procedure should include the appropriate methodologies, technologies and equipment. For some types of experiment, you will have to have a 'control' to act as a reference.

A control is an additional experimental trial or run. It is a separate experiment, done exactly like the others, except that no experimental variables are changed. A control is simply a neutral ‘reference point’ for comparison that allows you to see what changing a variable does by comparing it the situation in which you change nothing. Dependable controls are sometimes very hard to develop. They can be the most difficult part of your experimental set up. Without a control you cannot be sure that changing the variable causes the effects you observe.

1. *Prepare your materials and equipment*. Make a list of all the things you will need to perform the experiment, including chemicals, glassware and reaction flasks, instrumentation, etc. Gather the materials and equipment you need and make sure everything is functioning properly.
2. *Record the data*. Experiments are often carried out in a series. For example, you can perform a series of experiments by changing one variable by a different amount each time. A series of experiments is made up of separate experimental ‘runs.’ During each run you make a measurement of how much the variable affected the particular system you are studying. For each separate run, you change the variable by a different amount. These changes will produce a different effect on the system. You measure this response and record the data in a table or chart. The data you record is considered to be raw data since it has not yet been analysed or interpreted. Only when raw data is analysed can it be thought of as results.
3. *Record your observations.* Record your observations during the experiment, remembering to make a note of any problems that crop up. Don’t forget to keep careful notes of everything you do, and everything that happens from the beginning of the experiment to the end (no matter how trivial

or unimportant it may seem at the time!). Careful data collection and observation are crucial to the scientific method. Your observations will be invaluable later on when it is time for you to draw conclusions, as well as for identifying any experimental error.

4. *Analyse the raw data*. Now you need to perform the necessary calculations to transform your raw data into the numbers you'll need to draw your conclusions. For example, if you weighed an empty reaction vessel, this weight is recorded in your data table as 'wt. of round-bottom-flask' You then added some sample to the container and weighed it again. This would be entered as 'wt. of flask + sample.' In the calculation section, do the calculation to find out how much sample was used in this experimental run: (wt. of flask + sample) – (wt. of flask) = wt. of sample used. This is obviously a very simple example, but you get the idea! Nothing is too trivial to record in your lab notebook. Don't rely on your memory.
5. *Draw conclusions*. Using the trends found in your experimental data and your observations, try to answer the questions you asked at the start of the experiment or set of experiments. Is your hypothesis correct? This is the time to assess the experiments you performed. Ideally, you should be able to evaluate the relationship between the predicted result contained in the hypothesis and the actual results, and reach a conclusion as to whether the explanation on which the prediction was based is supported. Or not.

Other things to take note of when summarizing your conclusions:

1. If your hypothesis is not correct, what could be the answer to your original question?

2. Summarize any difficulties or problems you had doing the experiment.
3. Do you need to change the procedure and repeat your experiment? What would you do differently next time?
4. List other things you learned.
5. Try to answer other related questions that may exist. The interpretation of data may lead to the development of additional hypotheses, the formulation of generalizations, or explanations of natural phenomena.
6. Discuss any Experimental Errors

Finally: Can You Trust Your Results?

You've designed your experiment properly (you hope) and carried it out according to the methods and procedures you devised. If you did not observe anything different than what happened with your control, the variable you changed may not have any effect on the system you are investigating. If you did not observe a consistent, reproducible trend in your series of experiments, experimental errors may be affecting your results. The first thing to check is how you are making your measurements. Is the measurement method questionable or unreliable? Perhaps you are reading a scale incorrectly, or the measuring instrument has not been properly calibrated. If you are able to determine that experimental errors are indeed influencing your results, carefully rethink the design of your experiments. Review each step of the procedure to find sources of potential errors. If possible, have a more senior scientist or fellow graduate student review your procedures with you. As the designer of the experiment, you can sometimes miss the obvious!

Spotting Random Errors

If your measurement method is not the cause of error, try to determine if the error is either systematic or random. Random errors are easier to spot. They result in non-reproducible data that doesn't make sense. In this case, runs with the same combination of variables, and even the control itself, cannot be duplicated. Some randomness is always present in nature. No two measurements are exactly the same. You must judge if the differences in your data can be explained by nature operating normally.

A random error may be occurring because you are doing something differently in each trial. For example, if you have not thoroughly cleaned your glassware or instruments, some of the chemicals you've used may be carried over from the last experiment. You may be able to carry out various statistical tests to determine if the difference between experimental runs is due to randomness, or to the way you are carrying out the experiments.

Systematic Errors

Systematic errors are more difficult to identify. At first glance your data and results appear to be consistent and reproducible, so you are unaware that something is causing all your measurements to be off by the same amount. For example, if you were not aware that your balance was off by 3 milligrams, all your measurements of weight would be off by 3 milligrams. This type of systematic error will affect all of your data by the same amount. One way to check for systematic errors is to run experiments that are of a different design but which should give you the same answers. It is sometimes a good idea to carry out different kinds of experiments to cross check your results. Another way to locate errors is to have an independent investigator repeat your experiments.

Linked Variables

Your results may be invalid if your variables are not independent of one another, and you have failed to notice this relationship. Variables are only independent if they produce their effects separately from each other. In other words, if a variable is independent, changing it will not influence the effects produced by another variable.

What if Your Experiment Hasn't Worked Out as Planned?

No matter what happens, whether your experiment was a success – or not – you will learn something. Because science is not only about getting The Answer. Even if your experiments don't answer the specific questions you asked, they will provide you with ideas that can be used to design additional experiments. Knowing that something didn't work as expected, is actually knowing quite a lot. Unsuccessful experiments are an important part of the process in finding an answer. Incorrect hypotheses are often very valuable, as they can help point the way towards further investigations.

Chapter 6
Charting Your Progress Month by Month

If you fail to plan, you plan to fail.

After dealing with the initial problems and uncertainties of the first few months of life as a graduate student, you're most likely feeling more comfortable in your new environment. Your PC is up and running, you've acquainted yourself with the working habits of your institute, and you know how to acquire the data you need (doing experiments in the laboratory, or data mining in the library), and so on. You have been working long hours, and may even have been sacrificing your weekends. Some time ago you sketched out, together with your supervisor, the targets you planned to meet in the first year. They seemed reasonable on paper, and the planning looked realistic. You feel you are ready to make your first scientific breakthrough. Nevertheless, the gap between the actual progress you have made and the targets you have set for yourself is growing wider every day. Somehow, in spite of all your hard work, you are not approaching your goals. Soon this may even become your daily mantra: *Why am I not approaching my target when I'm running so fast?*

The problem with getting into this mind-set, is that it is often difficult to recognize the patterns that slow or even inhibit your progress. Your first thought may be that you need to work harder to catch up, but very likely you have already discovered that this approach doesn't work. It may feel like you're making one step forward and two steps back. Perhaps it has already crossed your mind that it might be easier to just quit. Fantasies of starting a bed in breakfast in the south of France begin to drift through your mind. As an undergraduate, when your targets typically had a time span of a few weeks, you were doing fine. Now you are starting to discover that there is more to reaching annual goals than adding up hundreds of daily steps. You need some sort of monthly evaluation to bridge the wide gap between your 1-day and 1-year plans. This chapter provides you with a tool to help: the Monthly Progress Monitor.

Monthly Progress Monitor: Four Questions to Keep You Goal Oriented

For a monthly evaluation scheme to be effective, we believe it should be simple and easy to use. So we developed a form (see the end of the chapter) that asks you to answer only four questions. The scheme has been tested extensively in various research groups in several countries including the Netherlands, Denmark, and the USA. The four questions are:

1. Of the results I obtained last month, which are the most important?
2. Did I deviate from last month's planning? If so, why?
3. What are my most important goals for the upcoming month?
4. What do I need to do to reach these goals? Which potential hurdles might I face, and how do I overcome them?

These questions are meant to help you understand the patterns inherent in your working style, so it's very important to fill in the answers to these questions, particularly prior to meeting with your supervisor. We suggest that you fill in the form every month throughout your entire doctoral studies. More frequently is not practical and too big of a burden on your time. Less frequently makes the targets too vague for direct action and practical solutions. From our experience we have found that your answers to the four questions will reveal the following:

Question 1 – At first, you will think that you have done so many things last month that it will be hard to summarize them. But if you focus on the really important issues that pertain to your thesis, you will be able to come up with a short list. It can be a bit shocking to realize how much time you spent last month on issues that are not on the list of major contributions towards your thesis (see the 80-20 rule, Chap. 3). Most newly minted PhDs agree, with the power of hindsight, that they could have obtained their degree much faster if they had only followed the paths that were productive. Of course, the very essence of research is that you do not know the answers beforehand, nor the productive pathways, and not all your lines of inquiry will work out. But prioritization of your work can do no harm. If you are lucky you will pick more productive approaches than just randomly throwing darts at a dartboard (while blindfolded) and trying to hit your target.

Question 2 – Now for the really tough part. Compare the answer of question 1 of this month's evaluation (what you have done) to the answer of question 3 of last month's evaluation (what you planned to do). Most likely you will have accomplished only a small fraction of last month's ambitious plans. Try to write down why you were not been able to do more. While it may seem obvious, by re-reading the answers to question 2 of the forms from the last few months you will start to see patterns in how you work. Recognizing the problems in your working style is very often the first (and most difficult) step in finding the solution.

Question 3 – Of course, ambitious as you are, you have numerous plans for the coming months. But after having pondered the answers to question 2, you have perhaps become more realistic and wiser. Your list of goals for next month will now be rather short, otherwise you will not be able to finish them and you will end up with the same long list of projects started but not yet finished. In fact, what you are doing now is prioritizing your projects for the next month. Because prioritization seems so obvious, it is often not explicitly done. The lack of proper prioritization is one of the main pitfalls on the road to getting a PhD. Be sure to make your goals for the coming month truly actionable. For instance, an action such as *understanding more about the chemistry of paintings* is too vague. A more measurable target might be: read and understand 3 articles (such as . . .) and Chaps. 2, 3, and 5 of the book 'The Chemistry of Paintings'. After readings these books, try to formulate a hypothesis about what is going on in the painting you are investigating and what a good approach might be to test the hypothesis. Indeed, it will take a few extra minutes to come up with such a refined plan of action. And don't hesitate to consult your supervisor or a more senior scientist about this if you need guidance. But stick with it, as this effort will pay off. Your original plan may have led to a conversation with your supervisor such as:

> I have been reading some literature about the chemistry of paint pigments.
> So what are you going to do next?
> Actually, I have no idea, maybe I should read more chapters in this book. I found the biochemistry sections quite difficult.
> I do not believe the biochemistry is essential at this point, maybe you should take some mass spectra of your samples and analyse those first.

In short, you've wasted quite a bit time by just reading, your supervisor is correcting this; he/she is again taking the lead in your project. Instead, if your initial discussion a month earlier had been more precise, you would have been reading the relevant chapters and could have come up with some suggestions for the next steps. Even if you suggest the wrong set of actions, you will have learned from thinking about it. Taking a more pro-active role in your research starts with making an actionable to-do list for the month ahead.

Question 4 – You're a pro when you master the answer to question 4. Knowing the potential hurdles and obstacles in the projects you have selected to work on in the coming month is far from easy. Finding solutions to circumvent these hurdles is even more difficult. Spending time on foreseeing the hurdles and taking proper measures to keep them from stopping you in your tracks is very rewarding. *Staying ahead of the problem* is a skill that will not only make your PhD a success, but one that will help you in all your future jobs. In fact, avoiding potentially wasted time in your projects in the future will save you an enormous amount of time. Make sure you properly use the time you have saved by being more efficient. Do not run blindly onto another track. Balance this extra time between: (a) working fewer hours (an hour in the gym can be more efficient then another hour in the lab); (b) thinking of other potential hurdles and how to circumvent them; and (c) doing a little extra work on the relevant problems.

What You Can Learn from Filling in the Monthly Progress Monitor

Once you've been using the Monthly Progress Monitor for a few months, you should go over the old forms again (file them properly – they make a great record of your research progress). You will typically find that:

- At first, planned work in the month-to-come tends to exceed the progress made in the previous month.
- After using the monitor a few times, your planning will become (more) realistic.
- Expectations and goals are brought in line, thereby reducing conflicts.
- The general progress of the project is improved as a result of the timely identification of possible hurdles.

Above all, be honest in evaluating your progress. An honest evaluation can help you identify patterns and obstacles that are slowing you down. If you have the courage to do so (as this will necessarily involve discussing weaknesses in your working style), discuss the big picture that comes out of these forms with your supervisor. Alternatively, you can consult a friend or a sympathetic colleague.

Monthly progress monitor

Name PhD student: Name supervisor:
Date: Previous meeting:

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1. Of the results I obtained last month, which are the most important?

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2. Did I deviate from last month's planning? If so why?

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3. What are the most important goals for the upcoming month?

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4. What do I need to do to reach these goals? What are the potential hurdles and how do I overcome them?

Suggested date for next month's meeting:

General agreements:

a. *PhD student fills out form prior to meeting with supervisor*
b. *At the meeting the answers are completed*
c. *Supervisor gets a copy of the final form after the meeting*

Chapter 7
Dealing with Setbacks

Science has promised us truth. It has never promised us either peace or happiness.

– Gustave Le Bon

You've settled comfortably into your lab routine: you've established your goals and objectives, your research project is well underway, and you've been carrying out experiments for several months. You feel good about your progress and are convinced that you're on the right track. You've mastered the concept of thinking like a scientist by working through the classic progression of hypothesis, experiment, and results, and you are feeling confident that you have a good handle on your project and your life as a graduate student. Each month you have faithfully filled in the Monthly Progress Monitor and you're keeping open the lines of communication with your supervisor and colleagues. So everything is wonderful. Right? Wrong. Because one day you realize that *nothing is working*.

Your carefully planned experiments are not giving you the results you expected or need. Your cell cultures have become contaminated for the umpteenth time. The PCR machine or the

HPLC or the UV spectrometer breaks down. Again. You can't get your chemical compounds to crystallize or you've injected your laboratory mice with a mislabeled syringe and they all die. Weeks or months of data are lost. To top it off, you find out that you've made a mistake in your statistical calculations and a year's worth of experiments are worthless. Gather a group of seasoned scientists together in one room and they will tell you horror stories like these and more. When something like this happens to you (and in all likelihood it will), what do you do, how do you cope?

Setbacks in the lab – and in life – are inevitable. It's how we deal with them that will turn a setback into an opportunity for growth. If you think of setbacks as not being failures, mistakes, or wrong turns, but rather a chance to learn and grow, you will be much better equipped to put yourself back on the right track.

The Cold Reality of Trial and Error

Your experiment worked beautifully the first time you tried it, but now you can't repeat it no matter what you do. You're tearing your hair out and losing sleep. The experiment was flawlessly designed, elegant in its construction, and the results you obtained fit beautifully with your hypothesis. And now nothing, nothing you do produces the same result.

Now might be a good time to remember that much of science involves trial and error. And it's an unavoidable fact that you will make a number of errors and false starts before you're able to uncover even a glimmer of truth. Science proceeds in fits and starts. There are no quick fixes, no overnight successes. The nature of scientific discovery requires that it proceed in its own time. Experiments that need to follow the timing of the natural world cannot be hurried, even if you do have a deadline looming.

Keep in mind, too, that it is virtually impossible to avoid surprises, unexpected results and setbacks in the lab. If all research proceeded without a hitch, scientists the world over would be able to skip the endless rounds of experiments and go straight from hypothesis to publication without breaking a sweat. And take heart from the fact that many things will go right, so try not focus on all that has gone wrong. Also, it helps to remember that a negative result from one or a series of your experiments, may be as valuable as a positive result.

Part of your training in learning how to 'think like a scientist' involves dealing with the inevitable setbacks that will occur, and learning to cultivate the virtue of patience. And you must do this with a fine sense of balance: being able to see the big picture, as well as glory in the small steps forward along the way.

So while the goal of your lab may be to find a cure for cancer or to understand the underlying mechanisms of a genetic disease, this goal is not going to be reached overnight or even next year, or very likely not even five years from now. Some scientific progress and so-called breakthroughs, occur over decades of hard, painstaking work.

But notwithstanding all this, if you feel that setbacks in the lab are taking their toll on your confidence, a logical approach to identifying the problems will help you put setbacks in perspective, turn them into learning experiences, and boost your confidence.

Identifying the Setback(s)

A setback can be defined as an event or occurrence that prevents you from achieving your goal (a failed experiment, a string of failed experiments, contaminated cell cultures or animal models, badly calibrated machinery leading to loss of data, etc.). To help you identify what your setback is (and how to recover from it) try answering as best you can the following questions (it helps to write them down).

1. What is your setback?
2. What (in your own words) have you failed to achieve?
3. What mistakes have you made?
4. Who, if anyone, has disappointed you? (your colleagues, supervisor?)
5. What do you regret doing or not doing (in relation to the setback)?

Now review your answers and explore your negative emotions and thoughts (are you feeling overwhelmed, over your head, sad, frustrated, angry?). Try not to take it personally. In other words, don't let the fact that you are experiencing a setback make you think that you yourself are a failure.

Take Action

When you're depressed or frustrated about your circumstances, it's easy to turn to self-destructive activities such as over-indulging in alcohol, junk food, or excessive TV watching. This is not to the time to eat your body weight in ice cream or drown your sorrows in drink.

First, ask for support from those around you. Talk to colleagues, friends, and family about your concerns. Then try to find concrete ways that will get you back on track in the lab. Talk to older scientists, your mentor, and your supervisor. Chances are, all of them will have similar stories of frustrations and setbacks.

Hopefully, the setbacks you are experiencing are just bumps in the road, not full-blown obstacles that will prevent you from reaching your goal. When you feel better, try to put things in perspective. Frustrations and setbacks are a part of life. It's how we deal with them that counts.

Tips for recovering from a setback

You're halfway to a solution once you acknowledge that you're stuck and something has to be done to get your research back on the road to recovery. Here we offer a few practical tips for getting past the point of acknowledging there's a problem and moving towards a solution.

1. *Take care of yourself*. Most likely you've been putting even longer hours into your work in order to recover from your setback. But running yourself down physically and exhausting yourself mentally will only make you feel more miserable and hopeless. Regular meals, plenty of sleep and lots of stress-reducing exercise will go a long way towards getting you back on track.

2. *Think outside the box*. Creative solutions require out-of-the-box thinking. So far, what you've been doing has not been working, so it's time to take another tack. You may need to change your experimental plan and work on something different. Perhaps you will even need to take more time to finish your PhD work than you had planned. Perhaps you will need the help of a Post-doc or more senior scientist to help you get your complex experiments going again.

3. *Involve others*. Although it will take some courage to admit to others that you are experiencing serious setbacks, you need the people around you now more than ever. Friends and colleagues can offer the moral support you badly need. Having someone who can listen to your problems (and even better, offer useful advice) will be invaluable on the road to recovery.

4. *Cultivate the art of patience*. It takes time to recover from a setback. Your problems will not disappear overnight, so it's important to cultivate the art of patience and being kind to yourself. Accept that it will take time to get back on track again. Focus on the things that are already going better, rather than on all the things that still need to be done. Take one step at a time and remind yourself that 'Rome wasn't built in a day.'

Should You Stop All Together?

You wake in the middle of the night – night after night – and a single thought weighs heavily on your mind: '*Things are not working out. Grad school is not what I thought it would be. I don't really want to be a scientist after all. Maybe I should quit altogether.*'

Life is fluid. Peoples' ideas about themselves and their place in the world change from one year to the next. You started graduate school all fired up, anxious to get on with your research and your career, but now you're not so sure anymore. It's not just a question of a few lingering doubts that drift through your head at the end of a bad day. We all have those. But if they are persistent and impossible to ignore, you may need to consider the possibility that going all the way to the end of your PhD may not be right for you. Should you quit? The answer to this question will be different for everyone. So much depends on who you are as a person, what your goals are in life, and how much you've already invested in the process of getting a PhD. If you're still in your first year and you're having serious and persistent doubts that you've made the right choice, it would be a good idea to sit down and talk to someone you trust (not your supervisor at this point – why set off alarm bells if you don't have to?). It's not too late to change your mind and move on to something else. If you're more than halfway toward your PhD, however, your decision will be more complex. You'll have to weigh the balance of losing the time you've already invested, with your desire to change careers. Keep in mind that having a PhD doesn't mean you have to go on in life as a bench scientist or work your way up the ranks of academia. There are many different career paths you can follow, from jobs in policy making, journalism, communication, teaching, and consulting. The list is practically endless. So if it's just a matter of having decided that you don't really want to be a scientist after all, it may still be worth getting your PhD and making use of the degree (and the title of 'doctor' that goes along with it) in another job area altogether. You may be surprised how much value your PhD is, even outside the world of science.

Saving an old master painting: a set of experiments fails and the team faces a major setback

For several months, Yousef and Isabel have been making measurements on a paint sample using the SIMS technique. Isabel has also been performing other types of spectroscopy, including IR spectroscopy and UV spectroscopy.

When they begin to analyse their raw data, however, both discover that the results they had been hoping for have not materialized. This represents a major setback for the team and both of them need to rethink their approach. Even Peter is suffering from this delay as he will not be able to make any further progress with the restoration until he learns more about the composition of the original paint and its degradation products. Isabel takes the setback personally and feels that the poor results are due to her own failings in the lab. Yousef is more philosophical about this downturn in events. 'You win some, you lose some' is his take on the situation. Better to just get back in the lab and get on with it. Isabel starts to have some serious doubts about her own abilities and is not sure that spending more time in the lab will fix the problem. Rather than jump back into things, she decides to take a couple of days away from the lab. She spends some time with friends and doing some fun activities to help recharge her batteries. Her friends convince her that setbacks are common and that she should not take it personally. When she is ready to get back into the lab, she finds that Yousef has drawn up an action plan for how to proceed. Peter has dealt with the situation by reading up more on the chemistry of paintings. Even though he's not doing any work in the lab himself, it helps him to feel more a part of the project. It also makes it easier for him to talk to Yousef and Isabel about their frustrations in the lab.

Chapter 8
Mentors, Leadership, and Community

If your actions inspire others to dream more, learn more, do more, and become more, you are a leader.
– John Quincy Adams

One of the best things you can do at the start of your scientific career is to find a mentor. A wise and caring mentor can mean the difference between wandering around aimlessly or striding purposefully down the path of academic life and beyond.

But don't you already have a mentor, you may wonder? Won't your research advisor play that role? Perhaps, but mentors and advisors aren't usually the same thing. For one thing, an advisor directs, a mentor guides.

If your research advisor is a natural mentor and is willing to take on that role in your life – and if that relationship works for you – count yourself lucky. Not every graduate student is fortunate to have such readily available guidance and counsel from a more senior person. So, chances are you'll need to look beyond your lab to find a good mentor. What should you look for, whom should you ask, and how can you help your advisor – and yourself – be a good mentor?

Mining for Gold: Defining Mentorship

Before you start looking around, you first need to take stock of what a good mentor is and what you hope to get out of the relationship. A good mentor has many characteristics but must first and foremost care about your professional development and have an interest in guiding younger scientists as they move through their careers.

This sounds time-consuming, and it can be. Why would anyone want to take time out of a busy schedule to mentor you? It's not all about 'taking' on your part. Many good mentors cherish the role of guiding younger colleagues. They gain something by giving back to the community of professionals from which they themselves were nurtured. Now that they've moved up in their careers, these scientists believe it's time to help others make the trek to the summit.

Mentorship is a lot about experience and wisdom. So it goes without saying that a good mentor will be someone who is further along on the career path than you are. Before approaching another person and asking them to act as your mentor, however, you need to think carefully about the kind of person and professional you wish to emulate. On a more specific level, is there someone whose career choices you admire? Who has a great work/life balance or is particularly good at getting work published in top-tier journals?

Importantly, a good mentor should have no ulterior motive in helping you (beyond the intrinsic satisfaction that mentorship provides). He should be able to help you meet your own goals (not follow his own agenda) by providing you with support and guidance, modeling successful behavior, introducing you to a strong network, and helping you identify your strengths and weaknesses as a scientist and a person.

Choosing a Mentor

When choosing a mentor, you'll need to be honest about your own needs and what you think a mentor can do for you. Do you want your mentor to offer you regular advice on how to negotiate graduate school and your career beyond? How specific or general do you want this advice to be, and how much of a time commitment will you require? Do you want your mentor to offer you detailed career and networking advice? Or are you just looking for someone who is a good listener and can act as a sounding board when you find yourself on shaky ground?

If your research advisor is also your mentor, you may want to establish clear goals for your relationship as both a PhD student and a mentee. For example, you may want to meet on a regular basis just to discuss issues outside your research. A good, comfortable relationship with your advisor, as well as a certain amount of personal chemistry, will be key for the mentor/mentee relationship to flourish.

But what if your research advisor isn't able or isn't willing to act as your mentor? If you find yourself in this situation, you need to take the initiative and find someone else. The first place to start is your own lab. How about a Post-doc or even a fellow PhD candidate who has more experience than you in the lab? If no one in your lab is a suitable candidate, someone else in your department may be. Some institutes even have a mentor program in place for those who are unable to find a mentor for themselves. Even if such a program is in place, however, you'll still have to do some work. Mentor/mentee relationships are largely personal, so it's important to have a mentor for whom you have great respect and warm personal regard.

If you do look outside your lab, be sensitive to possible rivalries or politics between research groups. Even within the same institution, many lab heads are in competition with each other for funding, lab space, and equipment. You won't want to risk angering your advisor by seeking guidance from a direct competitor. The same is true if you consider possible mentors in your field at other institutions; you may collaborate with them on some projects, but they could still be seen as a competing lab.

When you've identified one or two individuals who could act as your mentor, it's up to you to approach them. Some people may feel flattered that you've asked for their guidance. Others will turn you down out of fear that mentoring will take too much time, or that you will become overly dependent on them for all your decisions. Don't be hurt if your preferred mentor turns you down. It's most likely not personal, so be gracious and move on to someone else suitable.

Once someone agrees to be your mentor, hold up your end of the relationship by respecting your mentor's time and professional responsibilities. You and your mentor should decide how to move forward and how much interaction you will have. Perhaps you'll meet over lunch once a month or touch base regularly via e-mail, or your mentor will be available whenever you have a specific issue. Whatever you decide, remember that your mentor's role is to provide you with professional guidance and to help you develop independence, not to hold your hand every step of the way.

Working with What You've Got

What do you do if you try all these things but fail to find a suitable mentor? You may want to take a second look at your supervisor. Even if he or she seems less than willing, think of ways you can help your supervisor become a (better) mentor. Start by making an appointment to talk about your needs.

Recognize that time is in short supply and make it clear that you don't intend to add to their overly long to-do list. But be up front about your needs. Is it regular discussions you're after, an open-door policy, or just open lines of communication so you feel you can go to your supervisor when you need a bit of guidance and support?

Encourage your supervisor to involve you in group meetings and discussions, and state that you are willing to do whatever extra things need to be done to learn and grow in your field. Volunteer to give a presentation to the department, or offer to spend time with a visiting scientist as a way to expand your network. When it comes time to write your first paper, offer to write the first draft and meet with your supervisor for comments and suggestions.

Develop a Community of Peers – or Become a Mentor Yourself

Professional success doesn't begin and end with having a mentor. Your time in graduate school is an excellent chance to strengthen your professional and social networks and create a community of your peers. Some of these professional relationships will develop into lifelong friendships and be a source of support throughout your professional life.

Be a leader among your peers. Participate in group meetings and encourage quieter members to speak up. If you don't already have one, start a journal club in your group and invite others in your department to join. Set up social activities or team-building activities to help strengthen relationships outside the lab.

As you move up the lab food chain, become a mentor yourself by offering to supervise an undergraduate's research project.

Offer to teach when possible or provide tutoring sessions for undergraduates interested in pursuing an advanced degree.

As you progress through your career, you'll find that the mentoring you received as a graduate student and Post-doc and the networks you developed as a young scientist will provide both a firm foundation and a strong scaffolding for your career to grow. When the time comes for you to mentor others just starting out, use your insights and hard-earned wisdom to give junior colleagues a boost. It's also another way of giving back and saying thank you for the help you received early in your career.

Chapter 9
How to Get Along with Your Lab Mates, et al.

I used to think anyone doing anything weird was weird. Now I know that it is the people that call others weird that are weird.

– Paul McCartney

Working towards a doctorate requires collaboration with others. Your supervisor, a Post-doc in your group, fellow PhD students, the lab assistant, the computer expert, the technician from the workshop – they will all contribute to your thesis in one way or another. No man or woman is an island, so you'll have to deal with the people around you, whether you like them or not! With some of them you will have a natural fit, and the collaboration will be pleasant and productive from the start. Other people, well – they may be harder to deal with. They may have different opinions about planning, be more outspoken than you are (or less), stick too much to the details, or are unimaginative when looking at the big picture. With the aid of a simple tool this chapter aims to help you to understand others (and yourself) better, how they operate and what makes them tick. Then we talk about how your work can benefit from the inherent differences among people.

Creating a pleasant and productive environment for collaboration with both your natural friends and those you are more or less obliged to get along with will make your life as a graduate student that much easier.

How to Get the Help You Need from the Others on Your Team

To make your thesis research a success you need the help of others. If you assume this support will happen automatically, you might end up disappointed. Not everybody will line up at your doorstep to help you. Despite all your efforts, it may seem that some people are incapable of being any help to you because their way of doing things is so different from yours. Usually we blame these differences, or frictions in temperament, on people having different characters. Often we just accept the lack of rapport and cooperation from another individual (and usually blame the other person in the process – after all, it's never our fault!) and look elsewhere for help, or we try to do everything by ourselves. By working alone your progress will slow down, and the final result of your efforts might be of lower quality. This chapter describes how people – each with his or her own unique personality – can be the key to your success, if you learn the secrets of communicating and working well together. Once you understand what drives other people (and yourself), and accept that we are unique individuals with strengths and weaknesses, your collaboration can be extremely powerful. In fact, the progress of your PhD research will speed up more when you collaborate with people that are different from you, than with those you have a natural affinity with and who have similar strengths and weaknesses.

You, Me, Everybody

There are some people you just can't seem to get along with (no matter what you do) because they seem to have a whole different agenda than you do – maybe even an axe to grind. For some reason they are not interested in making the project a success. This chapter is not about them (see more about dealing with difficult people in Chap. 10). Dealing effectively with true problem characters is outside the scope of this book. More often, however, some of your lab mates will be different enough from you to cause a bit of friction. While they are just as much as you willing to make the project a success, they go about things in a different way. These differences might cause so many problems that you are unable to function effectively as a team, and the progress you expect fails to materialize. But no matter how hard you try, chances are slim that you will ever be able to change the behaviour of others. It is equally unlikely that you will be able to modify your own significant character and personality traits. What you can do however, is be aware of what motivates other people (and yourself) and respect all the ways that different people approach the same problem.

So what is it that makes people act differently in a team? Each of us is unique, but certain aspects of our personality make it easier to feel more comfortable with some people than with others. In order to make sense of human behaviour, psychologists have attempted to categorize these key aspects of personality in a variety of ways. For practical purposes we have chosen to illustrate the categorization of team members' personalities using four personality-preferences as introduced by Myers and Briggs in the 1950s. Following this somewhat oversimplified, but practical scheme, we can gain greater insight into others and ourselves. In the following paragraphs we discuss the different qualifiers of our preferences. Next we discuss how to identify which type you are and which type can be assigned to those around you. Finally, and most importantly, we discuss how you can get along with different personality types and even benefit from the fact that other people are different from ourselves! In this way you can build on your complementary skills rather than trying to turn everybody into a carbon copy of yourself.

MBTI: getting at the heart of personality

In 1920 the psychologist C.J. Jung made the observation that people are fundamentally different, and suggested that 'for all practical purposes we can be categorized by "function types"'. In the forties and fifties Jung's ideas were further refined by Myers and Briggs. They came up with four qualifiers that determine the basis of our behaviour. In the course of our lives these qualifiers do not fundamentally change. A component of this theory is that people are fundamentally different and will behave differently when operating in a team (a team can be two people). Here is where you, as a PhD student, come into play. In order to make your PhD project a success, you will need the help of others. Whether you like it or not you will have to cope with those others as being different from yourself. Understanding the different ways people behave is a first step in working together. As discussed in some detail in this chapter, Myers and Briggs devised the following categories to describe character: individuals are either (1) introvert (**I**) or extrovert (**E**); (2) driven by intuition (**N**) or sensation (**S**); (3) a thinker (**T**) or a feeler (**F**); and (4) finally you are either a planner who wants to draw conclusions (**J**udge), or are you more comfortable in an unstructured environment and want to keep things open (**P**erceiver). Altogether there are 2 × 2 × 2 × 2 combinations possible, hence 16 Myer-Briggs types. Scientists are often (but not always!) found in the NT sub-class of this scheme. For further details (and to determine your type by taking the test) take a look at this website: www.personalitypathways.com

How You Get Energized: Extrovert vs. Introvert

The definition of Introvert and Extrovert is slightly different than the one you might be familiar with. In the MBTI classification the key question here is where you get your energy from. Do you get energized at the end of a long day by a social event (E), or do you recharge best by having some quiet time to yourself (I)?

In meetings we all alternate between (inter-) actions and reflections. We talk, listen and think, and talk again. Most (E's) have a tendency to act first, and then reflect, followed by action again. While (I's) start with reflection before they go into action. So E's talk, think and talk, while I's think, talk and think again.

How You Think: Intuition vs. Sensation

The way you think about things is split into two preferences: sensation (S) -preferring people are fact based. They recall facts from the past, rely on facts in the present and want to know the facts for the future. This is in stark contrast with those preferring iNtuition (N, the I-label is already given to introvert). They recall the past in terms of patterns, and dream of exploring the future with all its possibilities, the details of the present interest them very little. While sensation-driven people look for practical solutions based on past experience, those who are driven by intuition are more interested in exploring new ways to get towards the goal. Intuitive thinkers are not hindered by the fact that their thoughts are based on assumptions rather than facts.

Are Your Decisions Driven by Objective Arguments or Feelings?

When it comes to making a decision, we tend to combine factual arguments and value judgements. Thinkers (T's) are more likely to choose or make decisions based on impersonal information. The logic behind the decision is more important than the impact the decision might have on others; conflicts are natural for thinkers. In contrast, feelers (F's) instinctively take into account the impact a decision may have on others. Factual (and unfeeling) data have little influence on their decision-making process. Avoiding conflicts is an important motivator in a Feeler's decision-making process.

The MBTI preferences are not gender specific in general. The F vs. T preference is the only exception. Slightly more women are Feelers than Thinkers, while for men the opposite holds true.

Unstructured Team Members vs. Planners

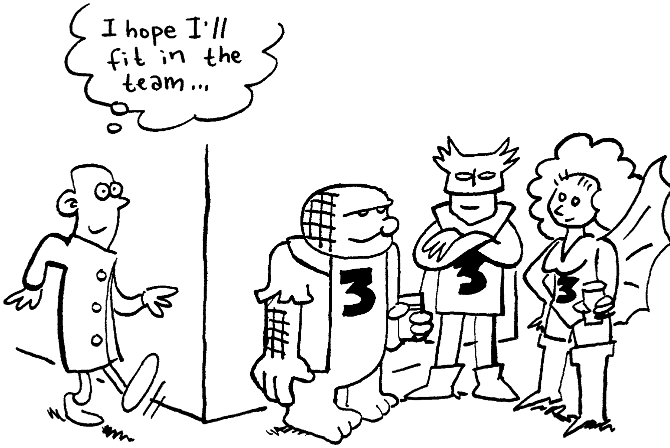
The fourth and last category in the MBTI classification scheme concerns the way a person organizes his or her actions. Some of us like to plan our actions in terms of tasks and targets and those people are classified as having judging (J) characters. Others have a preference to multitask and plan along the way. Those characters are known as perceivers (P) and enjoy the unstructured process in which the final goal only becomes clear towards the end. While J's dislike stress and try to avoid it by planning their activities, P's work best under some time pressure and get energized once the deadline is approaching. Mid-term results are most easily measured for the J's. They tend to have finished half of their tasks according to plan. In the meantime, P's have gathered lots of information and may have been working on many tasks, but it is difficult to see how far they have gotten in reaching their targets.

Which Type Are You?

Now for the fun part. In order to benefit from the MBTI classification scheme you'll first need to know your own type. The short description given above might give you an initial hint. To make a more thorough check, you can answer the official MBTI® instrument questionnaire at www.personalitypathways.com.

How to Collaborate with Your Counterpart

Although the MBTI is meant to classify individuals in one of the sixteen categories, and every category or type is different from the fifteen other types, we'll make a little shortcut here. For the four classifications we'll restrict ourselves to discussing the differences between team members with opposite characterizations, thus E vs. I, S vs. N, T vs. F, and J vs. P. Once you know the differences between yourself and others, our suggestions on how to get along best with each different type will help improve your working relationship with many different types of people.



Extroverts vs. Introverts

The ways other people think and act will already be apparent during your first group meeting. Once some new issue is put on the table, the E's in the team start immediately discussing it. They develop their opinion while the discussion is going on. The I's in the team need to think first before they discuss the issue. This state of affairs might lead to mutual irritation. The extrovert team members have the feeling that the introvert team members are not involved, since they are not yet participating in the discussion. At the same time the I's may get irritated by the E's because they start shouting out all kinds of ideas before they have even thought them through. To solve this difference in style, each type needs to respect the others' approach. So let the E's talk, it is their way of developing an opinion. What E's say in the beginning of the meeting may not reflect their final point of view. Give the E's a chance to change their minds. At the same time E's should ensure that the I's get a chance to contribute a little later after they have done some initial reflection on the new issue. If the leader of the discussion is an extrovert, she/he might overlook the 'shy' introvert team members. Since they have a hard time breaking in during the meeting, the I's keep thinking and listening. Eventually when the I's have an almost complete picture, they start talking. This style of communicating is often less appreciated than it should be. The others feel that the I's should have put their ideas on the table earlier in the discussion. It is almost arrogant not to say anything and throw in a full solution at once, feel the E's. Both E's and I's should make sure that introvert people get involved early on during the meeting. By nature, introvert people cannot contribute right from the beginning, but the delay should be minimal. During the break of a meeting everybody needs to energize again. The fact that the I's are going to sit aside with their coffee does not mean that they are not interested, they just need to charge their batteries in isolation or perhaps with one other person. The E's are motivated by the outside world and usually talk in groups during the break. Whichever type you are, be respectful of the other type and try to see the world through their eyes.

Intuition and Sensation Are Both Necessary for Success

Misunderstanding and bad communication between iNtuitive thinkers and more Sensation-oriented people are often the source of conflicts in teams and consequently result in a lack of progress. This is a particularly bad situation because most projects need both types of people to be involved. The absence of sensation-type personalities on a project can still yield nice results in terms of the big picture, but the project will be desperately lacking the necessary scientific data or facts on which such a picture should be based. On the other hand a team of only sensation-type people will often fail to discuss issues such as what the data is good for or what they are out to prove in the first place. The reasons sensation- and intuition-type of characters have difficulties working together is quite simple. The dreams and schemes of possible future projects of intuition-driven people are constantly being interrupted by factual information brought forward by sensation-driven people. These facts may prove that the big picture is impossible. On the other hand, the carefully obtained facts based on scientific findings by the sensation-type scientist are downplayed by the intuition-driven researcher who considers them just a bunch of details.

The bottom-up approach from the sensation researcher would benefit quite a bit from the global top-down picture of the intuitive minds. At the same time, the facts brought forward by the S can be essential to verify or falsify the initial hypothesis from the N-type team member. Again, respect and understanding for people with the opposite preference is key to avoiding conflicts in a team. Appreciating that the best solution can only be found by the team if members with opposite preferences work well together is a major step towards success.

Feeling Is More Important in Science Than Thinkers Want to Believe

Scientific answers are based on facts, so facts are essential in the eventual result of the scientific process. It goes without saying that thinkers are probably more attracted to this type of work. However, as has been argued before, to make progress in science, teamwork is needed. To get teams working well together many compromises will have to be made. Such solutions are not only based on the average point of view but will be affected by personal relations and personal perspectives. A Feeler can play an important role in making sure that the team works in harmony.

Science can seem very objective at first glance: results are results and should not depend on the way you think about them. The conclusions you make are fact based. However, the impact your conclusions have on the scientific community can very much depend on your presentation. Presenting conclusions is quite a subtle thing, in particular if you want to get some recognition for your work. If you are too modest, the scientific community will not notice your contribution, and you will get little credit. If you present your findings with too much enthusiasm, and you down-play the work of others in the field, you might easily make enemies. These people, in turn, probably won't credit you for your contributions. Again, the contributions of a Feeler can make a big difference in how successful you are in your work, no matter how objective and analytical you think a successful scientist should be.

Judgers and Perceivers Have Crucial Roles at Different Times in the Project

Judgers and Perceivers will use different approaches in planning a new project. They might get irritated by the approach of their counterpart, but in a respectful collaboration a mixed team has an enormous advantage over a team with just P's or J's. Before they even start on a project, Judgers will want to make a plan in which the goals are defined and the routes towards that goal are outlined. For instance, the count-down plan described in Chap. 15, will probably appeal more to Judgers than to Perceivers. Typically Judgers are restless at the beginning of a project when the plan is not ready. Once they know how they want to execute the plan, J's will start feeling more relaxed. With Perceivers, the opposite is true. In the beginning P's start gathering information, seemingly without a plan. They are quite flexible and relaxed. Towards the end of the project, when J's have already finished 90% of the tasks and move on towards the last bit, the Perceivers are just becoming very active as they wrap up all the loose ends.

These differences in approach can easily be a source of conflicts. Perceivers might get irritated by Judgers jumping in early to force the outcome (by making a rigid plan), while Judgers might feel that Perceivers have accomplished very little halfway, since they have not produced tangible results. Perceivers can benefit from the structure that a Judger brings to a project in the beginning. However, if the final goal is changed when the deadline is approaching, Judgers tend to panic: all their hard won results may have lost their value. At that point Perceivers are at their best, their adaptive and flexible way of working allows a reorientation of the plan even as the deadline is approaching.

More formal team meetings tend to have an agenda. Such an agenda is very important to J's, while P's pay little attention to any agenda. If the Chair of a meeting has a Perceiving character, she/he might forget to stick to the agenda, or even to make one. This makes Judgers quite nervous, and unproductive. A J has a hard time starting on any project or meeting if there is no plan. In contrast if the Chair of the meeting is a J she/he might stick quite exactly to that plan, while the contributions of the Perceivers, who like to wander around a bit, might fit less well into the rigid scheme.

A Varied Mix Makes a Good Team

In the above sections we discussed individual preferences and how they interact, rather than a combination of preferences (known as temperaments) such as SP's and SJ's. We refer the reader to the literature for this next level of MBTI classification. The discussion of the role of opposite characters in a team has already illustrated the idea that team members with different preferences contribute in different ways to the final result. Knowing your own strengths (and weaknesses), as well as those of others, is the first step in getting the most out of your team. Respecting each other and your unique working and communication styles will result in a successful team relationship. It may help to know that some organizations charged with setting up professional teams to execute complex tasks make a point of creating a team of people with different preferences.

The golden boy syndrome (he – or she – who can do no wrong)

Okay. So much for personality types. They're a great tool for helping you identify your own working style and that of the other people (including your supervisor) in your lab. But there is often a situation, more common than many people think, that can cause friction in your research group, and understanding personality types will not do much to help solve it. This is the Golden Boy, or Golden Girl Syndrome. In many groups, one of the PhD students (or sometimes a Post-doc), tends to stand out. The Golden

Boy or Girl produces data that go straight into high-impact journals. During group meetings, he or she seems to come up with all the bright suggestions. The head of the lab (your supervisor), praises this individual to the high heavens, and tends to spend all of his time with him or her. This further improves the contributions of the Golden Boy, leaving the others trailing in his wake. So how to cope? First you need to accept that we are not all created equal and that the Golden Boy or Girl may truly be exceptionally talented. Much of the attention this individual receives, however, may be less due to talent and more to the force of their personality. There is no point in fighting this or trying to get an equal amount of praise and attention for yourself. This strategy will most likely backfire on you anyway. However, since you do deserve a fair share of your supervisor's undivided attention, make a point of asking for regular meetings to discuss your work. These could occur every month after you've filled in the monthly progress monitor and have concrete issues to discuss. During your meetings with your supervisor, make clear to him or her that you appreciate their help. Make clear that you, too, are making progress in a particular area. Don't mention the Golden Boy, and certainly don't try to complain about this individual or put him down, but don't allow him to steal the spotlight and all the credit all the time. You deserve respect from your supervisor, as well as the other members of your group. So stick up for yourself and make sure you get your share of the limelight.

Saving an old master painting: the team learns how to overcome their different styles of communication and work effectively together

At some point early on in their collaboration, Isabel, Yousef, and Peter realize they are a special kind of team. They do not belong to the same research group and each has a different supervisor. They have been brought together by their common research goal, and the ability to work together in a cooperative manner will be key to their success. Isabel points out that they should understand and respect each others' different working habits and approaches to solving scientific problems. Their fragile collaboration, without a formal structure, could easily fall apart due to conflicts. Yousef agrees with Isabel, and suggests they use a model to understand their behaviour and internal driving forces. So they decide to do the MBTI test and discuss the outcome.

Of the three, Isabel is the least interested in taking such a test to characterize their personalities. She joined anyway, because she liked the idea of discussing together their behaviour as a team. The test indicated that **Isabel** is an **ESFP**, an extrovert, sensing, and feeling perceiver. Initially Isabel disagreed with being identified as a perceiver (score 60% P, 40% J). Isabel argued that she organized her office properly, a typical signature of a judger. On second thought, thinking about her private lifestyle, she realized that her organizational skills did not come naturally. Isabel felt forced to organize things to do the complex experiments properly. Anyway, she recognized herself in the description of ESFPs. They are open and enthusiastic towards the world around them. They seek the company of others and have a deep concern for friends.

Yousef, who introduced the MBTI test to the team, enjoyed taking it. According to the test **Yousef** is an **ENTJ**, an extrovert, intuitive and thinking judger. Being classified as an extrovert surprised him somewhat, since he did not see himself as having an extremely outgoing personality. However, in terms of acting first and then thinking (E), vs. thinking first (I), he felt he was definitely an E. Yousef recognized himself quite a bit in the description of ENTJs: he enjoyed being in charge and managing his projects with conceptual models. For instance, the goal setting strategy used in the monthly progress review appealed to Yousef.

Peter was curious to find out why some things seemed to work very well in their team, while others failed. He wanted to fill out the questionnaire alone, however, despite the suggestion of the other two to do the whole exercise together. The MBTI test indicated that **Peter** is one of the few **INTP**s, an introvert, intuitive and thinking perceiver. The thinking part was new to Peter, he just never realized that his seemingly detached behaviour was described by the thinking type. Peter had no problem with the typical INTP description: as he was driven to conceptually understand phenomena, was a little detached as far as people were concerned, but was an excellent teacher, in particular for advanced students.

Once they all knew their MBTI classification Isabel, Yousef and Peter discussed their differences and how to make the best use of them, including how to cope with the 'think first' (I) attitude of Peter, the 'attention to details' (S) characteristic of Isabel as well as her open and enthusiastic attitude towards others (F), and Yousef's tendency to organize things up front (J).What they learned most from the whole exercise was that it is essential to the success of the team that they be different, and to recognize that they are stronger when combining their individual strengths.

Chapter 10
Group Dynamics: Dealing with Difficult Colleagues

Man needs his difficulties because they are necessary to enjoy success.
– Abdul Kalam

In the last chapter, we talked about how to get along with – as well as work alongside – people with a variety of personality types. In this chapter, we take a closer look at how to cope with labmates and colleagues whose behaviour could be labelled as 'difficult'. By difficult we mean the kind of person who has a severe personality quirk, and can toss major obstacles your way that create roadblocks to your progress. Why are some people difficult to work with and be around? We'll leave the answer to that thorny question to the psychologists and psychiatrists among us. In the meantime, if you've got a difficult individual in your midst, you need clear strategies to minimize any potential damage they can cause to your progress and your career.

If you learn how to cope with contrary colleagues early in your career, particularly in the competitive atmosphere of a lab, you'll develop valuable coping and people-management skills that will serve you time and again, wherever your career path takes you.

In an ideal world, your lab would contain only bright, capable people working harmoniously together in the pursuit of scientific knowledge. If this describes your lab, count yourself lucky, because most scientists work in close quarters with at least one person who tries your patience or is difficult to get along with.

Take a look around your lab or department (and in a mirror, too!) to see if you recognise any of these 'types' who have the potential to sink your career or your self-esteem:

- **Star Researcher** (a.k.a. The Hotshot): The Star Researcher is on the fast track to success – or so he thinks – and has an ego to match his ambition. He or she dominates group meetings and touts his own success while belittling the contributions of others. To make things worse, your supervisor gives him the best projects and showers him with attention and praise.
- **The Energizer Bunny:** This dynamo seems to live in the lab. He's there when you arrive in the morning and when you leave at night and seems to run twice as many experiments as anyone else. All this would be fine if it weren't for his tendency to treat with derision anyone who doesn't show the same fierce dedication that he does.
- **The Stealth Bomber:** The Stealth Bomber attacks without warning. Right in the middle of a group meeting or department gathering, she'll say something about your latest failed experiment or cock-up in the lab. The Stealth Bomber operates best in front of an audience and loves nothing more than to ambush others.
- **The Know-It-All:** Without any prompting, this person will launch into a lecture on the right way to do a procedure or protocol or look over your shoulder and announce that what you're doing is 'all wrong.' 'Here, let me show you' is the Know-It-All's mantra as he plucks a pipette from your hand.

- **Woe Is Me:** Ah, the chronic complainer. Everything in this person's life is grist for the mill. Experiments aren't going well, she isn't getting along with her supervisor, there are problems in her personal life, and the equipment is not up to par. If it exists, this individual will complain about it.
- **The Hornet:** A prime candidate for anger-management coaching, the hornet will explode with wrath for no reason at all or if confronted, challenged, or rubbed the wrong way. You and everyone else in the lab walk on eggshells in fear that The Hornet will deliver a nasty sting.
- **Sneak Thief:** The Sneak Thief borrows your equipment and expertise, picks your brain for ideas, then refuses to give credit when credit is due. When the Sneak Thief has a success, he'll say he did it all on his own.
- **Who, Me?:** This person has a hard time keeping commitments. Say that you've decided to work on a project together and have divided up the work. Then it comes time to deliver: 'Who, me? Was I supposed to do that experiment? Order those supplies? Calibrate the machine?'

Strategies for Coping

Perhaps you're the type of person who usually turns the other cheek in difficult situations and prefers to avoid conflict at all cost. If that's the case, your strategy so far has been to ignore the difficult person. But in a lab situation, avoiding the difficult person will only make matters worse: He or she will go on being difficult, and you will feel increasing discomfort, not to mention resentment. Bringing the problem to your supervisor's attention may seem like another option, but not all supervisors are good managers.

So how do you deal with a difficult co-worker? Each type of person requires a different approach, but there are some simple things you can do to diffuse the tension. For some types of difficult behaviour, the best approach may be to talk to the individual about how his behaviour affects you. For other types, more subtle and oblique ways of dealing with the problem behaviour may be required.

When dealing with the Star Researcher, it's easy to get defensive: 'Why does she get all the attention?' In this case, though, the best response is no response. Confrontation may cause things to escalate, and you'll end up with a powerful foe. When alone with your supervisor, resist the temptation to mention your irritation with the Star Researcher's ego; criticism from you will seem like sour grapes. Second, concentrate on producing great work. When you submit your own (dazzling) work for publication, the peer-reviewers won't know or care about the Star Researcher's outsized ego. It's the work that counts in the end, so make sure yours is top-notch.

To the Stealth Bomber you might say: 'During group meetings, I've noticed you habitually bring up problems I'm having with my research. I understand that this makes for dynamic discussions, but I'd feel better if I could bring up those issues myself.' The advantage of this approach is that by explaining why a certain behaviour upsets you, you focus on the behaviour rather than the individual. By being direct but subtle, you also allow the Stealth Bomber to save face by, it is hoped, getting him to see your point of view. This approach also lets the Stealth Bomber know you're aware of what he's doing. Every time it happens, bring it up again until he stops.

With the chronic complainer, you might try adopting a stance of neutral listening rather than co-complaining and feeding the complaint cycle. For example, acknowledge what the complainer is saying by nodding and making neutral statements such as, ‘Hmm, I’m sorry to hear that.’ Let the complainer moan about how bad everything is for two minutes and then move into problem-solving mode. You might say: ‘It must not be easy to get work done when your equipment keeps breaking down. So what are you going to do about it?’ In short, reward positive action, not endless complaining.

When dealing with aggressive individuals such as The Hornet, the best way to cope with an angry outburst is to do nothing. In some cases, it is best to let such an individual rant. Remain cool and detached, and when he’s finished, walk away. Or, depending on how volatile the situation is, you might suggest that you’ll discuss the issue when he’s ready to talk calmly about it. By adopting a Zen approach and not allowing an outburst to escalate, you probably will eventually stop being a target of his anger.

The Know-It-All can be particularly irritating in the competitive atmosphere of a lab, where everyone is working hard to become an expert. One way to defuse the Know-It-All is by agreeing with everything he says. Nod thoughtfully and then introduce your own thoughts and opinions in a questioning manner: ‘Your way of doing that procedure sounds terrific, but have your ever considered . . .?’

As for the Energizer Bunny, so what if she puts in 16-hour days in the lab and runs marathons on the weekends? If that’s not your style, so be it. Embrace your positive attributes and don’t beat yourself up because you work at a pace different from someone else’s. It might help to find subtle ways to let the Energizer Bunny know that your work is just as important to you as hers is to her. If you make it clear that you won’t be intimidated by her input or output, you may even earn her respect.

Monitor Your Response

Finally, take a look at how you react when dealing with a difficult person. Do you get defensive, angry, intimidated, irritated? Or are you able to brush it off? A big part of dealing with difficult people is having confidence in your own work. Building confidence takes time, but as you start to amass a steady stream of successful experiments and publications, other people's attitudes and behaviours will matter less. In the short term, it might help to remember that difficult people often act as they do out of fear. And ultimately, because you can't really change another person's behaviour, all you can do is change how you handle it. So keep working on your own goals and don't allow others to undermine you.

Working with difficult people is never easy. But if you learn how to cope with contrary colleagues early in your career, particularly in the competitive atmosphere of a lab, you will develop valuable coping and people-management skills that will serve you time and again, wherever your career path takes you.

Chapter 11
The Art of Good Communication

Is poor communication with your supervisor getting in the way of your progress in the lab? Perhaps you've reached an impasse in your research and can't see a way through. Or maybe it seems that – from your supervisor's point of view – nothing you do is good enough. If you and your supervisor have different expectations of your output, and the two of you haven't spoken in months, then a lack of communication is surely holding you back.

Once settled into their projects, many graduate students are left to work things out on their own. That's as it should be, to a certain extent, as much of graduate training is focused on having you develop the ability to meet problems head on and solve them on your own. But your supervisor must ultimately approve your thesis, so keeping the lines of communication open is crucial. Don't wait until you get into serious problems before knocking on your supervisor's door. Even if your supervisor keeps her distance, as a seasoned researcher, she should be able to provide appropriate guidance, and, one hopes, a neutral perspective. Even if you feel that your supervisor tends to place his or her interests above your own, initiating communication on a regular basis will give you the opportunity to voice your concerns.

Some people are born communicators; if you aren't, and talking to your supervisor feels like talking to a wall, take heart: Good communication skills can be learned. If you're having trouble connecting with your supervisor in a satisfying way, the key to better communication is understanding your supervisor's personality and communication style, as well as your own. Everyone is different: Some like the free-and-easy approach; others like more structure. Either way, better communication is likely to involve planning and a conscious effort on your part. If communication with your supervisor is poor or nonexistent, and has been from the beginning, don't blame yourself. It's also not a good idea to try to change your supervisor's ways; it won't work. Instead, focus on what *you* can do to improve the situation.

Understanding Styles of Communication

Does your supervisor always seem to address the lab as a whole rather than each of you as individuals with different needs, skills, and abilities? Perhaps in your weekly group meeting, she scans the room, asks, 'Everything going okay? Any problems? No? Great,' and then dashes back to her office or to another meeting. This kind of behaviour doesn't make your supervisor a bad person; it may mean she is busy and perhaps insensitive to cues from lab members about the need for regular contact.

Perhaps your supervisor talks to you on an individual basis, but he's a 'hit and run' artist, tossing out a query about your progress as he breezes through the lab, and then hides behind a stack of journal articles on his desk.

If your supervisor is an assistant professor just starting out, she may spend most of her time in the lab working beside you. If that's the case, there will be many opportunities for discussions, formal and informal. And unless your supervisor is very bad at communicating, good rapport will develop naturally.

If your supervisor is established at the institution and highly regarded in her field, she may rarely appear in the lab at all. In between international conferences, she sticks her head in the door for a quick hello and may only meet with her most senior Post-doc to assess the lab's progress. If this is your situation and you feel like a 'worker bee,' with a supervisor who is remote or hard to approach, it can be difficult to speak up and make your concerns known.

But no matter what your supervisor's style, you can find ways to make yourself heard. The most valuable thing you can do is to make an appointment to talk face-to-face whenever you have something important to discuss. Even if you have lots of access to your supervisor and engage in many informal chats, a formal talk will allow you to structure your questions and clarify important issues. If you prepare well for the meeting, all you'll need is 15 minutes or so of your supervisor's time.

No matter how busy your supervisor is, plan to meet at least once a month – more often is even better – to discuss your research and other issues you want to address. Suggest a time of day when a meeting is likely to be most successful. Is he more focused first thing in the morning? Then make your appointment before he is swamped with other priorities. Immediately after lunch is another good time. Avoid making appointments late in the day, because they are likely to be canceled as other priorities press in and the end of the workday approaches.

Structured Communication is Key

Informal, spontaneous communication plays an important role in building relationships and establishing trust. Informal chats about work or other common interests can help build rapport, and the more comfortable you and your supervisor are with each other, the better. A good rapport based on trust and mutual respect can be a great asset.

It is not, however, something you can force, and you can still make progress without this kind of rapport. The most crucial form of communication takes place during regular, short, face-to-face meetings between just you and your supervisor.

Once your appointment has been set up, take time to prepare. Go to your meeting with a written list of questions and concerns. Keep them brief – no more than three issues per meeting. Be specific; it won't do any good to ask, 'So, how do you think I'm progressing?' A question like that will just encourage your supervisor to respond in general terms or say something encouraging but meaningless, or – worse – disparaging but meaningless. If you need guidance on how to move your research forward, for example, come to your meeting with two or three of your own ideas about how to proceed. Give your supervisor enough context to be able to provide you with helpful input. If you haven't spoken for a while, give him a brief summary of your most recent results.

During the meeting, take notes and jot down your supervisor's suggestions, assuming it's okay with her; some people find it disconcerting to have their remarks written down. As you chat, gauge your supervisor's enthusiasm and interest by paying attention to body language and other non-verbal cues. At the end of the meeting, thank your supervisor for her time and immediately send a follow up e-mail that summarizes what you discussed. That way, you'll have a record of your questions or concerns and your supervisor's responses. Print out the correspondence and keep it in a file, along with your original list of 'talking points,' for future reference.

In addition to your face-to-face meetings, you may want to chat with your supervisor whenever the chance arises, as well as send him informal monthly updates of your progress by e-mail. Even if your supervisor is unwilling to work with you on creating a Monthly Progress Monitor, sending an e-mail at the end of every month, with a brief summary of the experiments you've done and results you've achieved, is another effective way of keeping your supervisor up-to-date on your work. But none of this should substitute for regular, short, structured meetings with an agenda you prepare. Allowing too much time to pass between structured communications may cause your research – and your relationship with your supervisor – to veer off in a direction in which it shouldn't go.

With all the focus on structure, why bother to have a meeting? Can't it all be done by e-mail? Not really. E-mail and other electronic forms of communication are useful, but they aren't adequate. Even if you're reciting lists and focusing on facts during your face-to-face meetings, you're sending and receiving a complex set of verbal and non-verbal cues that are crucial to establishing trust, the foundation of a strong working relationship. E-mail fails to convey this crucial information. Emoticons are no substitute for real emotions. Meeting frequently and regularly with your supervisor, asking relevant questions, and documenting her input will increase the probability that good communication flows in both directions and that your research is in line with what your supervisor wants and expects.

Learning good communication skills in an unstructured environment can be a challenge. But fostering effective communication with a supervisor, particularly if he or she is a poor communicator or difficult to approach, is a skill that will serve you well throughout your career. Even if you become an independent entrepreneur without a boss, you will surely have clients and colleagues who will benefit immensely from your ability to communicate well.

Effective Communication in the Lab – A Practical Approach

Progress in your research project is by and large determined by interactions with others. Spending some time to solve communication issues can be quite helpful to smooth the way and speed up your PhD project.

During your PhD research, more effective communication will yield more helpful contributions from others, and improve the progress (time and quality) of your research project. Once you have learned how to continuously educate yourselves in improving those communication skills, you will benefit from it throughout you career.

For example, driven by comfort we have a natural tendency to drop by a friend's office in case we need a favour, while requesting help in a more formal way (e.g. by sending an e-mail) comes more naturally to those we get along with less well in the lab. While there is nothing wrong about chatting with a friend, we argue here that you should spend even more attention and energy to get things done from those you get along with less well.

So what are the ingredients of effective communication? In all cases it starts with a sender, let's say you, who wants to gets something done from someone else. To that end a message is sent to the receiver. To make the communication effective it should be done in such a way that the receiver takes the desired action as intended by the sender. As we all know it is easy to say something, however it does not necessarily result in the action we aimed for.

One can divide communications into three categories, that differ in the timescale in which the desired action will take place, and how you are learning these skills to optimize the communication. Firstly, there are short-term communications in which you ask or tell someone something in a face to face interaction what you want someone to do right now: e.g. can you please take that sample from the fridge? We are all trained in this type of communication since we are born, although the 'sample' for a young child will be a different item than that for a PhD student.

At the other end of the spectrum we have long-term communications in which either the reception takes long (it may take months or even years before someone reads an article you have written) or the action following the reception takes quite a while (while someone may listen now to your oral paper – it may take a long time before it results in follow-up experiments by the receiver or quotation in a scientific journal of your work. Fortunately most PhD students have the opportunity to give oral presentations and/or write articles about the research they have done. With feedback from your supervisor and group members you will improve your long-term communication skills along the way. In fact most people believe that those with a PhD have superior long-term communication skills.

The third category of communication takes place on an intermediate timescale: you send the message and expect actions by the receiver on a timescale of days. The communications can be sent as an e-mail; a voice mail; by a telephone call; or in a face to face encounter. We spend mostly limited time in selecting the optimal channel to get the most action from the receiver upon our message. We discuss here all four channels and how to use them most effectively. You also might want to take into account how the receiver of the message prefers to be communicated with. Some like e-mail over the distraction of having people constantly dropping by their workspace.

E-mail: While traditional communication styles have their etiquette, e-mail is often used quite bluntly. In the last two decades e-mail has replaced many other ways of communications. The general acceptance of e-mail is helped by its ease of use, the possibility to send attachments with the message and the comfort that messages are easily stored on a PC (allowing both parties to refer to the message later on).

For the sender, e-mail seems to be as simple as dropping by someone's office, and senders tend to forget that the message is read and perceived somewhere between a phone call and a proper letter. Improperly phrased lines, typed in a hurry, are easily misinterpreted by the receiver and may lead to irritations. The message and all the megabytes of attachment arrive instantaneously in the inbox of the recipient, but are not always read (many have hundreds of unopened emails), let alone an appropriate action is taken. We advise you to verify three things before you push the send button:

1. Ensure the e-mail has an *appropriate subject header* that states the actions that are expected from the people receiving the e-mail. If no action is required you can start the header with FYI: for your information. Sometimes the action is so clear that there is no need for putting information in the e-mail itself (e.g. Tuesday's progress meeting is cancelled), in that case you can close the header with –eom (end-of - message). 'Please review enclosed draft article by next week' is a good example of a header indicating what the e-mail is about (the draft of an article), what needs to be done (review) and when the sender hopes to get a response. In the main text you can politely ask for help and ask the receiver whether it suits his/her agenda to do the review within the allocated timeframe.
2. Read the e-mail over, once finished, to check for typos and, more importantly, read it through the eyes of the recipient to ensure your message comes across as meant. Restoring the damage caused by an ambiguous e-mail will take much

more time and effort than spending the extra minute to double check whether your intentions are clear.

3. Make sure your e-mail message conveys clearly what you expect from the recipients. Do this at the beginning of the e-mail, and repeat this in the summarizing statement that closes your e-mail.

In some formal circumstances it may be desirable to have your communications documented. E-mail communications are perfect for this purpose (demonstrating once more you need to be careful). Be aware that in those circumstances in which you need a formal record of your communication, you are often far away from a collaborative setting.

Voice mail: an unexpected side effect of the massive use of mobile phones is the revival of voice-mail messages. Many PhD students use mobile phones for work-related communication. Calling someone on his/her mobile is viewed as an easy way to get a message across. However, there is a fair chance that the phone will not be picked up and you'll be directed to a voice-mail box, giving you the opportunity to leave a message. Avoid starting the voicemail with a lot of uh's, and think of the message before your make the call in the first place. This will also help in the unlikely event the phone is picked-up. Once you are directed to the voicemail box keep the message short, and make clear what you expect from the receiver. In fact the voice-mail messages are quit similar to e-mail headers by stating the topic, what is the expected action and by when it should be achieved.

Phone call: while there is only a limited chance that the phone will be picked up (see above), a phone call is still a powerful way of communication. In contrast to e-mail and voicemail there is not a one-way message sent but there is interaction while sending the message. The voice of the receiver will tell the sender to some extent how the message is received and how likely the receiver will take the much desired action.

Face-to-face: there is nothing like a good old face-to-face meeting. A meeting can be a scheduled event (in which you sit together with your supervisor to discuss your progress) or a quasi incidental encounter at the coffee machine. Probably you have noticed that some very effective people spend quite some time in informal encounters. Anyway, in face to face meetings not only is the message communicated but supported by non-verbal behaviour of the sender. The actions to be taken by the receiver will - to a large extent– depend on this non-verbal support. The real-time interaction allows the sender to adapt the (non-verbal and verbal) message while sending it.

Ground Rules to Optimize Effective Communication

Since communication is so important in any job requiring the execution of complex tasks, you have probably set yourselves some guiding principles about how and when you use the above mentioned communication channels in case you want to get something done on the timescale of a day to week. Most likely you do not make a consciousness decision every time you communicate how you are going to do it. Here we give a few generic tips that might help you further improve your communication skills.

1. **Spend most time on communications with those who are the least willing to collaborate.** In any lab – just like normal life – you will get along better with some people than with others. Communicating with friends is much more pleasant than with those that are hardly willing to help you. We

all have a natural tendency to spend more time with our friends making the communication with them most effective. However, the progress of your project is often determined by the task (mini-project) on which you make the least progress (weakest link principle). Hence you should spend quite some time in the communication with those willing the least to help you.

2. **Consider the communication channel you pick given both the message and the recipient.** The type of message makes some communication channels better suited than others. If you cancel a regular progress meeting an e-mail will do the job. However if you have decided your demanding PhD project does not permit you to spend a lot of time on projects of others, it is probably a better idea (though not easier) to say this in a face to face encounter. The tougher the message the more we are inclined to use impersonal channels (such as e-mail), while a personal approach is a better choice, given the long-term collaboration you are in (remember getting a PhD takes years and you'll have to work together with the same team for all that time). It will depend on the relationship you have built up with the receiver how well a particular communication channel will work. For those willing to help you, e-mail is probably fine, while those less inclined to support you are better approached in a face to face meeting.
3. **Try to make communication a two-way event.** There is a subtle difference between a request for help and an order for support. Orders phrased as a polite request might be more effective in the end, while as a PhD student you are not often in a position to give orders anyway. The receiver will perceive your desire more as a request for help if you set up the communication as a two-way event in which you try to involve the receiver, e.g by asking suggestion for an optimal way to get the desired outcome. In face to face meetings and phone

calls it comes more naturally (to most) to get the involvement of the receiver, while for e-mail and voice mail you have to spend some effort. For instance, in an e-mail you can state that you're looking forward to the input to solve a technical problem that is frustrating the progress of your project. . .. Or you might close a voicemail by saying please let me know when this message is unclear or you believe there is a better way to achieve the goal.

4. **Combine several channels.** As discussed above all communication channels have their pro's and con's. In many cases it might help to combine channels. In some cases combining e-mail and a phone call can enforce the message as it is meant to be. A call in which you announce that you are working on an e-mail and you give the message and explain what you expect from the receiver has a higher chance of being properly handled by the receiver than just sending an e-mail to an inbox overloaded with unread messages. Also after a face to face meeting it can be very powerful to repeat the message in an e-mail (Dear supervisor, as we just discussed your agenda allows you to review my conference abstract next week, so I will make sure I will send it to you before the weekend, etc.).
5. **Verify that someone received the message and acted as intended.** Once you have sent the message (e.g. by e-mail) you might feel your job is done. That is not so, you did not send the message just to push the problem to someone else. You should somehow verify that the message is understood as it was meant and that the receiver takes appropriate actions. Sometimes this is obvious (if you can immediately see the action), in other occasions it might help to verify that appropriate actions are taken. Chasing others in an effective manner is often a subtle process that you can start by asking

that you are looking forward to knowing how the receiver plans to take the actions for the desired goal.

6. **Ask how you can help turn the message into an successful action.** Although you probably need help from others for some parts of your PhD project, sending a message is not enough to get the help. As argued above, communication on the desired action is a two-way event, but also you should probably contribute to make the desired action effective. In those cases the receiver will not solve the problem alone, so make clear in your communication that you of course can and will help where appropriate to accomplish what is needed for your PhD project.

Since communications are key for making your collaborations effective it is worthwhile to invest in your communication skills. Mastering those skills will be of great benefit to you throughout your career.

Chapter 12
Mastering Presentations and Group Meetings

The newest computer can merely compound, at speed, the oldest problem in the relations between human beings, and in the end the communicator will be confronted with the old problem of what to say and how to say it.

– Edward R. Murrow

How to Give a Great Presentation

Many people rank public speaking as their greatest fear. But talking in front of an audience doesn't have to be a scary prospect. The trick is to be prepared, know your stuff, and practice until it feels completely natural to talk about your work in front of a group.

For several months now you have been designing experiments, carrying them out, and collecting data. At some point your advisor will ask you to present your findings to others. Perhaps your first presentation will be in an informal setting, such as other members of your lab during a weekly or monthly group meeting. Or you may be asked to give a presentation to the entire department. At some point as a graduate student, (and count yourself lucky if you're given the chance this early in your career), you may even be invited to present your research at a large regional or international conference.

Let's talk first about giving a presentation to a fairly large audience. This type of talk is by nature more formal than a group meeting and requires a more structured preparation.

Get Prepared

Although giving a presentation may seem daunting at first, spending time to prepare will take a great deal of *angst* out of the process. Whether you have an audience of two or 200, your approach and general objectives are the same: getting your message across in clear and simple terms that leave your audience hanging on the edge of their seats and hungry for more.

Where to start? Not by rushing to the computer to experiment with fancy PowerPoint templates and a snazzy array of bullet points and arrows. Before you create even one slide, take some time to sketch out on paper the basic structure of your presentation. Make sure you have an appropriate framework for your talk and a logical reason for any information you wish to present. So, stop what you're doing, turn away from the computer, and ask yourself three things:

1. What is the *objective* of my talk? (to highlight new data, give an overview of my research, get input from the audience?)
2. Which *main points* do I want to present?
3. What is the *key message* I want people to remember after my talk is over?

Make a list of the answers to these questions as the starting point for your presentation. Then sketch out your presentation in draft form, using keywords and bullet points rather than complete sentences. After you've done this, review what you've written. Is your presentation logical and consistent? Are there extraneous pieces of information that can be left out? Are you trying to present too much information for the amount of time you've been allotted? As a general rule, 2 minutes should be spent on each slide, so calculate how many slides you should ideally have.

Identify Your Audience

Now that you've established your objectives and made a rough outline of your talk, the next thing to consider is your audience. How can you achieve your objectives given the knowledge level and interest of your audience? How well do they know the subject of your talk? If the audience is made up of people in your own research group, their knowledge level will be very high; if the audience includes other people in your department, the level might be somewhat lower. With a general audience their grasp of your particular subject will be even lower still.

Many graduate students make the mistake of assuming that they need to tell the audience everything they have done in the lab from the very beginning of their project. Not so. In fact, this is a common error and you risk confusing people if you try to unload too much information on them at one time. Keep your talk short, simple, and to the point. It is not necessary to wow the audience with your productivity by telling them everything you've done so far. Your main message will just get lost in a mass of unnecessary details and digressions.

Once you've identified your audience, fill in the basic message of your talk with the appropriate supporting details. Do not be afraid to give context or background information where necessary, or to explain the meaning of any acronyms – even if they seem obvious to you. This will be immensely appreciated by the people in your audience who do not know your subject as well as you do.

For your first couple of presentations, it isn't a bad idea to write out your talk to make sure you don't leave out any crucial information. Whatever you do, though, do not read from a script during the talk itself. This approach is guaranteed to put everyone asleep. It is also not a good idea to have your whole presentation written out as a prompt sheet. No matter how nervous you are, reading from a script is a disaster rather than a help. You will talk in a monotone voice and your audience will be bored after just a few minutes and will tune out everything you say.

Rehearse Your Presentation Out Loud

You've structured your talk and made your slides. Now for the fun part: It's time to rehearse your presentation out loud. First to yourself (this will feel strange at first, but it is very effective for putting yourself at ease and for getting used to the sound of your voice in a quiet room). Then practice your talk in front of a few fellow students or other trusted colleagues. Use these practice sessions to rehearse the pacing of your talk and to master the effective use of visual aids. Ask your colleagues for their comments and honest assessment of your performance at the end of the presentation. Productive criticism from friends is useful for making improvements, and it's better to hear it from them rather than suffer the grumbles and complaints of strangers as they file out of the lecture hall.

Giving the Presentation

On the day of the presentation, show up early and make sure you know how to use the equipment. If there's a microphone, find out how to turn it on and adjust the volume.

Okay. Now you're on. Greet the audience and tell them who you are. (Don't assume that everyone knows you, even in an informal setting.) These introductory remarks have the additional purpose of getting the audience to settle down and direct their attention toward you. Clear presentations usually follow a standard formula:

1. In a sentence or two, tell the audience what you are going to tell them.
2. Tell them in detail.
3. At the end of the talk, tell them what you have told them.

The first part helps you to prepare the audience. By stating what you are going to talk about, you place your presentation into context. Next, give your talk as you practiced it, using your visual aids to support your words. Finally, sum up what you have told them, keeping your key message in mind and what it is you want them to remember after they've left the room.

Keep to your allotted time. If you've been given 20 minutes for your talk, then talk for 20 minutes. Fifteen minutes is even better so that you can allow some time at the end of your presentation for questions and/or discussion. For many people, the question-and-answer session is the most nerve-racking part of the presentation. After all, you have no control over the questions asked, so you can't really prepare the answers. Or can you? A good exercise is to try to anticipate the questions you may be asked and prepare the answers in advance.

When you're asked a question, it's always a good idea to repeat it to make sure everyone has heard it properly. That will also give you time to formulate an answer. Then go ahead and answer the question based on the data you presented (and on what you know). You can also put the question into a larger context by drawing upon data and information outside your own work. If you don't know the answer (and you're not expected to know everything!), or don't have enough data to support a proper answer, then say so. It's better to be honest than try to bluff your way through. The audience will notice this and question your credibility at large. If appropriate, tell the questioner you'll get back to them with more information when you have it.

Tips for a Perfect Delivery

Public speaking is an art. Some people are great at it, others less so. But certain skills that will greatly enhance your ability to give a good presentation can be learned. Everyone loves to listen to a great speaker. Aim to be the kind of speaker you enjoy listening to.

During your presentation, your voice, facial expressions, and body language are your most important attributes.

1. *Be conscious of how you use your voice*. *How* you say it is as important as *what* you say. Speak clearly and project to the back of the room. Don't rush. Use a natural pace, but don't be conversational. A monotone voice is boring and will put people to sleep, so it is important to vary the pitch and speed of your voice as you talk.
2. *Pause at key points* to allow the audience to absorb your words.

3. *Look at the audience throughout your talk*. You will create a rapport with the audience by establishing eye contact with as many people as possible. Just be careful not to fix your gaze on one individual as this can be unnerving. At the same time, be aware of your facial expressions. If you look bored, the audience will be bored. If you are animated and alert, the audience will be interested in what you have to say.
4. *Don't talk to the projection screen behind you*. Address your remarks to the audience. Pay attention to the audience's body language and non-verbal reactions to your remarks. Know when to stop and when to omit part of your presentation if you begin to sense that you are going on too long and the audience is losing their ability to pay attention.
5. *Avoid these annoying habits:*

   – Blocking the screen with your body
   – Excessive gesturing with your hands or moving about too much, such as pacing up and down
   – Mumbling and turning your back to the audience
   – Reading from your slides, word for word

Visual Aids

Giving a talk on scientific data is complex, so you will require the use of visual aids: charts, graphs, and tables will most likely form the core of your presentation. Using visual aids effectively will be as important to the success of your talk as your delivery.

There is nothing worse than sitting through a presentation and being forced to look at slides that are badly made, indecipherable, unreadable, or have so much information crammed onto them that they are impossible to understand.

Visual aids can be of many types:

- PowerPoint slides
- Video and film
- Flipchart or whiteboard
- Molecular models or other 3-D aids

Whatever you decide to use for visual adds, keep it simple. Avoid switching from the whiteboard to slides during the same talk. This is confusing and distracting. While it may be an obvious point to make, do be sure you know how to operate the equipment you'll need beforehand.

Slides should contain the minimum amount of information necessary to get your point across: no more than three lines of bullet-pointed text, one graph or one table (with entries large enough to be read from the back of the room). Try to limit the number of words per slide to a maximum of 10–12. Use a minimum 18 pt Times Roman or Arial font for easy readability.

Don't just photocopy graphs or diagrams from published reports for your slides. Redraw them so that they will be easily readable.

Be careful with using colour on your slides. The most readable slides use a dark blue background with white or yellow text.

Be aware of the room lighting. If there is too much light near the screen, it will be difficult to see the detail on your slides. Don't make the room too dark, however, or you risk having your audience fall asleep!

Common Mistakes

With the spotlight on you, it's tempting to try to impress your audience with an avalanche of data and plenty of bells and whistles. *Look how much work I've done!* Nothing could be worse than this approach. In fact, this is a common error, and you risk confusing people if you overwhelm them with too much information. Keep your talk short, simple, and to the point. It is not necessary to wow the audience by giving them a minute-by-minute account of your prowess in the lab. Your main message will just get lost in a tangled thicket of unnecessary details and digressions. Less is more. So keep it simple.

Finally, no matter how nervous you may feel, relax, and try to look like you're having the time of your life

Group Meetings

A group meeting offers a more informal forum for presenting your research to your lab or department. It's still a presentation though, no matter how informal, so keep in mind the pointers and tips from the previous section.

How to Handle Your Group Meetings with Style

If your research group is typical, the person who heads up the lab will organize either weekly, bimonthly, or monthly group meetings, usually depending on how big the lab is. When it's your turn to discuss your work during the meeting, don't assume everyone in the group knows the exact nature of the problem you're working on. When it's your turn to talk, put that week's/month's problem in context so that everyone in the meeting is on the same page. Be sure to give credit where credit is due. If a student or colleague has contributed to your data, acknowledge their work. Listen carefully to your colleagues when they are speaking. Show them you are interested by asking pertinent questions.

Even if you're having difficulties in your project, try not to focus on the negative. Ask your colleagues for advice and support in an open and non-defensive way. Don't be afraid to admit you don't know something. Everyone is there to learn. No one can know everything.

Chairing a Session

If you are asked to lead a group meeting, this is your chance to sharpen your organizational skills. Keep the following in mind and you will impress your supervisor and lab mates with your professionalism:

Chairing a meeting requires preparation. Every minute of preparation and planning you do before the meeting is well spent. Try to anticipate what might happen during the meeting and plan for any unanticipated obstacles. If you can anticipate (and eliminate) surprises in advance, you can deal with the core issues of the meeting more efficiently.

1. *Start on time.* This is a courtesy to those who bothered to show up at the meeting on time and sets a tone from the start that you and your group are serious.
2. *Stick to the planned agenda*. Everyone should have a copy of the meeting agenda. An agenda keeps the meeting on track by ruling out unrelated discussions. Everyone should have the opportunity to place an item on the agenda. Allow group members to submit agenda items in advance of the meeting.
3. *Make sure each person has a chance to participate.* If you're not careful, some people will dominate the discussion, while other people will leave the meeting feeling that their opinion and ideas were not heard.
4. *Stick to the time frame.* Respect everyone's busy schedule by ending the meeting on time. If a discussion is becoming long-winded or is unresolved, ask the group members if they would prefer to extend the meeting or to continue the discussion during a follow-up meeting.
5. *Keep to the rules of conduct during the meeting.* The rules of conduct for the group should be agreed upon by everyone and they should be adhered to. As Chair, you need to keep control of the discussion and disallow any discourteous or disrespectful behavior.
6. *Chair the meeting properly.* Your job is to monitor the meeting and make sure the agenda is adequately discussed. Do not

abuse your position as Chair to dominate the discussion with your own ideas and opinions. In most cases, your role will be to summarize the discussion. It is your job to make sure that the agenda issues are discussed and the necessary decisions are made.

A Final Observation

Learning how to give a good presentation and conduct a successful meeting are important skills that will be useful to you no matter which career path you eventually take. Take advantage of the opportunities to you as a graduate to give as many presentations and run as many meetings as possible. Don't be shy and volunteer if necessary, as the more presentations you give, the easier it will be to stand in front of a group of people and make a lasting impact with your words.

Saving an old master painting: Peter gives a presentation to the art history department

Two years into his PhD work, Peter has been asked by his supervisor to give a presentation to the Art History department on the progress he has made so far with the Lorenzo Monaco painting, *The Coronation of the Virgin.* Peter has given small presentations before in front of just a few people, but never for the entire department. He spends a great deal of time preparing his slides as the visuals will be important when discussing the painting. He prepares full-colour slides of the whole painting as well as various close-ups. He also makes copies of other Lorenzo Monaco paintings as well as those of his contemporaries for comparison. In addition, he talks to Isabel and Yousef for some detailed information on the chemistry and physics of the degradation of the pigments. He starts the presentation off well, giving a brief introduction to the painting, putting it into historical and cultural context and then outlining the problem. Peter is excited to show the department the knowledge he has learned about the chemistry of paintings, so for the rest of the presentation, he launches into a complex discussion of a highly specialized nature (with the help of cue cards) involving the chemistry of pigments and their degradation products. He is so enthusiastic about showing off his knowledge in this area, that he doesn't notice the puzzled looks or fidgeting from the audience (he hasn't even bothered to explain was the acronym SIMS means). Furthermore, he has so many slides that he goes over his allotted time by 10 minutes. When the presentation is over, Peter is disappointed that there are no questions. The next day Peter asks his supervisor for some feedback on the talk. His supervisor tells him that the talk was interesting but that he tried to present too much information. Peter has made the common error of trying to talk about everything he knows about this painting and the chemistry of painting in general, all in one go. He also failed to gauge the level of understanding of his audience and ended up dazzling them with complex chemical information that they were unable to fully understand and appreciate.

Though Peter disliked to be criticized, as we all do, he learned to keep the knowledge-level of his audience in mind when preparing his next talk and only present enough information to support his key message.

On the next occasion to give a talk Peter rehearsed the presentation with some labmates not involved in his project and incorporated their feedback. This second talk worked out much better: it was well received and he received interesting suggestions during the Q&A session. One of the suggestions really helped him make unexpected progress. The time spent on the preparation of the talk was repaid many times over.

Chapter 13
Searching the Scientific Literature

The history of science knows scores of instances where an investigator was in the possession of all the important facts for a new theory, but simply failed to ask the right questions.

– Ernst Mayr

Before you carry out your first experiment in the lab, you would be well advised to spend some time in the library (whether virtual or real) doing a thorough literature search of your research topic. Perhaps you worked on a project in this same field as an undergraduate, or think you are familiar with the field because it is related to other work you have done. Even if you have some knowledge of the literature on your project, you shouldn't skip this step. The investment of time in the library will pay off many times over in the lab. You don't want to risk doing work that someone else has already done, or going down the same worn path that others have traveled before you. Science is not carried out in a vacuum. It is about steady forward progress over long periods of time and wise graduate students will take the time to read and benefit from the research findings of their predecessors.

As you embark on your literature search, you may feel quickly overwhelmed by the pile of papers you accumulate, so keep in mind that is impossible to read all the research ever published in your area. Being selective about what you read is key to getting a thorough overview of a particular field, without drowning in too much information.

But whatever you do and however you decide to go about it, *do not skip this step*. You will live to regret it.

Getting Started in the Library

Get comfortable with the layout of the library and with the research tools available at your institute. Introduce yourself to the reference librarian(s) and explain that you want to carry out a literature search on your thesis topic. These individuals are great sources of information and are there to help you in your search. You'll be spending a lot of time spending a lot of time in the library so take time to get to know all its services. What kinds of scientific literature exist and which ones will be most important to you? Broadly speaking, scientific literature can be divided into two types of articles: peer-reviewed and popular.

Most of the articles published in scientific journals, both primary (original research) and secondary (review articles) have gone through a stringent process called peer-review. Before an editor will accept a paper for publication, he/she will send it out for review to at least two experts in the field. The identity of the reviewers is always kept secret from the author so that any comments will be impartial.

It is the author's responsibility to correct any errors or discrepancies in interpretation before the paper can be accepted for publication. This process, while not infallible, insures that most articles are as free from error as possible. Articles published in popular scientific magazines are not subject to peer review, and are therefore not always reliable sources of information.

Secondary literature is published in the form of review articles. As the name suggests, these articles are often very comprehensive in nature and review the scientific findings in a particular field over a particular period of time. Reviews do not present new and original data, they are compilations of other people's work, but very often written by a big name scientist in the field. Review articles can be a goldmine of information and will significantly help you with your literature search by cutting down on the amount of time you have to search out individual (primary) research articles.

Using the Internet

By now you have already identified the scope of your research project (see Chap. 1: Getting Started). Take advantage of the breadth and scope of the internet and do an electronic search on your research topic (use key words wisely, or this type of search can get quickly out of hand). Start by searching popular and comprehensive databases such as MedLine, PubMed, Georef, and ScienceDirect. Your university library should have a subscription to some of these and other databases that are password protected. Download and copy the articles that are the most pertinent to your research. As you get more involved in your search, you will start to a get a feel for the important researchers in the field. Mark down their names and research institutions.

Another excellent way to get started with your literature search is to read recent review articles published on your topic. Think of this as a bit of a short cut. Someone, somewhere has done much of the work before you and compiled it in a comprehensive review article that may contain up to 200 references.

Another tip is to make photocopies of the first papers in the field. These papers represent the seminal work in your area of inquiry. It is critical to know how the field started, which experiments were done, and who the principal players were. As you search databases, identify review articles and key publications, you will begin to create a chronological picture of your research topic. It's very important to have an understanding of the early stages of the inquiry into your research topic. As you read the papers chronologically up to the present, you will develop an understanding of how knowledge of your area proceeded. Surely in fits and starts as science tends to go, but as more research is carried, more pieces of the puzzle are filled in.

Perhaps now you are beginning to understand why this process is essential. You need to be familiar with all the work that has been done on your topic, not just as a tool for learning, but to avoid repeating work that others have done before. Imagine the graduate student who spends six months doing a series of experiments only to discover (belatedly) that someone else has done them 10 years ago. This happens more often than you think, so don't let it happen to you.

Making Good Use of the Science Citation Index

This important tool can help you weed through literally hundreds of research articles to find the most cited, and hopefully, the most important articles in your area. Once you've gathered a solid collection of articles, you will need to scan through them and summarize and record pertinent information. How best to organize all this information? Keep a notebook for building your bibliography.

For each article, write down the author, title, name of journal and year of publication. Jot down a few words about each of the following:

1. Statement of the problem
2. Hypothesis
3. Theories and assumptions
4. Research methods
5. Data collection tools/procedures
6. Research design
7. Methods
8. Interpretation of data (did data support or reject the hypothesis?)
9. Conclusions/suggested future research

If this sounds daunting and like a massive amount of work, just remember that investing time now in a proper literature search will save you vast amounts of time later on when you start writing up your own research articles (see Chap. 12), not to mention your thesis. You won't want to spend days and weeks in the library hunting down papers or finding out (oops!) that you've duplicated experiments that someone else has already done, just when you're getting ready to write everything up.

How Do You Know When Your Literature Search Is Successful and Complete?

You'll know you've made a comprehensive literature search when you have performed the following tasks:

- Identified the most recent (last 10 years, plus seminal articles) articles on your research topic.
- Skimmed each article and prepared a brief summary of each one.
- Assessed each article for the strengths and weaknesses of the experimental setup, methods and procedures used, data collection and analysis.

It is up to you to develop an organized method for storing and retrieving this information. Many people copy each paper and then attach a cover sheet with the summary and assessment points to it. Also, record this information on your computer and type the name of the author, journal, etc. of each article in standard format. This will save you oceans of time when you go about writing up your own articles and have to refer to these references.

Libraries are great places to spend time. They can offer a much needed refuge from the lab and help you place your work into context by reading about the work of others. Don't feel you're wasting your time if you find yourself in the library when others are in the lab. Remind yourself that you might just know something they don't.

Chapter 14
Your First International Conference

Human beings, by changing the inner attitudes of their minds, can change the outer aspects of their lives.
– William James

For a long time you have been working in relative isolation. Interactions with the wider academic community have been limited to reading articles in scientific journals and perhaps hearing some anecdotes about other groups from your supervisor or more senior PhD students. Now you are going to meet some of these big-name scientists at your first international conference. Your excitement about the trip is mixed with some apprehension, since presenting your own results was a requirement of attending the conference. You are not just going to listen to the big-name scientists, you will also be participating by reporting something to them. Moreover, just organizing the details of the trip is more of a hassle than you expected it to be. This chapter aims to help you sort out all the things you need to know to make your first international conference a pleasure, rather than a pain, so that your experience of the conference is what it should be: one of the perks of working in academia.

Making the Most of Your First Conference

Going to a conference is a valuable investment in your career as a graduate student and beyond. In addition to your personal contribution to travel and other expenses, you will be investing quite a bit of time at the conference. Altogether a conference visit will take about two weeks: one week to prepare and travel to the conference, and another week in attending the meeting. Fortunately, your investment will be well spent as you should get out of the conference what you put in, so take the time to prepare well. At a minimum, your attendance at the conference will bring you up to date on the latest research findings in your field; you can start building your network within the academic world; and the feedback you receive at the meeting will give your research additional momentum. Finally, attending a conference has some aspects in common with a short holiday – particularly if the conference is held in an interesting location. But in order to get the most out of this potentially enjoyable investment, you will have to put some effort into the preparation. This chapter guides you through the main issues involved in making the most of your first international conference.

First Things First

Selecting the appropriate conference to attend is crucial. Your supervisor may even have suggested that you attend a particular meeting. However, in spite of what your supervisor may have suggested, you should also consider attending the one that is most useful to you. Selecting an appropriate conference can be based on a few criteria. If you want to go to a conference that was not suggested by your supervisor, good arguments based on your criteria might help to persuade your supervisor that your preference is the better choice. We discuss here four criteria for deciding which conference is best for your entrée into the world of international scientific meetings.

First of all, it is important to make sure that your research fits well within the scope of the conference. This is a must. If the work presented at the conference has little relevance or overlap with your own work, the chance is remote that you will get any practical tips and inspiration out of the meeting. If your work is a good fit, you will enjoy the meeting much more. Especially when you realize that others are also interested in the type of scientific questions you are addressing, and you will become energized and inspired by their response to your work.

Second, make sure you will be able to present your work in some form, whether as an oral or a poster presentation. The fact that you haven’t completed your research project should not stop you from making a progress-report type of poster. By presenting your work at the meeting, you change your role from that of a spectator to that of an active participant in the field.

Third, a conference is more than an endless series of scientific presentations and poster sessions. Interactions with others and networking with the conference attendees are equally important. Workshops and small conferences with less than 100 participants are best suited for getting to know other researchers in your field. Once you have established a network and have some feeling what others are doing in your direct proximity, you might want to consider attending a bigger conference.

Finally, try to pick a conference in a pleasant location. After all, enjoying a conference can provide additional inspiration to continue your research. In a pleasant setting interactions with others tend to go more smoothly. Even the top scientists in your field will be more relaxed and perhaps even willing to involve you in scientific discussions. Make sure the location is somewhat isolated. On a mountain or small island everybody will stick around the conference site, while in a major city other diversions will offer too many distractions for you and the other attendees.

You may imagine that organizing your trip will be straightforward. You're not wrong about this: it is indeed a simple matter to register for the conference and book a plane ticket, but the list of details to be taken care of can be rather long. There is a little bit more involved than buying your ticket and showing up at the airport. Without a little bit of organization, preparing for the conference can be quite time consuming. Two tips to help you organize your trip: work with a checklist, and pay attention to things that require some lead time. On your checklist, write down all the preparations you have to do, such as: find the best way to go to the meeting, buy the tickets, register for the meeting, send your abstract to the organizers, make your presentation (either oral or a poster), bring pre-prints of your work and an A4-sized handout of your poster presentation, define the goals for the meeting, pack your stuff, and so on. Some of these things you can do on your own at any moment. Others require interactions with other people and have a (often underestimated) lead time. For instance, prior to sending your abstract to the conference you should show it to your co-authors for their comments. They might not respond immediately and you may become nervous and irritated as the deadline for submission approaches.

Keeping things running smoothly while you are away should be an item on your preparation list. Leave a note on your desk that informs others when you will be back and how you can be reached if necessary. Put your e-mail in 'out-of-office' mode if you will have no e-mail access at the meeting. In addition to these small courtesies, you should also think of the projects that will be ongoing while you are away. Give proper instructions to an undergraduate student or lab technician who can operate equipment, or keep experiments running in your absence. Order materials from the stock room so that they will be available and read to use as soon as you are back.

There are so many things to do at a conference, and so many possible distractions, that we suggest you write down a short list of goals you would like to reach during the meeting. Such goals can be related to your own presentation (such as asking the audience for input on a particular experiment, or showing that you have performed the first experimental demonstration of a particular effect); or faithfully attending the presentations that are key to your research, or building your network (talking to a member of another research group to find out how they prepare their samples, for instance). During the meeting you will find that there are many more interesting things to do, none of which you had anticipated. Nevertheless, check your short list of goals every now and then just to make sure you are staying on target, and then consider how to execute your original plan.

How to handle the overwhelming conference programme is an art in itself. A large conference will have plenary lectures, keynote speakers, parallel sessions, multiple poster sessions, industry booths, etc. Prior to the conference you have most likely been browsing through the booklet that summarizes the programme. Now that you've arrived at the conference site, you are enthusiastic about attending the first Monday morning session. You will probably enjoy quite a few of the lectures, while some may be less interesting and of less relevance. The Monday evening poster session seems only marginally relevant to your research. But you go there anyway since you're determined to get as much out of the conference as possible. But by Tuesday afternoon you've faithfully attended every presentation and are beginning to feel tired. You may even be having a hard time following the lectures, no matter how interesting they are. You're so tired now, and have already absorbed so much new information, that you even lack the energy to interact with others during the breaks. In the second half of the week the amount of information you actually absorb has shrunk considerably. Too bad you missed the very interesting and relevant talks on Thursday. You realize, perhaps too late, that a week at a conference can be a very long time indeed. Our advice is simple. Follow the tactics of a marathon runner and do not start out at full speed. Pace yourself and carefully plan your attendance at presentations. You are not being graded on how many lectures you attend. It may seem obvious, but save your energy for more important things by choosing not to attend presentations that have little relevance to your own work. Our advice for getting the most out of the full week of presentations and interactions is to skip a good fraction of the programme right from the beginning. Use that time to relax, talk to others and digest all the information you have taken in so far.

As stated previously, we believe that building a professional network is one of the major reasons for going to a conference. That is why the coffee and meal breaks can be as important as the presentations themselves. Presentations usually highlight what has worked in a particular line of research. In other words, at a conference people tend to showcase their successes. It is only during the breaks that you will find out about the attempts that were made that did not work out. In retrospect, newly minted PhDs often realize that most of their efforts during their PhD research did not contribute to the work reported in their thesis (see also 'The 80/20 Rule' in Chap. 3). During informal discussions you can learn from others about what not to do, as well as strengthen your sense of community and to realize that you are not working on a problem in isolation. The kind of information you discover can be mundane, or it can be as important as learning that the type of sample preparation you've been attempting is worthless. By sharing failures and setbacks with others, you will also receive useful feedback on your research project. A second reason to work on your network is that wild ideas about new research directions and collaborations on that research often get their start during conference breaks. In addition, when you're finished with your PhD you might want to continue doing research in another academic group as a Post-doc. Meeting people from research groups in different countries will allow you to make a more informed decision about were to go next. You might also collect a few interesting stories about former PhD students who have left academia. Finally, informal chitchat can be a welcome interruption from staring for hours at all those PowerPoint presentations. So we'll remind you again: don't forget to enjoy the meeting. Having a cappuccino on the steps of the conference building can be more productive an enjoyable than fading away in boredom at yet another incomprehensible lecture.

Making Your Presence Count

Most likely you will be presenting a poster rather than giving an oral presentation at your first conference. It might seem to you that poster presentations are a minor aspect of the conference and not very important to focus on. During these sessions, however, there is a great deal of personal interaction and they can be extremely rewarding. In oral presentations given in front of a large audience, there is often little response to the work presented, aside from a question or two from the audience. The interactions and discussions that occur during poster sessions might yield a couple of valuable suggestions for moving forward in your research, either at present or in the future. At smaller meetings the posters are often displayed throughout the meeting in the same area where coffee is served. In this case your poster will get quite a lot of exposure. Naturally you cannot stand by your poster at all times, so be sure your poster is self-explanatory, with a clear introduction, methods and results sections, and clearly stated conclusions. Make up a stack of A4-sized sheets of your poster and place them in a folder that is tacked to the bulletin board to which your poster is affixed so that people can take a copy with them. Also, it's a good idea to put your photograph somewhere on your poster. This helps people to find you later on if they want to discuss your research with you.

Choosing which presentations to attend from the myriad on offer requires some strategy. Before even entering the lecture hall, decide whether this particular presentation will be of interest to you. If you've chosen unwisely, or find yourself listening to a presentation that has little relevance to your research, do not despair or leave the lecture in frustration. Trying to follow the lecture at this point will just be a drain on your energy, so the best tactic is to ignore the presentation altogether and just let your mind wander. Some of the bigger conferences have parallel sessions and if you will not be too obtrusive, you might try to slip out a side door so that you may attend another presentation.

If however, you find yourself listening to an interesting presentation that has great relevance to your work, make an effort to focus your concentration on the message and key points of the presentation. Two things can help. First of all, make notes. By writing down the key points, it will become clear what you understand and what you do not. Secondly, prepare a question. Possibly the session chair will not allow questions due to time constraints, or perhaps you won't dare to raise your hand. Nevertheless, you should prepare a question anyway. It will make you a better listener. Later on, during the break, there might be an opportunity to discuss the question with the speaker (most speakers love it when people approach them after their presentation), or, if not, someone from the same research group.

If you've put a lot of effort into reading the programme, you might be tempted to zigzag through the programme so that you can attend all your favourite talks. We strongly advise you to hop as little as possible from one parallel session to the other. The session chairs seldom stick to the schedule, and you might feel frustrated if you enter the lecture hall after, rather than before, the start of your favourite talk.

We hope you've been having a good time at your first international conference. But no matter how enjoyable you find the conference to be, remember that it is distinctly different from a vacation. Do socialize at the bar, but do not become so caught up in the conviviality of the moment that you are tempted to skip the first interesting lecture in the morning. Organizers know that people tend to straggle in late so they try to schedule the most appealing talks for the first session of the day.

Post-conference Reality Check

Finally, the conference is over and you're back home again. You need to take care of an overwhelming number of things now that you're back at your desk and in the lab. Your inbox has way too many e-mails; you have to teach a class later this week; you want to socialize with friends you haven't seen for a while. In short, within a day you have almost forgotten the whole conference, in particular all the new ideas you picked up while you were there. Before the conference becomes a distant memory, take the time to go back through the conference programme and look at your notes. Keep, in a convenient place, the business cards you have collected. As an added incentive, offer to hold a group meeting or departmental talk, if possible, in which you summarize the highlights of the research findings presented at the conference. Those who were unable to attend will highly appreciate this gesture on your part and it will provide an opportunity to discuss with others some of the research findings that sparked your interest.

Saving an old master painting: how Peter submitted his conference proceeding

Peter is planning to submit an abstract to a large international conference. Based on the submitted abstracts, the conference organizers will decide who to invite to participate in the conference or give a presentation at the meeting. As planned, Peter wrote a first draft of the abstract and gave it to his supervisor. Peter's supervisor agreed to look at it as soon as possible. Then an emergency came up and the supervisor had to put his abstract aside. Unfortunately, Peter's supervisor is not very well organized (most likely the cause of the emergency in the first place), and has many other things to do. So, after fixing the emergency, he forgot about Peter's abstract, which is now lost on his desk, or at the bottom of a pile of other things to do. At the end of the month Peter has not only not submitted the abstract, but he has also lost quite some time in chasing after his supervisor. Even worse, because Peter is irritated by all this wasted energy, he is less effective in carrying out other projects. The irritating obstacle of the conference abstract has to be overcome. It would be a shame if Peter missed out on attending the meeting just because his abstract had not arrived in time. Now that he has identified the hurdles, a solution might be to confront his supervisor with the deadline and ask his permission to send it out without his review, in the event he has no time to look at it.

Such a direct approach has two drawbacks. First, most supervisors do not like to be told what to do, so some sort of indirect gesture needs to be made. Second, without input from others, the abstract might not be good enough to be accepted by the conference organizers. Someone has to read the abstract to improve it. Therefore, Peter asked Isabel and Yousef to read the abstract as if they were the supervisor and to come up with suggestions. He approached his supervisor and told him that he understood that he had little time to look at his abstract, and that the abstract could not be sent out without his permission. Peter mentioned his solution and repeated the useful suggestions made by Isabel and Yousef. Peter wondered what else he could do to ensure his abstract would be in time. Now his supervisor looks briefly at the abstract (which he miraculously picked out of a seemingly disorganized pile), and agrees to submit the paper. Peter has not only managed to finish the abstract but he also identified routes to make it happen. He is more in control of the situation and his proactive and constructive behaviour has made it much more likely that his abstract will get submitted on time and be approved.

Chapter 15
From Data to Manuscript: Writing Scientific Papers That Shine

The scientist is not a person who gives the right answers, (s)he's one who asks the right questions.
– Claude Lévi-Strauss

You've completed a series of experiments and have collected enough data to write up your findings in a scientific article which you will submit to a peer-reviewed journal in your field. At this point in your career you have already read dozens of scientific papers and are familiar with the format. Following this format and tailoring it to your own work is easy if you keep the following points in mind as you write.

A scientific article is a written document of your work in the lab or in the field. Keep in mind that its purpose is to disseminate your research to the scientific community and to provide researchers in your field with specific kinds of information:

- Which questions did you ask?
- Which experiments did you perform to answer these questions?

- Which kinds of data did you collect and how did you collect them?
- Which conclusions did you draw from your data and what suggestions have you made for further research?

But before we get into the particulars, a few general points should be kept in mind while you are writing. Research demands accuracy and precision. Scientific writing should reflect this in the form of clarity. Unfortunately, if you glance at almost any scientific journal you will discover that clarity and concise writing is very often lacking. Many of the complaints by non-scientists of obscurity and elitism within the scientific community partly stem from the fact that many scientists are incapable of expressing their hypotheses and conclusions clearly and simply. Don't allow yourself to fall into this trap. Part of being a good scientist is not just designing good experiments, but being able to present your work and to write it up in clear and simple language. Obscure language will not make you sound more intelligent, it will only confuse others. As a result your work will have much less impact on your intended audience.

A well-written scientific article will answer all of the above questions. The standard format found in nearly all peer-reviewed papers will help you organize your material into a logical order. Take a look at any paper from a respected journal in your field and you will see that it is organized into the following components:

- Abstract
- Introduction
- Materials and Methods
- Results
- Discussion
- Conclusion

Title

A good title is an art in itself. Give your article a strong title for maximum impact. Try to create a 'dynamic' title rather than a 'static' one, i.e., a dynamic title contains the key result of the study. Dynamic: '*Cyclophosphamide inhibits tumorigenesis by blocking the phosphorylation of protein zeta*'. Static: '*The role of cyclophosphamide in tumorigenesis*'. See the difference?

Abstract

The abstract is a one-paragraph summary (approximately 200 words) of the work that is described in the article. It should be a self-contained summary that is complete enough for the reader to understand the research and results without having to read the entire article. The abstract should contain the following elements:

1. The central question (purpose) of the study
2. A brief statement of what and how the study was carried out (Methods);
3. A brief statement of the results found
4. A brief statement of the conclusions

Note that many computer search algorithms make use of the information in the abstract. Make sure, therefore, that you have the relevant key words in your abstract so that your article will be easy to find by Internet search engines.

Introduction

For many people, this is the most difficult part of the paper to write. Deceptively simple, the introduction must contain a great deal of information in a short amount of space. This means you will need to write crisp and concise sentences to put your work into the proper context. It's important to include enough background so that a reader not familiar with the field can understand the relevance of your work and put it into context.

The purpose of the Introduction is to explain to the reader why you decided to conduct your research. So this is the place in which you answer the question: which questions were you attempting to answer? State any information about previous related research or existing knowledge in the field. How did the information that already exists help you in planning your own experiments? In other words, the reader of your article wants to know: why did you, the researcher, do this work? Be sure to clearly state your hypothesis and objectives. Read the introductions of several well-written papers to get an idea of the content and style. Some journals allow you to write the main conclusion at the end of the introduction. Make use of this when you can as it will prepare the reader for the main body of your article.

Materials and Methods

In the Materials and Methods section you will provide a clear description of exactly what you did and how you did it. This section is extremely important and details count. What was your experimental setup? Which type and brand of equipment did you use to collect your data. How and when was the equipment calibrated. Which chemicals did you use (sometimes even the company you ordered them from and the batch number can be important). Keep in mind as you write up this section, that you will need to provide enough information so that other researchers can understand exactly what you did and will be able to duplicate your work. Again, study several well-written articles from respected journals to get a sense of what to include in this section and the style that other authors adopted. Please note that it is common practice to describe methods using the passive voice: 'The pigment sample was heated to 50°C' rather than 'We heated the pigment sample to 50°C.'

Results

The Results follows logically from the Materials and Methods section, being the section where you present the data you collected. Not data in its raw form, but analysed data, which is usually displayed best in graphic or tabular form for ease in presentation and interpretation. Particularly if your data collection resulted in a lot of numbers, you will need to determine the best way to present it. A combination of tables and graphs usually works best, so that the reader can see both the numbers and a graphical presentation of the relationship between two variables. The Results section must closely match your Materials and Methods section. For example, if you present temperature data in the Results section, then the Materials and Methods section should say when and how you measured the temperatures you obtained.

A Note on Tables and Figures

Tables and figures should be used when necessary to way to convey data in a more efficient way. Both tables and figures must be able to stand alone and should be accompanied by an explanatory caption that enables them to be understood without having to read the body of the paper. Do not repeat in the body of the manuscript information that is in the captions of tables or figures as this would be redundant. Do mention the information in the figures and tables, however, when appropriate.

Tables

Do not repeat information in a table that you are already depicting in a graph or histogram; include a table only if it presents new information, or the exact value of the measurements is relevant to your results.

It is easier to compare numbers by reading down a column rather than across a row. Therefore, list sets of data you want your reader to compare in vertical form.

Provide each table with a number (Table 1, Table 2, etc.) and a title. The numbered title is placed above the table.

Figures

Figures can be graphs, histograms, spectral traces, etc. Provide each figure with a number (Fig. 1, Fig. 2, etc.) and a caption that explains what the figure illustrates. The numbered caption is placed below the figure.

Graphs and Histograms

Both can be used to compare two variables. However, graphs show continuous change, whereas histograms show discrete variables only. Decide which is the best way to represent your data. You can compare groups of data by plotting two or even three lines on one graph, but avoid cluttered graphs that are hard to read, and do not make the (common) mistake of plotting unrelated trends on the same graph.

For both graphs, and histograms, plot the independent variable on the horizontal (x) axis and the dependent variable on the vertical (y) axis. Be sure to label both axes, including the appropriate units of measurement.

Tips for making great graphs

At first glance, all graphs might look great, but make sure yours aren't confusing, or that they don't have complicated axes or extrapolations that claim more than they should. Here are a few tips for making graphs that are both accurate and 'honest'.

1. Whenever possible, begin your axes at zero and use appropriate scaling. Sometimes a valid trend will disappear on a graph with a zero axis, and all the data points will bunch together at that top. In a case such as this, inform your readers that the graph's axis is not zero, either by stating this in the text, or with a break in the axis.
2. If a data point represents the mean from a number of observations or experiments, indicate the variability by a vertical line through each point and state whether this is standard error of the mean or standard deviation. Also specify the number of observations or sample sizes.
3. When comparing two graphs, make sure to draw them both to the same scale for ease of comparison. If possible, place them side by side in the article.

4. Be aware of the limitations of your data. Extrapolating a line or curve beyond the points shown on the graph may mislead the reader.
5. Pay special care with line graphs. A false impression of your data may be given if successive points are connected by lines. It may be better to present the data as a histogram, or to leave the points on the graph unconnected by a line.

Drawings and Photographs

These pictorial forms are used to illustrate organisms, experimental apparatus, models of structures, cellular and sub-cellular structure, and results of procedures such as gel electrophoresis or electron-microscopy. Preparing such figures can be time consuming as well as costly, so be sure that each drawing/photograph adds enough value to your article to justify its preparation and publication. On the other hand, a good illustration that shows the key result in your article can be of great value. You might want to try to get such an illustration on the first page. It will make a handy reminder for others when they are searching through a pile of articles in search of yours.

Discussion

In this section of the paper you interpret the analysed data presented in the Results section. You are allowed a little leeway here, but don't get too carried away with assumptions and wishful thinking. Be prepared to back up your analysis with solid evidence as presented in the Results section. Be careful that you don't include in your analysis a piece of data that you neglected to mention in the Results. Journal editors and reviewers are trained to look for these types of discrepancies. In a nutshell, the Discussion section explains the meaning of the results. For example: Did temperature effect the rate of fading of a particular pigment? Don't make the common mistake of confusing the Results section with the Discussion section. The Results section contains only the data you obtained from measurable parameters. The Discussion section explains the relationships observed in these data. Any patterns that you discovered in your data are described in the Discussion section.

In addition, the Discussion section provides space for you to answer the questions that were posed in the introduction (and that arose in readers' minds as they read your paper). In other words, did you discover what you thought you would (did your experiments prove or disprove you hypothesis?) Were the results different from what you expected? What have you learned from your analysis? How does your work relate to other work in the field? Does it confirm or refute existing information?

The Discussion section is also the place for suggesting ideas for future research. You may have answered some of the questions you started out asking, but most certainly the work you carried out has led to new questions. Pose those new questions here. It will provide possible new leads for other researchers as well as for yourself.

Literature Cited

Cited literature is the last section of the paper. Follow the style for citing references as described in the Instructions to Authors for the journal to which you will submit your paper. Within the body of the text, you must cite another researcher whenever you refer to his or her results, conclusions, or methods in your paper. The reference in the text is made only to the author's name and date of publication. There are three common ways of doing this:

1. Both the name and date appear inside parentheses as the name is not actually part of your sentence. Not all journals include the comma between author and year.
2. The parenthesis with the author and year stated is placed at the end of the sentence of clause containing the reference. Any necessary punctuation comes after the citation.
3. Another way to cite a study is to make the last name of the researcher the subject or object of the sentence or clause and follow it immediately with the date of the study in parentheses: Holloway (1993) found that cobalt-containing pigments degrade in UV light. Because Holloway (1993) showed that cobalt-containing pigments degrade in UV light . . . These data support the conclusions found by Holloway (1993). If you wish to emphasize the date of the cited study, you can omit the parentheses: As early as 1968, Jackson showed that UV light can severely degrade cobalt-containing pigments. This strategy is often effective for presenting a historical perspective of the problem, which can be useful in the Introduction.

Note that it is never correct to separate the date of publication from the author's name: Holloway found that UV light degrades cobalt-containing pigments (1977).

If you wish to cite more than one study per reference citation, i.e., if more than one author has reached the same conclusion or worked on the same problem independently, you may list them together in the same parentheses and separate their names by semicolons: UV light has been shown to degrade cobalt-containing pigments (Jackson 1968; Holloway 1993). By convention, these citations are listed in chronological order.

Revising the First Draft

Once you have written the whole article in the format described here, it's time to take a well-deserved break. Congratulations. But you're not finished yet, you have written only the first draft. Print out your article and put it away for a few days so you can get some much needed distance from the process, because in the next stage, you will have to switch hats: from that of writer to editor. When you're ready to return to it in a few days, read it all the way through with a cold and critical eye (just like a reviewer and eventual reader will do). Don't be lazy about this step as you'll just delay publication. Any sloppiness on your part will be spotted by your peer-reviewers and the paper will be sent back to you for corrections and alterations. An extra round of reviewing can take several months. To learn how to write a good scientific article, it's best to try it first on your own. Input and feedback from your co-authors and your supervisor, in particular, however, are essential for presenting your work in the best possible form. When you've given the paper a good read through, be sure to allow the other authors on the paper (including your supervisor of course) to read it and give you their comments.

Chapter 16
Celebrate Your Success

Success is not the key to happiness. Happiness is the key to success. If you love what you are doing, you will be successful.

– Albert Schweitzer

Finally, you have gotten the results you've been working towards for a long time. You may be so busy (and tired) that you do not even realize that you have indeed achieved a certain measure of success. Perhaps it will take a few more months before your work can be presented at a conference or be submitted to a scientific journal. But what you present or submit for publication will be based on the results you have just obtained. You have reached an important milestone, so it's time to celebrate! Too often success is not celebrated properly, and you just set your nose back to the grindstone without even taking a moment to pat yourself on the back. In this chapter we make an argument for the importance of celebrating your successes, as well as taking the time to thank others for their contribution and support. So whatever you do, put down your lab notebook, turn off the Bunsen burner, and take a moment to bask in the glory of the rewards of hard work.

The Art of Celebrating Success

Striving for the best requires a lot of effort. You will encounter many hurdles on your way to the top. Such platitudes hold true for many areas of life including research and sports performed on the highest level. There is, however, one major difference between athletes and researchers. In the sports world they know how to celebrate success. No matter what you know about the sporting world, or whether you care very much about it, you are familiar with the way that athletes celebrate their triumphs. We have all seen pictures of overflowing champagne bottles and athletes cavorting with glee as they cross the finish line ahead of the pack. In fact, every sport has its own tradition, where the research world seems to lack the tradition of throwing a proper party. We are serious scientists, after all! But sometimes it's necessary to 'let your hair down' and throw a party. Apart from the fun involved, it is a great way to celebrate your success.

Why Celebrate Your Success?

Scientific research can be a long and tedious process. It starts with ideas and brainstorming, followed by research protocols and experiments, and ends with a report to the scientific community. But it shouldn't stop there. Here are three reasons why proper celebrations should be an integral part of the research life.

To acknowledge co-workers for their contribution to your success. We make progress in life and work because we stand on the shoulders of others. It goes without saying that we make use of collaborative networks established by others; we use equipment built and designed by others; we analyse data using software written by others; we do research based on concepts

sketched by others, use questionnaires developed or validated by others, and so on. In spite of this, it's natural to feel that your work (and your work alone) made your recent progress possible. We all have a tendency to underestimate the contribution of others. By celebrating your success with others and thanking them for their contribution you acknowledge, in an explicit way, their contribution to your success. They deserve it and, by thanking them in a visible way, they will be more willing to help you again towards your next milestone.

Because reflection is an important part of the learning process. You've probably discovered that you can learn valuable lessons about a process by studying what went wrong. But it is equally important to reflect on your successes. Why did it work (against all odds)? Why has nobody else performed these experiments? What triggered the research? What helped you in getting the data first, before anyone else? Who's assistance has been critical? Analyzing the reasons for your success might help you in the next phase of your research. Luck is for those who know how to find it. And that's something you can learn.

Celebrations create a positive atmosphere. When you and your co-workers celebrate progress on a regular basis, you will create a winners' mood within the team. In such an atmosphere your team will find more inspiration to tackle the next problem, helping to pave the way to the next milestone.

What Defines Success?

Of course winning the Noble prize is a good reason to throw a little party. But that should not be the standard definition of success. After all, few people actually ever win the Nobel. But during your PhD years there will certainly be a couple of occasions for thanking others for their contribution and support. A very natural moment to celebrate your success is the acceptance of a manuscript by a scientific journal. At some institutes, it is a tradition for the first author to bring cake for the whole team on such occasions. In other research programmes it might take much longer before the publications appear, for instance, because new equipment or methodology has to be developed and tested. In that case you might celebrate when the equipment is ready (don't forget to include the people from the technical workshop) and fully operational.

How Can You Celebrate Your Success?

Celebrating success works the same way as giving someone a thank you present. It is important that you do it immediately and with the best intentions. Just as you would give someone a nicely wrapped present the day after someone passes an exam, you might bring a cake and other celebratory foods to the lab the day after you obtained the key data for your article. Whatever you do, use your imagination and do something fun for yourself and those around you. Everybody enjoys a good party. So take a moment, to raise your glass and toast yourself and those around you for a job well done.

Chapter 17
How to Make the Best of Your Annual Evaluation

If you don't learn from your mistakes,
there's no sense in making them.
– Anonymous

One way or another, no matter which programme or department you're in, you will most likely receive a yearly evaluation from your supervisor. This chapter will help you prepare for – and survive – that all-important evaluation, as well as give you some advice in getting the most out of it what can be a stressful situation.

Very often the yearly evaluation is a requirement orchestrated by administrators high up in the system. Even your supervisor cannot do much about it. You may even believe that it is a waste of time and just another bureaucratic hoop to jump through. But if you approach it in a positive frame of mind, you might be able to see the benefits of this kind of yearly assessment, as it will help you come to grips with your progress and performance in the lab.

There is no standard type of evaluation. Although some universities and institutes have standard forms and procedures that must be followed, most likely these forms are rarely used properly and the official procedures are not followed to the letter. At other institutes, there may be no formal annual evaluation at all. However, every now and then, even in the absence of formal procedures, you should arrange to have a conversation with your supervisor about the long-term perspectives and goals of your PhD programme. No matter how casual these discussions might appear, they are very important as the road map of your PhD and your performance in the lab will be discussed. In the suggestions given throughout this chapter we have assumed you will have some sort of a formal discussion with your supervisor on a yearly basis. But most of the suggestions still apply in situations where the discussions are more informal.

Do not forget that most supervisors tend to dislike these evaluations just as much as you do. First of all, your supervisor is a scientist, not a trained human resources manager. Most scientists value freedom very highly, which is a perk of academic research, and they dislike the paperwork associated with universities and government organizations and the type of planning and structure which they believe is typical in the corporate world. Secondly, as a result of such an evaluation, mutual commitments will be made. For instance, commitments about the type of research you will be doing, and the frequency of your progress meetings, etc. Your supervisor may feel that all these additional commitments will absorb his or her last bit of spare time for doing research, on top of teaching obligations and writing grant proposals. This state of affairs has a way of raising the stakes on both sides of the table, so it may help to keep in mind that the evaluation is not just about you, but will also involve commitments of time and energy from your supervisor. Finally, during such an annual evaluation you will very likely receive criticism about your work and your performance in the lab. Most supervisors have not been trained in giving constructive criticism, so you may come away from the experience thinking that the criticism you received was unduly harsh and not constructive at all! Nobody likes to be criticized, so try to keep in mind that your supervisor may be just as uncomfortable as you are and that at the end of the day he/she is only human, and is certainly not the last word in who you are as a person or in determining the value of your work and contribution in the lab.

Some supervisors announce the evaluation a few days in advance, as they should do. Others do not. Anyway you should take the time to prepare yourself for this discussion. If your supervisor does not make a habit of announcing the evaluation, or there is no formal evaluation requirement at your institute, it is a good idea to prepare for an evaluation anyway, so you'll be ready no matter what happens.

First and foremost, coming prepared to an evaluation session will enable you to feel relaxed and confident. Make a list of all that you have accomplished in the past year. Experiments done, course-work completed, skills learned, students supervised, classes taught, etc. Then make a list of the areas in which you think you could have done better. This will let your supervisor see that you have spent time thinking about the areas in which you can improve. If you don't admit to these things yourself, before your supervisor points them out the you, it will be difficult to avoid the all too human reaction of becoming defensive and inflexible in the face of criticism.

When you sit down with your supervisor, take the lead by presenting an outline of your accomplishments of the past year (make a copy of your list for your supervisor to refer to during the meeting). This way, you start out on a positive note and bring to your supervisor's attention the fact that you have done quite a lot during the year. A list of accomplishments will erase the idea from your supervisor's mind that the project is going nowhere. Second, while discussing last year's progress, be sure to name a number of hurdles that prevented you from making even more progress (data was not available, equipment broke down, collaborating individuals haven't delivered what they promised, ...), but be careful not to make these sound like excuses (it's easy to fall into the trap of blaming outside circumstances and other people's failings for falling short of your goals). Finally, discussing what should be done in coming year will establish a road map that will take you closer towards your PhD. Make sure your plans are not too ambitious and realize that next year's progress will probably be of the same order of magnitude as the previous year's accomplishments. Making a workable plan for the coming year, and sticking to what has been agreed, is very important for keeping a good relationship with your supervisor. Not to mention managing his or her expectations by keeping a firm hold on what can realistically be accomplished. Be an active partner in the process, not a passive participant.

Besides planning, evaluations should be about the things that have gone well and about things that haven't. Frequently the first part is forgotten and only negative issues are discussed. You should make a list of the most important things that you have accomplished. Moreover, praise (!) your supervisor for the things you appreciated about his or her role in your work. Compliments can work wonders (as long as they are sincerely expressed) and by stressing the pleasant qualities and work habits of your supervisor, you will motivate him or her to keep behaving that way. Next on your list should be a few things you are struggling with, some of which your supervisor probably hasn't noticed yet. These can be technical problems, but also social problems, in fact anything that stops you from doing your best work. Remember: addressing a problem is halfway towards a solution.

You might believe at first that the conversation during the evaluation is not in your hands. However, you can control the evaluation in many ways. You do not have to wait until your supervisor comes to you to discuss your long-term plans and last year's progress. Go to your supervisor and tell him or her that you have being thinking about your recent progress and what to do next and that you would like to make an appointment to discuss this. Almost every supervisor will welcome such a proactive PhD student. During the meeting you will want to make sure that both of you have constructive intentions.

How to assure that the evaluation has a long-lasting impact? Once you have gone through the hassle of the evaluation, you'll want to make sure that the impact does not fade away the next day. Therefore you should focus on a few topics and assure that by the end of the meeting you have decided on actionable conclusions to these topics about which you both agree. In the absence of official forms you might formalize these conclusions by sending your supervisor an e-mail in which you list the agreed upon actions. "*We should talk more often*" is not a truly actionable conclusion. "*Let's sit together every Friday for half an hour after lunch*" is a much better actionable result of your evaluation (make a SMART plan as discussed in Chap. 3).

Altogether, an evaluation is not as bad as it might seem. When properly prepared and carried out, with positive intentions from your side and closed with actionable conclusions, you will get much more out of it than you probably expected at first.

The Surprise Attack: How to Act When You're Caught Off Guard

It might happen that you are taken by surprise. Out of the blue your supervisor comes to you with a list of things that have gone wrong, at least that is his or her interpretation. To you this criticism is all new; you never received even some much as a sign that things might be going wrong. The annual evaluation has suddenly turned into an unpleasant attack on your abilities and performance in the lab. Probably you will react by becoming angry and defensive during the ensuing discussion: why has she or he never told me this before? Why has my supervisor not highlighted the things that have gone well? The way he/she talks to me makes me feel like a failure.

What can you do about these unfair allegations? Do not expect that the problem between you and your supervisor will be solved during the evaluation. It is not very likely that you will convince your supervisor on the spot that she or he is wrong. Neither will the problem go away by just ignoring it. Probably the best thing to do is (1) try to summarize the criticism, (2) agree to disagree, and (3) ask for a follow-up meeting in a week or so. In the mean time you should prepare for that follow-up discussion. You might want to talk to a friend or one of your colleagues. At the follow-up meeting, the following three things should be discussed:

1. **You and your supervisor have a communication problem.** Somehow your supervisor has not been able to communicate your shortcomings during the year and has bottled up and kept to himself all that has gone wrong with your project. It might very well be that your supervisor feels that this yearly evaluation was exactly the right occasion to tell you the truth, with no holds barred. Someone in such an aggressive mood will probably not be willing to listen to counter arguments, so you need to save them for the follow-up discussion. At the follow-up discussion, you need state the fact that you have a communication problem and discuss ways to solve it. Probably you have no proper monthly progress review (see Chap. 6). You might suggest to your supervisor that you start

having monthly discussions. Mention that you are willing to prepare the homework for these monthly discussions by filling in the monthly progress monitor. Be pro-active and offer to do the work to take some of the burden off your supervisor, but make it clear that you require more regular discussions in order to improve communication between the two of you.

2. **Establish the things that have gone well.** During the initial discussion, all the attention has been focussed on things that have gone wrong. It is important to collect yourself and to build a basis of mutual trust with your supervisor. On this renewed basis you can and should proceed with your PhD programme. So for the follow-up meeting prepare a short list of the most relevant things that have gone well. Try to be honest with yourself when making this list; overstating your qualities will not help establish \new common ground with your supervisor.
3. **Come to the follow-up meeting with a few practical suggestions on the most important (perceived) shortcomings in your work as a PhD student.** No doubt that you believe that some of the issues raised by your supervisor are not completely irrelevant or incorrect. For those issues it should be possible to put a positive spin on things and identify ways in which you have made progress. Remember, building common ground to continue your PhD is just as important as resolving the issues you have. On second thought you might even admit that some of the issues raised by your supervisor have some grounding in reality. If you have a plan about how to work on a specific issue, tell your supervisor. For some of the issues raised you have no clue how to improve. Be honest with your supervisor about this. He or she has a stake in your success and should be willing to help you on those issues, in particularly since you have demonstrated your commitment by coming up with a solution for other issues. Your

supervisor will be happier upon realizing that telling you the truth, while painful, has indeed set many things in motion.

Saving an old master painting: Isabel in the hot seat

Wednesday morning, just after teaching his classes, Isabel's supervisor drops by her office. After some chit-chat about the lack of knowledge of the first year students in his classes, he suddenly announces that they should talk about the progress of Isabel's project and what she should do in the coming year. Although Isabel very much wants to have such a discussion, she is absolutely not prepared at this moment and feels very nervous. She manages to suggest that they have their discussion the next morning rather than right away.

That afternoon Isabel thinks about the things she feels are most important about her project and comes up with three[1] items she wants to discuss: (i) she likes the interdisciplinary team work with Yousef and Peter and wants to ensure that she can continue to work in that setting (remember that confirmation of things that are going well is an important aspect of such evaluation discussions); (ii) she wants to go to the big meeting on art restoration

[1] *Three* is for all practical purposes an important upper limit for the things you want to discuss. Restricting yourself to the things you want is always good. Restricting yourself to three topics is important because few people can remember more than three arguments, or recollect more than three issues at a time.

next year; (iii) she wants to start her new project as she anticipates long lead times in the preparation of samples.

At the meeting on Thursday her supervisor asks whether Isabel would like to say something first. Being prepared, she takes the opportunity to do so. The conversation starts on a good note when Isabel mentions that she is really enjoying the teamwork. On the other two issues raised by Isabel her supervisor is not willing to answer immediately. After some polite pushing by Isabel, her supervisor does set clear goals about what should be done to register for the meeting and what needs to be finished before a new project can be started. When Isabel mentions the long lead time of some parts of the new project, her supervisor is pleased to hear that she is 'staying ahead of the problem' and agrees that she should work on the new project for half a day a week.

Towards the end of the meeting her supervisor asks the usual question comes: do you have anything else to say? A few minor points cross Isabel's mind but Isabel decides to drop them in favour of the crucial point: that they agree on a short list of conclusions that came out of the meeting (later to be written down by Isabel and e-mailed to her supervisor for his approval). This way, Isabel will have a written record of their conversation and the agreed upon plan of action.

Chapter 18
The Final Year: Countdown to Your Thesis Defence

There is no happiness except in the realization that we have accomplished something.

– Henry Ford

You're nearly there. One or more articles are already in print, and another one is in the publishing pipeline. Moreover, you have masses of promising data that still need to be analysed. It is not yet clear, however, how these analyses might be integrated to create a cohesive body of work. Finally, there is one last project your thesis advisor wants you to work on. Altogether, there are several bits and pieces that fit into your thesis, and other things that don't seem to have a logical place. You feel confident that you will be able to pull everything together within a year's time. But at the back of your mind a lingering question arises: how do I get there? This chapter provides you with a framework to help support you in the crucial last months of your doctoral work.

Establish Your Achievements

The first step in planning the route towards your final goal is often neglected as unimportant, but it is essential to get a clear picture of where you are right now. In order to make explicit what you have achieved so far, you need to make a list of two types of research projects.

Start with the projects that are finished. For example, a piece of research that has already been published as a journal article and needs only a bit of editing to fit in your thesis. Next, list the unfinished projects you are currently working on. Try to identify the steps you'll need to take to finish those projects. These might include tasks such as sorting out the relevant data, writing and running a data analysis programme, synthesizing a message out of the analyses, or searching the literature (again) to find out in detail what type of conclusions, closely related to your own research, that have already been reported. Do not forget to estimate any potential hurdles you will have to overcome to finish these ongoing projects.

Verify Your Achievements with Your Supervisor

Now that you yourself have a good idea of what you have accomplished so far, you should make an appointment to discuss your insights with your supervisor. She or he might have a slightly different perspective on what you have achieved. For example, your supervisor may feel that not all of your finished research projects are appropriate to include in your thesis, or perhaps he will suggest that you include in your thesis some research that you have done in collaboration with others. Concerning the ongoing projects, your supervisor will probably not have the same detailed insight in their status as you do. She may underestimate what needs to be done, or bring up additional aspects of the projects that you haven't thought of. So ask for a meeting with your supervisor in which you want to discuss all the results you have achieved so far. Present your analysis in the form of a brief written report to your supervisor prior to your meeting. In this way your supervisor will be motivated to prepare for the meeting as well and can reflect on the state of your research results ahead of time. The key outcome of such a meeting is to establish a common understanding on what you have achieved for your thesis so far, and what still needs to be done.

What Else Should Be Included in Your Thesis?

Most likely, you and your supervisor will agree (after a productive conversation) about what has been accomplished so far, and what still needs to be done to complete your ongoing projects. Opinions might diverge, however, when it comes to additional material that should be included in your thesis. Sometimes there will be stakeholders in addition to yourself and your supervisor. For instance, it might be that your direct supervisor is not your thesis advisor, or there may be a thesis committee that is actively involved in defining the content of your thesis. For the remainder of this chapter we will assume you have both a direct supervisor and a thesis advisor.

It might well be that while you believe that finishing the ongoing projects provides sufficient content for a thesis, your direct supervisor might want you to include a minor addition, while your thesis advisor, being only remotely involved so far, wants you to start a new ambitious project. Debating and agreeing on these issues is not easy. But you will need to make up your mind about what you believe is a proper balance between the quality and quantity of the content, on one hand, and the time it will take to get there on the other hand. Do this before you start discussing these issues with your thesis advisor. This preparation is a two-step process: first describe the final (as yet unfinished) project that needs to be included in your hesis, and second, make a countdown list (see below).

Describe Your Final Project

To facilitate your discussion with your supervisors on what remains to be completed, your brief description of the (potential) final project should address at least three issues: First, prepare a brief project description including the means of acquiring the data, your plans on how to analyse the data, and your best guess on the type of answer you might get from your research (the hypothesis you are testing). Secondly, you should make an estimate about the types of hurdles and pitfalls you might encounter on the project and how you plan to overcome them. Base your estimates on the experience you gained in your previous projects. Once you know the required actions to finish the project, you will be able to estimate the time it will take to finish it. Again, do not be too optimistic or unrealistic. It is best to base your estimate on your past performance in similar projects. This exercise will provide you with the missing information you need to complete your countdown list.

The Countdown List

An example of a typical countdown list is shown in the inset and consists of two parts. The first part describes the content of your thesis (your ultimate goal), while the second part describes the planning on how to get there. Writing down most of the chapter titles should be straightforward, once you've had a proper discussion with your supervisor about your achievements and results to date. The chapter on the new project may be an open-ended issue. By including that chapter both in the content list and planning section, it will become clear what the consequences will be if you add this project to your thesis. In the countdown list, time is allocated to each task. In reality you will not be executing one task at the time, but rather working on a few tasks in parallel. To get an impression on the total time the thesis preparation will take, you can just write down the tasks sequentially. The best way to estimate how long a particular task will take is to use your own experience from executing similar tasks. Otherwise consult your peers.

The countdown list

Part I – Contents of your thesis
- Chapter 1: Introduction to the field of research
- Chapter 2: Methodology, research instruments
- Chapter 3: Research project 1 (already published as journal article)
- Chapter 4: Research project 2 (manuscript submitted for publication)
- Chapter 5: Research project 3 (data available, no conclusions drawn yet)
- Chapter 6: Research project 4 (the new project??)
- Chapter 7: Conclusions/summary
- List of references
- Part II – Planning
- (order of the actions might be different in practice)

Week 1 Transform your journal article into Chapter 3

Week 2 Transform the submitted manuscript into Chapter 4

Week 3–4 Write introduction (Chapter 1)

Week 5–6 Write methodology (Chapter 2)

Week 7–10 Analyse data for Chapter 5

Week 11 Conference preparation

Week 12 Conference

Week 13–14 Draw conclusions for Chapter 5

Week 15–17 Prepare final project (Chapter 6)

Week 18–20 Write Chapter 5

Week 21–22 Vacation

Week 23–29 Data acquisition for Chapter 6

Week 30–33 Analyse data for Chapter 6

Week 34–35 Draw conclusions for Chapter 6

Week 36 Start job search

Week 37–39 Write Chapter 6

Week 40 Write summary (Chapter 7)

Week 41–43 Buffer (at least 5–10%)

Week 44 Finalize draft thesis for thesis committee (*)

Week 45 Approval of thesis (*)

Week 46 Printing final version of your thesis

Week 47–48 Continue job search (see Chapter XX)

Week 49 Prepare thesis defence

Week 50 Thesis defence (*)

(*) Note that the actual procedure for the final approval and thesis defence differs for different universities. Check with your thesis advisor how much time it typically takes at your university.

Typical Things You'll Learn from Making the Countdown List

Once you have made such a list, you should reflect on its consequences. The first thing you may discover is that time flies. You may have already made a mental estimate of how long it would take you to finish your thesis, but now that you have made your list explicit by writing it down, you may notice it will take longer than you thought. Also, tasks you may have ignored initially, but are now clearly important, will also eat into your time frame. But don't panic. This is the time to hone your time management skills and your ability to focus on what is important. Your schedule is tight, so good planning will count. You can control your own time management, but be sure to take any necessary measures to make sure that delays, caused by waiting for others, will be minimal. If you are working in a team and need crucial data from the others, now is the time to plan a meeting to discuss exactly what needs to be accomplished in the (limited) time that is left. Finally, towards the end of this period, you will have to deal with the often complex procedures that come with submitting your thesis for approval. Make sure you know well in advance exactly what needs to be done and when.

Handling Uncertainties

Probably the biggest uncertainty in your planning scheme will be the time you need to allocate to execute your new project (7 weeks in our example). Note, however, that if you exceed the allocated time by 4 weeks, the total planning (of 50 weeks) changes by less than 10%. Your total margin of error could indeed be larger. However, you might be in the unfortunate situation that the time it takes to execute one of your tasks is very uncertain. For instance, for the new project you have to rely on a sample that needs to be prepared by other people. Without that sample the project will be impossible to complete. In case you foresee such problems and other potential bottlenecks, it may be useful to make two countdown lists. One, assuming that the sample is going to be delivered to you, and another one in which that project is impossible to complete (see also inset). Estimating these risks upfront will enable you to have a valuable discussion with your supervisor about these potential scenarios. Most importantly, this type of forward planning will minimize the uncomfortable feeling that you have a potentially critical problem ahead of you that is completely unanticipated and out of your control.

Discuss Your Planning with Your Supervisor(s)

Now comes the hard part. You need to discuss your planning with your supervisor and thesis advisor, although you might feel that this is more a negotiation than a discussion. At one end of the table is you, the hard-working PhD student, who wants to wrap up the work in a reasonable amount of time (you don't want to be in graduate school forever!). At the other end of the table is your thesis advisor, hungry for more research results that can be used in a future presentation or publication. And your daily supervisor stands somewhere in between. However, you are well prepared to back up your arguments by having made the countdown list. Perhaps your supervisors are not skilled communicators – they have been trained as scientists, after all. But your carefully structured plan will probably appeal to them. Give them your plan well before the meeting so they can think about it. In the event that you have a major disagreement during the meeting, keep your cool and avoid getting angry. Summarize the issues you don't agree about and ask for some time to reflect on their point of view. Sometimes these planning discussions cannot be finished in a single meeting, but they are worth doing properly. You will save yourself quite a bit of thesis preparation stress if you manage to structure a countdown plan on which all parties can agree.

The Countdown Planning is Not Carved in Stone

Once you have made a countdown list that your supervisor and thesis advisor have agreed upon, you should try to stick to it. However, while working on the tasks in the countdown list you may notice that you are deviating from the planning. Even worse, gaining back lost time is not a likely prospect. If you find that you are really getting off track or that things are taking much longer than anticipated, your first reaction may be to work even harder and longer hours, or to go into denial about how much time you really need to finish. Rather than sticking your head into the sand, face your situation, make a new plan and discuss it again with your supervisor.

Saving an old master painting: Yousef wraps up his final year

Yousef is well into the last year of his PhD programme. From the start of his PhD project he has explored a new line of research in the small, start-up group led by his supervisor, Paul. At several meetings, including a prestigious international conference, Paul reported on his plans for this new ambitious project. Although some results have been obtained already, major breakthroughs have yet to materialize. In particular, they have had difficulty preparing the high quality samples that are required for this type of research. All kinds of problems have cropped up that were not anticipated. Yousef has often felt uncomfortable about the situation. At this late stage in the game, finishing in time almost seems impossible. Even if he gets the six months extension he has applied for, he has just over a year to complete his thesis research. Yousef vaguely knows that writing his thesis and submitting it to his thesis advisory board will take quite some time as well. Taking into account all these factors, Yousef realizes that only a few months remain for him to do the actual research. Some of Yousef's peers suggest that he make a countdown list. But even though Yousef, as an ENTJ type (see Chap. 8) is a strong believer in lists and structures, he is afraid that a list will be of little help in his case. The uncertainty of finishing the new project, in particular obtaining the high quality samples he needs, goes far beyond the planning of tasks on a weekly basis, as required by the countdown list. Yousef ends up spending more time thinking about what to do than he does actually working on the project. His supervisor, Paul, notices the slow down in progresses and sees that Yousef is hanging around in the hallway chatting with colleagues rather than working in the lab. On several occasions Paul passes by and urges Yousef to speed up the work, reminded him of the deadlines that are looming. This passing communication between supervisor and student is of little help. Yousef decides to talk to his mentor in the department. The mentor suggests that Yousef talk to Paul about establishing a Plan B, one that involves some simple experiments, just in case the more ambitious project fails. Yousef and his mentor realize that Paul is probably not yet willing to give up on the project, because if successful, it will bring so much glory to the newly started group – and to Paul's reputation in the field. Therefore, the mentor suggests that Yousef do two things. First, convince Paul that at some point a Plan B is the only way to rescue the thesis. Second, that a logical moment should be defined when it is time to switch over to Plan B. In order to structure that discussion Yousef created two scenarios, as described in the countdown list. In the first plan it is assumed that the much desired breakthrough is made in a reasonable amount of time (e.g. 3 months). The second plan describes how to continue, if, despite all the effort, the sample preparations do not work out.

Yousef decides to take the risk and goes to see his supervisor with the two versions of the countdown list in hand. Paul, the ambitious supervisor, is upset about the idea of abandoning the project when Yousef makes a suggestion along those lines. Wisely, Yousef decides not to reveal the countdown plans just yet. A few days later Paul and Yousef meet at the coffee machine. Paul admits that the project may be a little too ambitious for Yousef to successfully complete. Yousef finds it difficult to accept this subtle attack on his skills, when the judgement of his supervisor about the feasibility of the project's success has also played a role. Yousef suggests that they talk again and that he will think about alternatives. At that second meeting he brings the countdown plans and shows them to his supervisor. After some discussion, Paul and Yousef agree to do the utmost in the coming ten weeks to make the project a success. If, by that time, the sample preparation still hasn't worked they will switch to Plan B. After the meeting Yousef feels relieved. Now he can start concentrating on his work. Much to Paul's surprise, he rarely sees Yousef hanging around in the hall anymore. Yousef is much too busy in the lab working towards the completion of this thesis research.

Chapter 19
Writing Your Doctoral Thesis with Style

If I have seen farther than other men, it is because I stood on the shoulders of giants.

– Sir Isaac Newton

All the raw material for your thesis is ready – at least it should be if you've successfully worked your way through the count-down plan as described in Chap. 15. So now it's time to wrap things up and write your doctoral dissertation. This is easier said than done, of course, and you cannot hide from the fact that you still have a lot of work ahead of you. But don't let the thought of writing your thesis paralyze you into a state of inertia. Like any big project, writing your thesis is easily doable if it's broken down into smaller steps. In fact, you have already done this by having written at least a couple of articles that are ready to be transformed into chapters. Keep in mind, however, that a research article written for a peer-reviewed journal is not the same thing as a chapter in your thesis. Even if you've published several articles, you can't just staple them together and – voila! – create an instant thesis. There are some fundamental differences in these two types of writing which we will discuss in detail in this chapter.

Although you may be feeling a bit stressed (or even a lot stressed) that the deadline for completing your thesis is approaching, writing a thesis will be a new (and hopefully exciting) phase of graduate school. See it as a challenge, and whatever you do, don't stop now. Too many graduate students leave their programme without having written their thesis. One way or the other, your degree will be of help in your further career. It would be a shame to have done so much work and leave graduate school without that coveted degree. Likewise, you may be the kind of person who loves working in the lab, but hates sitting down to write. In this chapter we present a few suggestions for making the process as straightforward and painless as possible.

First Things First: Decide on the Table of Contents

If you didn't make a count-down plan as described in the previous chapter, there is at least one aspect of it that you need to address before you start writing: make sure you and your supervisor agree on the table of contents of your thesis. This might seem obvious, but we have seen too many students start working on chapters without discussing it with their supervisor, only to find that those chapters had to be tossed out. As soon as you have agreed upon the table of contents, you should start talking with your supervisor as soon as possible and in more detail about what you are going to put in those chapters. We've repeated here the schematic table of contents that was discussed in Chap. 15.

Table of Contents

Cut the Problem Down to Size: Write an Outline

Now that you've agreed on your table of contents, it's time for the next step: writing an outline. For a written document as complex as a doctoral thesis, it is essential to work from an outline to keep you on track and provide you with a framework for your text. Writing an outline will also force you to break up the writing process into manageable pieces. Your outline should consist of several pages that contain chapter headings, sub-headings, figure and table titles and some keywords and essential comments. Once you have created a comprehensive outline, you will have a framework or scaffold from which to work. In addition, an outline is a great tool for preventing writer's block, as you only need to fill in one section at a time of your outline, rather than face the enormous task of writing a document that will be well in excess of a hundred pages. With an outline in hand, when you sit down at the keyboard, your aim is no longer to write an entire thesis – a daunting goal without a doubt – but something much simpler.

Your new aim is to write a paragraph or section about one of your subheadings. It helps to start with an easy section: this gets you into the habit of writing and gives you self-confidence.

Getting Down to Fundamentals: What's a PhD Thesis Anyway?

Depending on whom you ask, you'll probably get a different answer to this question. But before you get heavily involved in the writing phase it may help to get a grasp of what it is that you are attempting to accomplish. Most people tend to agree on the following definition of a what a PhD thesis is (and is not):

A PhD Thesis Is:

- A formal document, quite substantial in length, that presents original data in support of a particular thesis or supposition.
- A comprehensive body of data that supports a particular hypothesis and is well-supported with appropriate evidence. The scientific method requires you to state a hypothesis and then gather data to support or negate your hypothesis. Before you can write a thesis defending a particular hypothesis or hypotheses, you must gather *sufficient evidence* to support it.
- A thorough analysis and interpretation of the data you have collected. This analysis forms the heart of your thesis.
- A document in which *every statement* is supported by citing the scientific literature or your own (original) work.
- A document in which every statement must be correct and defensible in a logical and scientific sense. There is no room in your thesis for suppositions and conclusions that you pull out of thin air.

A PhD Thesis Is Not:

1. **A diary of your days in the lab.** You must be able to present your work in a way that demonstrates your mastery of a given topic. You will not be awarded a PhD just for writing down everything you did in the lab over the course of several years.
2. **A collection of published articles.** A PhD thesis is similar to writing a book. While you can take your published papers and turn them into the core of your thesis, the thesis as a whole should stand alone and be coherent in presentation and scope.
3. **Written in solitude.** It is important to have other people involved in the thesis-writing process, if for nothing else then for checking your first drafts and proof-reading your final ones. You also need to have a supervisor who will tell you when to stop writing. As the person doing the PhD, you are too closely involved in the process – you must, therefore, ask for expert and third-party advice. Remember, too, that a good thesis, just like any text, is designed for the benefit of the reader. So try to get several people to read your thesis and listen to their suggestions for improvements.

As you work, be sure to keep the above points in mind. It may also help to re-read several dissertations from former PhD students in your group or department in order to get a feel for style and tone.

Pick a Straightforward Format and Layout

You can spend an endless amount of time designing a special format and layout for your thesis. If you are not an expert in desktop publishing, however, we suggest you save yourself a great deal of frustration and time by copying the format of another student whose thesis layout appeals to you. Make sure the format is easy to use, however, as you do not want to find yourself spending many days on learning a new and fancy software programme – at least not at this stage. Once your thesis is sent to the panel or committee for review (a process that usually takes several weeks or months), you might want to consider upgrading your layout. For the time being this should not be your major concern.

Transforming (Published) Articles into Thesis Chapters

You most likely have a few articles already in print in peer-reviewed journals or at least submitted for publication. So it may seem like a straightforward matter to transform those articles into thesis chapters. But transforming articles into thesis chapters isn't just a question of copying and pasting the appropriate text. The following are some suggestions for creating cohesive thesis chapters from your published articles or submitted manuscripts.

- First of all, you will have to **rewrite the introduction section** of each article to put the chapter into perspective with all the other chapters. There is no reason to repeat in your chapter introduction what you have already explained in your general introduction and literature survey in Chap. 1 of your thesis.
- Also, the **methodology section can be shortened** since you have already presented most of that information in the chapter on Materials and Methods. Don't make this section too brief, however, since the reader must be able to read each chapter independently without having to flip back and forth to other chapters for important information.

- **Update your references.** If your article is somewhat out of date, you should include the latest literature in your list of references. Moreover, refer to the other chapters of your thesis, where applicable, rather than just referring to your published journal articles. The thesis must be a cohesive piece of work in its own right that can be read and understood without having to refer to additional literature.
- **Avoid repeating figures used in preceding chapters.** No matter how useful it was to show in each single article a (slightly modified) version of your experimental set-up, for example, in a thesis such a series of illustrations is often unnecessary and redundant.
- **Adapt the format of your article to that of your thesis.** For instance, if you transform a short article or letter into a chapter, insert the headings (introduction, results etc) at the appropriate positions.
- **Include paragraphs that did not make it into the final version of the article.** Often there are space restrictions on your article set by the journal editors. So you may have had to sacrifice a couple of interesting paragraphs to meet the journal requirements. Now you can use these paragraphs (and figures), since they will be a valuable addition to your thesis.

Chapter Two: The First Piece of New Text

Now that you have transformed your published articles into chapters your thesis is starting to get some heft to it. Although you probably realize that the tough part has yet to be done, take a moment to enjoy your success so far. From now on, you will have to write new text for the remaining chapters and that will slow down your progress quite a bit. Since writing the methodology chapter is relatively straightforward, we suggest you start with that one. You have already written several methodology sections for your articles so you probably won't need much help in making a first draft. Since a thesis has fewer space restrictions, you should take the opportunity to describe some of the details of your work that did not make it in the articles. It is better to err on the side of being too detailed than too little. Be generous to the next generation of researchers. A detailed description of your progress and failures, in terms of your materials and methods, will save them a lot of time.

The Last Set of Data: Chapter or Article First?

Now that you have worked your way through the initial chapters and have written most of your thesis, it is time to tackle your final project. In this particular case you probably haven't written an article yet and you will need to decide whether to write the article first and transform it into a chapter or the other way around. If there is stiff competition in your field to get results published as quickly as possible, your supervisor will probably insist that you write the article first. If this isn't the case, we suggest that you write the chapter first, as this approach will allow you to describe your work, including all the details, from which you can select the appropriate parts for an article later on. While the thesis is out for review with your dissertation committee, you can transform the chapter into an article and submit it to a journal.

The Introduction: The Final Hurdle

A good introduction to your thesis is crucial for putting your work into context and it is probably the most difficult section of your thesis to write. This is your opportunity to describe your work in a broader perspective, including an explanation of why the research is relevant (to the scientific community and society in general) in the first place. Although you will probably write this chapter towards the end, you should start thinking about it long before then. During your last year as a PhD student you should make a file in which you collect ideas and article clippings that might fit into the introduction. Once you start writing the chapter you will have a source of ideas, some of which might fit in well, while other notions may be harder to incorporate. This strategy of collecting ideas for your introduction requires some discipline, but it will save you from writer's block when faced with writing the introduction. It can be highly stressful if you have no clue what to write, all the while with a deadline hanging over your head like the sword of Damocles. Having a file with ideas will be of help in writing a comprehensive and elegant introduction when the pressure is on.

The Summary

You may be required to write a summary for your thesis, but even if you're not, a good summary is essential, so take the opportunity to write a high quality one, as this is the one section of your thesis that is sure to be widely read. In a few pages you will have to describe the main findings of your thesis research, so it is best to write this part after you have finished all the other chapters. Do not try to describe all your results in the summary. If the density of information becomes too high, people will stop reading your summary, and probably put your thesis aside altogether. Also, be sure to clearly designate in which chapters particular findings are described in more detail.

Going for Gold: Towards an Error-Free Thesis

Since a thesis is usually written under serious time constraints, it is difficult, and probably not realistic, to write a thesis that is completely free of typos and other minor errors. Spell-checkers do help, but they have limited use for a document such as a thesis that by definition will contain scientific and technical terms that will not be recognized by the spell-checking software (you can build these into a glossary on your computer, of course, but this takes time). In addition, errors of grammar and syntax are not always highlighted and minor scientific errors can be easily overlooked. Your goal, of course, is to have the minimum number of errors in your thesis as possible. We suggest you do two things to make this a reality. First, put the manuscript aside for a short while after you've written the first draft. Once you're feeling refreshed and have gained some distance from the material, read it over again with a sharp eye, not for content, but in the guise of a proof reader who is just looking for errors. Second, you should give a copy of your thesis to one or two trusted peers to read and find a way to reward them for every error they find as an incentive to go through your thesis with a fine-toothed comb.

Be Generous with Acknowledgements

Some universities allow you to thank and acknowledge co-workers at the end of your thesis. Take that opportunity and thank whole heartedly all those people (don't forget family and friends), including other students, Post-docs, your supervisor, and lab technicians, who have made your work possible.

Ten tips for a stress-free dissertation

1. Don't save data analysis to the very last minute. Plan ahead.
2. Confirm your table of contents with your supervisor.
3. Write an outline (and stick to it as you write).

4. Don't reinvent the wheel: transform your published articles into thesis chapters.
5. Create a time frame (and deadline) for yourself and stick to it.
6. Find a quiet place to write where you will be free from distractions (the lab is usually not a good place to write a thesis – work from home or in a quiet place like the library).
7. Assign yourself a number of pages to write each day and stop when you are done. This will prevent you from spending 24 hours a day at the computer, agonizing over your progress. When you've written your assigned 4–5 pages, then you're finished for the day. Turn off the computer and do something else.
8. Take plenty of breaks, and be sure to spend time with friends and family. Just don't bore them, however, by constantly talking about your thesis and complaining about how hard it is to write.
9. Get some exercise, eat well, and take care of your health.
10. Don't work in utter solitude. This is not the time to turn into a hermit. If other PhD students in your lab or department are writing their theses at the same time, consider creating an informal support group where you can share the stresses of writing a thesis and have people at hand who are willing to read or proof read certain sections or even the entire manuscript.

Chapter 20
The Final Act: Defending Your Thesis with Panache

The aim of science is not to open the door to infinite wisdom, but to set a limit to infinite error.

– Bertolt Brecht

The day has arrived and you are almost ready for the final act. You have completed your *magnum opus*, submitted it to your thesis committee, and received permission to move onto the next and final step: defending your doctoral thesis. Whether you like it or not, it is show time. You may have been working towards this day for several years, but defending your thesis will require a different set of skills than you are used to using for your regular research and writing activities. The prospect of this 'oral exam' may seem extremely daunting (not to mention frightening) to you at this time, and you may be wishing you had already passed through the whole thing and were holding your coveted degree in your hands. However, if you think of your thesis defence as a rite of passage, a necessary test of knowledge and competence, and the final challenge that you must undergo before you reach your final goal, it will not seem all that insurmountable. And if you take the time to prepare for your thesis defence, you will feel strong and confident going into it. In this chapter we offer a few suggestions to help you defend your thesis with panache.

Depending on where you carried out your PhD research, there will be quite a range of formal procedures and regulations for your actual thesis defence. In some countries, and at some universities, the defence is almost a formality, with no tough questions fired in your direction, and no prospect of failing. If this is the case at your institute, your thesis defence will consist of an hour or two of non-aggressive questioning in front of your friends and relatives. At other places, the candidate is endlessly interrogated behind closed doors by an international committee and there is a small, but finite, chance that the candidate will not pass. For the remainder of this chapter we assume that you will have to deal with a situation that lies somewhere in between these two scenarios: an oral defence that is open to the public in which serious questions about your thesis will be asked, but the chances you will fail are minimal. Although our advice assumes that you will be participating in a mild form of thesis defence such as this, our suggestions should also be of help to those who must undergo a more rigorous defence.

In our opinion there are only three things you need to do to ensure that your thesis defence is successful: prepare, prepare, and . . . prepare.

Familiarize Yourself with the Formalities

A thesis defence has the characteristics of both an exam and a ceremony. All ceremonies, from PhD defences to weddings, tend to have a set of formal rules that must be followed during the ceremony itself (such as standing when the committee enters the room, etc.) and things that must not be done (address the examiners by their first name, etc.). Since you are probably not familiar with these rules, you will have to pay extra attention to how you behave, all the while having to answer difficult questions and keep your composure.

Combining these two tasks is not easy and may even require a little ‘sleight of hand’ to pull it off. One thing that can really help put your mind at ease, in terms of the formalities, is knowing the formal procedure by heart beforehand, so you can focus all your concentration on answering the questions posed to you. To that end, you might want to go to a few thesis defences of your peers prior to your own defence. You will get a feel for how the rules work in real life and there won’t be any surprises during you own thesis defence (at least in terms of rules and procedures). In short: don’t go into your thesis defence unprepared. Familiarize yourself beforehand with the rules and regulations such as how to address the examiners, when to stand and sit down, what the dress code is, and anything else that will be expected of you during the ceremony.

Prepare Yourself Scientifically

There is no doubt that you are the expert on the science you’ll be discussing and defending during your thesis defence. After all, you’ll be talking about work that has been the focus of your time and attention over the past several years. Do not, however, underestimate the committee’s knowledge of your subject. Moreover, in the formal setting of a thesis defence, you have one truly big disadvantage: while your examiners have been able to prepare their questions beforehand, you have to reply to them on the spot. Some of your examiners will be very good at finding a few delicate or controversial issues in your work and they will certainly question you about them. Remember, it is much easier to ask a difficult and probing question than to answer it on the spot, with hardly a moment to collect your thoughts. While standing in the spotlight, you may even realize (*quel horreur!*) that it has been quite some time since you even thought about some of the issues now being pointedly addressed. So we advise you to read your thesis again, this time with a critical eye and perhaps with a highlighter in hand, in the week or two before your thesis defence in order to refresh your memory about the experimental details, experimental setups, results and conclusions that are described in your thesis. As you read, put yourself in the role of the examiner. What would you ask the writer of this thesis? Where are the trouble spots, the unresolved issues, the shaky conclusions? If you can guess some of the questions you will be asked beforehand (and prepare the answers), you will be much better off and more prepared for the defence itself.

No matter how well you know your own research, and how well you've prepared beforehand, it is not always easy to phrase the answers properly in public. To improve your skills in responding in public to all kinds of incisive or roundabout question, we suggest you take part in a fun exercise. Invite a couple of peers from your institute to have dinner at your place. Make sure that you invite both experts in your field (e.g. a Post-doc you worked closely with) and those who are less familiar with your work (the PhD student working in another group down the hall). While you serve and eat dinner (the multitasking aspect of the exercise) your guests will ask you questions about your thesis. Some of these questions may trigger you to read a particular part of your thesis again, while other questions will train you to bring your work into the context of an outsider's perspective. No matter what kinds of questions you are asked by your dinner guests, however, you are training yourself to respond right away – and with poise – all the while staying cool and collected as you serve and eat a meal.

Prepare Your Act

Since a thesis defence is a formal ceremony as well as an examination, you will have to act accordingly and play the highly scripted part that is expected of you. It will not be sufficient to give a brief reply to a question while staring at the floor. From experience we can assure you that the examiners will not be pleased if you keep replying to their questions with, 'yes, no, no idea,' and so on. Answering a question properly is a three-step process.

- **First, you need to listen to the question carefully.** Too often PhD candidates stop listening halfway through a question because they believe they know what the question is all about, or they are so nervous they start preparing the answer while the question is being asked. Sometimes the real question only comes at the very end of a long exposé (in which the examiner may be trying to show off a bit), so you have to listen carefully the entire time the examiner is speaking. To ensure you maintain your concentration throughout a long monologue, you might want to take notes, or jot down key words as they are spoken by the examiner.
- **In the next step, you should begin your answer by rephrasing the question briefly and politely** (remember it is also a ceremony) such as 'esteemed professor your question on the research described in Chap. 4 addresses the issue of the aging of paint pigments from an interesting perspective. If I understand your query correctly you wonder why...' This rephrasing has a twofold purpose, first to establish whether or not you have understood the question properly. Second it will give you a moment to collect your thoughts and to prepare the best possible answer.

- **In the final step you should answer the question.** This might seem obvious, but too often the candidate makes no serious attempt to answer the question, and starts going on some related or unrelated tangent or explication to make it appear as if the question were being answered. Some questions may be just too difficult to answer right away, or you may be caught off guard and have no idea how to answer the question that has been posed to you. In this case you have two options. First, you could start talking about the research in the chapter while not giving an answer at all, and try to bluff your way through it. A better solution is to admit to the examiners that you probably will not be able to provide the full answer to the question raised, but that you will discuss a few issues that can contribute to finding a proper answer. While the public will not notice the difference, the experts (and most of the examiners are experts) will understand the distinction between a candidate who is prevaricating and sidestepping the question, and one who makes a real attempt to address the question, as thorny and complex as it may be. The latter behaviour is what the examiners will expect from someone soon to be awarded a doctorate.

Your Physical Condition at the Actual Defence

No matter how well prepared you may be, there is a fair chance that you will be a little nervous – or a lot nervous, depending on how you operate under stress. After all, you have been working towards this point for years and a lot is at stake. Each individual reacts differently to upcoming stressful situations. You may or may not have already discovered which strategies work best to help you perform well under stressful circumstances. You may have had some experience with this before (such as in sitting examinations), but the scale of defending a PhD thesis puts the circumstances of a thesis defence into a different class altogether. So in the days before your thesis defence, try to find a proper balance between (i) focussing on your research by reading your thesis (again and again) or going for a long and relaxing walk; (ii) drinking lots of coffee to activate your brain or imbibing in a cup of herbal tea to relax; (iii) preparing your thesis defence locked up in a room alone (this may work for introvert candidates) or sitting in a café with a couple of friends. Whatever you do in the run-up to your defence that will help you feel more poised and relaxed, try not to develop a completely new strategy at this stage for managing stress. It may be best at this point to do what has worked for you in the past. Get some sleep, go for a walk, eat regular meals, talk to friends. Breathe.

Our advice for getting through your thesis defence with a minimum of discomfort and the best chance for success? Prepare, prepare, prepare, and then just let it go and do your best. We hope you sail through your defence with flying colours.

Chapter 21
Putting It All Together: A PhD...So What's Next?

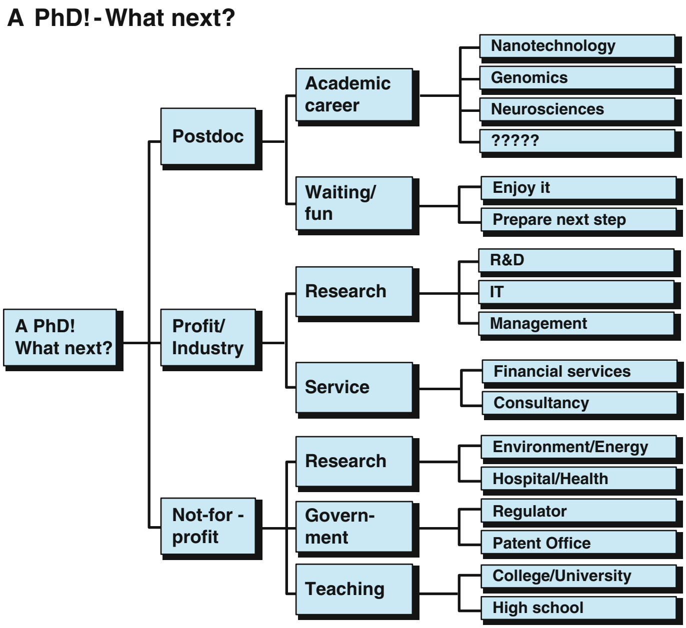
Science is a wonderful thing if one does not have to earn one's living at it.
– Albert Einstein

You're about six months away from your thesis defence. After spending so many weeks and months at the computer writing your thesis, it is probably hard to imagine that there is life after grad school. Many graduate students are so intent on getting through their thesis defence, that they tend to ignore that after the PhD thesis defence ceremony, a true milestone in your life, they will have to find a job. Deep down, however, you are aware that you must make some important decisions.

For example, do you want to stay in academia? Or would you rather pursue a career in industry? Should you stay in your own country or do you want to explore new opportunities abroad? These questions are not easy to answer and you will probably not be able to answer any of them overnight. This chapter aims to get you started in the decision-making process and assist you in guiding your thoughts. Two issues will be addressed: Which kind of job suits you best, and how to go about getting your dream job.

Opportunities for a Newly Minted PhD

Once you start thinking about the type of job you'd like to have after your PhD, you will soon discover that the possibilities are overwhelming. Somehow you will have to find a way of making sense of all these potential opportunities – and which will be the right path for you to take. A decision tree like the one shown below can be of help in narrowing down the choices. This tree assumes you have a PhD in the natural sciences, but keep in mind that it is just an example, and, depending on your discipline and interests, may look quite different. This model tree



should inspire you to make your own personal decision tree. For many of you the first question you might try to answer is: do I want to do a Post-doc or not? The no-Post-doc category can be further broken down by splitting it into two categories: positions in for-profit organizations and positions working in government and other not-for-profit organizations. In the following sections we discuss these three options in some detail.

The Next Logical Step: A Post-doctoral Fellowship

You are trained as a lab scientist, your supervisor is a scientist, and perhaps a professor you met at a conference has offered you a position as a scientist. So what's stopping you from taking the natural next step: accepting the offer to work as a Post-doctoral fellow? Post-doc positions are relatively easy to come by and accepting such a position saves you the hassle of going through several job interviews. But there are at least two better reasons than this to continue your career by taking on a Post-doc position: (1) being a Post-doc is the logical and expected next step on the academic ladder; and (2) as it is less stressful than getting a PhD (you've got no impending thesis hanging over your head like the sword of Damocles), it is a good way to really enjoy doing science.

An ambitious PhD with his or her eye on doing a Post-doc, will often wonder which school is best for them and how to choose a research area that will optimise their chances of working their way of to the top of the academic ladder. No doubt it helps to go to a top school and work in a field that is currently in fashion (nanotechnology, genomics, neurosciences). But there are many other ways to become successful in the long term.

Whatever you decide, make sure you do what is right for you, and that you are making decisions that are realistic and will help you reach your goals.

Looking further down the road, when you apply for an assistant professorship (after being a Post-doc for a few years), the search committee will want to see what you have achieved during your post-doctoral period. If the science you have done is impressive, the rest is less relevant. Ask the senior scientists around you what choices they made to get them where they are now. As you will probably discover, they have all done good research, some at top schools, on trendy projects. If you decide to do a post-doctoral fellowship, while knowing that you do not intend to pursue an academic career, make sure you choose a position, location, university, and/or lab that you will enjoy, and start thinking about what you will do afterward, such as work in industry or for a not-for-profit organization. Also, consider getting involved in some extra curricular activities that might be relevant to your new field.

For-Profit Organizations: Where Business and Science Meet

We'll start with the most important message first: if you think you want to work in industry, do not wait. Get started on your search right away. Jobs that most PhDs have in for-profit organizations can be classified into two types of industries (1) research-related companies that hire skilled experts and (2) service companies that need analytically skilled staff.

Research-related industries either make high-tech products (e.g. Microsoft, Philips, Siemens, IBM) or need high-tech people to make their products (Shell, Exxon, Unilever, Springer-Verlag). These industries tend to be large and multi-centred. Jobs in small and medium-sized enterprises (SMEs) may be scarce these days, but not impossible to find if you have the right connections. Often scientists start in the IT or R&D branch of the company, and then move on in the course of 5–10 years to management positions. Sometimes you can start immediately in a management-type position. Many PhD students are put off by the idea that they will not be able to do research forever within a company – after all, isn't bench science what you've been trained to do? However, very often you will find that your interests change over time. For the real scientific diehards, and those who can't imagine working outside the lab, almost all companies have some senior research positions.

Service companies tend to be less interested in the actual content of your PhD research, but value your analytical and problem-solving skills. Quite a few PhDs find jobs as financial analysts, risk assessment analysts or management consultants. All major financial institutions and global operating consultancy firms hire talented people with a PhD in the natural sciences, as well as in other disciplines.

Not-for-Profit Organizations – The Best of Both Worlds?

Several years in the lab have taught you one thing: you like doing science and using your analytical skills, but you want to avoid both the insecure academic track and the acutely business-oriented approach of for-profit organizations. If this sounds like you, a not-for-profit organization may offer an appealing career alternative.

Actually, there are a wide variety of jobs that welcome PhDs in the natural sciences, that have either more or less emphasis on doing research. We discuss three of them in decreasing order of their research component.

- *Government labs.* Rather than concentrating on the fundamental aspects of research, government-sponsored laboratories focus on areas of research that have a broad impact on society, such as future energy sources and technologies, public health, and the environment. Their research goals are often long term, and relevant to society's needs. By focusing on the long term, the pace in these laboratories is often less hectic than that in industrial laboratories. The nature of the topics, however, and their relevance to real life issues, often helps researchers feel highly motivated about their work.
- *Governmental organizations.* These types of organizations offer a wide variety of jobs for which a thorough understanding of science and technology is often required, but no active research is carried out. National patent offices and regulatory bodies are examples of such institutions. Setting rules and prices for electric power, telecommunication, and so on require technical insight in the subject, understanding of the market economy and how the government regulates it. Big companies depend heavily on this relationship between government and industry. Also, their Regulatory Affairs departments welcome PhD's with technological backgrounds and analytical skills.
- *Educational institutions.* Finally, let's not forget to mention the fount of all scientific progress: education. While you must have Post-doc experience to be able to teach at the university level, colleges and high schools are desperately seeking highly qualified teachers. If you like the idea of shaping young

minds, it can be a rewarding experience to educate and inspire the next generation of scientists.

Once It’s Been Made, Is Your Final Decision Carved in Stone?

Many PhD students believe that once you have chosen between academic/for-profit/not-for-profit you’ll be obliged to stay on that career path forever. Since these choices are often thought of as being carved in stone, the decision can seem overwhelming and is often postponed. But how final is that decision really? How difficult is it to swing from one branch of the career tree to another? To give you some idea of what this might look like, we’ll describe an average situation that could have occurred any time during the last 10 years, noting that the flexibility of the job market can play an important role.

Just because you may choose to take a position as a Post-doc, it does not automatically mean that you have to follow an academic career path. Many Post-docs end up in industry or in not-for-profit careers. However, the older you are as a Post-doc, the more difficult it may be to find a job in one of the other branches. For-profit industries are notorious for wanting to hire young and hungry PhDs for their entry-level positions. So if you are sure you ultimately want to pursue a career in the for-profit sector do not hang around working as a Post-doc for more than a year or two.

Going from the for-profit sector to a not-for-profit organization is a move that can be made at any time. Going from a for-profit industry back to the academic track, however, is more difficult. In practice, only those who work in a research department of a multinational company manage to make the transition to senior academic positions. Finally, the not-for-profit jobs have the (undeserved) reputation of being a dead-end; once you are in, you will never get out. This is certainly not true for all jobs. For instance, once you are an experienced employee for a patent authority or regulator you are also a very attractive experienced hire for for-profit organizations.

From Searching for Opportunities to Getting the Job

Congratulations. You've figured out which type of job is right for you. Now what? Suppose you have selected a job type based on a decision tree like the one shown in Figure 1, the next move will be figuring out how to get that job. A toolbox of skills to help you in applying for such a position includes writing an effective cover letter and curriculum vitae, learning how to emphasize your strong points and deal with your weaknesses, etc. There are many books, workshops, and courses available on how to acquire the skills you need to get a job, hence they will not be discussed here. Three specific issues related to PhDs will be discussed here, however: a) When to start your job search, b) How to use your network (yes you have one!), and c) How to prepare for a job interview.

When to Start Your Job Search

The key to the numerous steps involved in getting a job is the ability to see things from the employer's perspective. Suppose you are a recruiter for a large company that hires 30 scientists a year. Two candidates come into your office. Candidate number 1 tells you that he got his PhD six months ago. Right after his PhD he took a trip around the world for four months. It was while he was unpacking that he realised he needed a job and that's why he's here. Candidate number 2 says: 'my PhD defence is in two months, after which I plan to take a month's holiday. I am here to find out whether you will have an opening for me three months from now.' Which candidate would you be more interested in hiring? For many, job planning is essential, and you can demonstrate that skill by timing your application properly and showing your interest ahead time. It should be obvious, unless you are independently wealthy, that you should start your job search well before you obtain your degree.

How to Leverage Your Network

Although the website of your preferred future employer can provide you with a wealth of information, it lacks the richness, essential details, and the necessary inside information that you only can get from a real expert: a former colleague who happens to be working there. Go and talk to him or her. You will get a feel for the company culture, find out what type of job opportunities exist, and get a sense of whether you will like working there once you've taken a position there.

Every career coach will tell you to use your network, but where is it and do you even have one? It seems you know almost no one who has the type of job you are looking for. However, many PhDs have graduated from your institute in the past 5 years and your supervisor or other staff members most likely know where they are. Contact these former colleagues. They have been in the same position that you are now, and probably they'll be very happy to discuss the pros and cons of their current employment.

As a PhD Student, Which Typical Skills Do You Possess?

More than you probably think! Suppose you apply for a position for which a PhD is not mandatory. The recruiter will probably perceive that you, having a PhD, have certain competitive advantages over other candidates. What are these advantages and how can you demonstrate them? To help you get a better sense of who you are and all that you can do, make a list of all the skills you developed during your doctoral training. Don't forget that your training as a grad student has taught you much more than science. You have acquired valuable skills in problem solving, analytical thinking, time management, project management, supervision, giving oral presentations, communication, and teaching to name just a few.

How to Prepare for an Interview

It goes without saying that being properly dressed and behaving politely are important when you meet your prospective future employer for the first time. There are many books and workshops available on how to make a good impression during an interview. Make use of everything that is available to you regarding this important phase in the job hunting process. At some point, you'll move beyond talking to the people in personnel and have to start talking to the people in the department to which you are applying. Keep in mind that these people are not professional interviewers and meeting new applicants is just one of their tasks. First they will ask what you have done in the past, what you expect from your new job, and what your long-term plans are. Since you have already prepared the answers to all these questions, you have nothing to worry about for this part of the interview at least. But now comes the hard part: you have to become an excellent listener and pay attention to the interviewer when he/she tells you about their job. For the purposes of the interview, he is an expert in the field and you are completely ignorant, so be careful to act accordingly and not to come across as someone who knows it all. Sometimes you'll be lucky and happen to know one or two things about the work being described. Most likely this part of the interview, and how well it goes, will play a major role in the final decision of whether to hire you or not.

You can impress the interviewer by being a good listener. So pay attention, try to summarize what he has been saying (So if I understand you correctly, you are doing...) and most importantly ASK QUESTIONS. They know you are not an expert so feel free to ask if you do not understand things. Most applicants ask too few questions because they're afraid to show their ignorance. You have to practise asking questions, so try to do that before the interview, either alone or with a friend. Good opportunities for getting accustomed to asking questions can be found at the colloquia you are attending. Force yourself to ask one question at each colloquium. At some point you will get used to it and asking questions during your interview will feel as natural as breathing.

Do You Want the Job?

During your job search, you might become so anxious about getting a job, any job, that you may forget to ask yourself whether you really like the position that has been offered to you. Again, stay in the lead. Make sure you have made an active decision based on what you want (e.g. by making a decision tree). Use the interview to get a better feeling for whether you would like to work for that particular department/company. Also, make a realistic estimate regarding any other positions you might be offered if you decide to decline an offer.

In summary, don't wait too long to start thinking about what kind of job you want after your PhD. Before you write your CV and start sending out applications, you need to become familiar with the opportunities available and have a good idea of which job will be the right one for you.

Chapter 22
Is Industry Right for You? Opportunities to Explore

Logic will get you from A to B.
Imagination with take you everywhere.
– Albert Einstein

In the course of your doctoral studies it may have crossed your mind that your research might have little short-term value – after all, it's mostly curiosity driven. Join the club. If you're good – or lucky – your research may contribute to society in the long run. If you're ready to work for an organization this is largely driven by the short-term impact on society, your next step may be to find a job in a for-profit organization. Although work-for-hire may seem a bit mundane to an academic, this kind of work serves society in the short term in a tangible way: someone is willing to pay for the service or product you produce.

A wide variety of companies hire PhDs. In this chapter we first describe several aspects of doing research for a company. It might help you decide whether a corporate lab is an appealing destination for you. Next, we discuss opportunities outside a research environment, where you are expected to solve problems, use your analytical skills, explore unknown territory, and learn while you're working, in short, the world of management consultancy.

Research in a Business-Driven Setting

For better or worse, the science-related corporate world values research differently than that of academia. Industry typically views research as an essential part of its business strategy. For scientists, this means less freedom and, very likely, greater short-term impact. This difference in values generally results in different ways of working, and a different set of required skills.

The distance – in time and effort – between a wild idea and a product that can be purchased by a customer is longer than you might imagine, and most potential products get lost (or abandoned) along the way. The steps between wild idea and product vary somewhat with every new product, and vary widely between industries. A new gadget for a mobile phone goes through different phases than that of a drug developed by a pharmaceutical company.

Still, almost all products in science-based industries go through research, development and engineering phases before they enter final testing and production.

Industry's research phase comes closest to the type of work you are most familiar with. Corporate research focuses on the company's long-term product pipeline: the products it hopes to launch over the next 5, 10 or 15 years. Research activities may not be related to a product the company is already selling or about to launch (this isn't true for pharma companies); rather, the company may be exploring new products or even whole new technologies that may or may not become marketed products, eventually.

Not every science-based company has a true research and development department. Even some pharmaceutical companies prefer to bring in promising ideas from outside, by licensing technologies and ideas from other (usually smaller) companies or academic labs.

The first phase in the development of a commercial product is, well, development. Development means transforming the initial conception into a prototype that demonstrates the product's desired functionality. In the development phase, the concepts are either proven or abandoned.

Finally it takes a lot of engineering to figure out how to produce a reliable product, which has the desired functionality and quality, at reasonable cost. The engineering phase is most likely the furthest away in scope from the type of research you're most familiar with, but the challenges are no less formidable, as are the costs to achieve the desired result in a given time frame.

The early stages of the research part of R&D can be still quite academic; they are, however, largely motivated by the company's strategy and product roadmap. In the design and engineering phase cost and timing issues are crucial. A good idea – or even a good product – cannot serve a company's business needs if it's too late to market or too expensive to produce.

Some scientists find such constraints disagreeable, considering them to be restrictions on their curiosity-driven work, or a compromise of science for commercial ends. Yet there is an undeniable thrill in knowing that you're working on something that will be actually used, whether it's to make the world a profoundly better place or merely to give pleasure to consumers. Moreover, resources such as people, equipment, and money are much less of a constraint as you get closer towards the end product.

The Difference Between Academic and Corporate Problem Solving

One important difference is that in academia the line between colleagues and competitors is vague, while in corporate research it is quite clear: the 1000+ people employed by the same global company work together towards the same ends. Communication is fast and open within the company, while interactions with the outside world are restricted: the process of publishing is carefully timed and controlled in industry so as not to put the company's IP at risk, or to disclose too much of its strategy. In contrast, the academic world is not so starkly divided; today's competitor may well be tomorrow's collaborator, and vice versa. Alliances are always shifting.

In an academic setting, a surprising result can be a breakthrough, providing a new way of looking at a problem. Even if it isn't a breakthrough, you always have the freedom to redefine your problem and keep your science marching forward. In such a setting serendipity can be an important ally (even though some researchers claim, once the work is done, that a breakthrough was intentional and anticipated). This academic attitude – being relatively relaxed on the direction of research – has facilitated much of the progress in fundamental science. It has the additional benefit of allowing researchers to plumb the depths of a new scientific insight, hitting a problem hard until it yields its secrets, a process you probably have experienced during your PhD!

Corporate researchers rarely have such freedom. In a corporation, research is an expense that is expected to generate revenues in the future. Only a small fraction of conceivable research has profit potential given a company's expertise and other resources, and only the most promising are likely to be undertaken. Every new project is a roll of the dice, and an unexpected result requires a whole new calculation of risk and potential benefit.

Thoroughness, too, must often be sacrificed: Too bad that problem can't be solved completely; in industry what's needed, especially in the development and engineering phases, is a way forward on budget and on schedule, and not necessarily a completely rigorous solution. There may not be time for an elegant, scientifically rigorous approach – but a practical answer to a difficult problem has its own sort of elegance, and can be equally satisfying for researchers.

Another consequence of the strong connection between research and the product roadmap is that sometimes projects end prematurely. If your company decides for financial or strategic reasons to abandon a line of activities, research in that area will likely be curtailed. You may be required to abandon your professional passion of the last months or years and embrace something entirely new. It can be frustrating but, in the long run, regular changes of direction can be stimulating and good for your career.

Finding Out If Corporate Research Is for You

Companies provide information, via their Websites and recruiting brochures, about their (research) activities and employment opportunities. But such information tends to be quite general and promotional; it's a start, but really you need something more direct. As a start, attend career fairs and other career events. Talk to recruiters or whoever else is manning the company's booth. This is a better way to get a feeling what type of folks they are and who it is they are looking for.

A better way to investigate is to talk to people within the company with backgrounds similar to yours. Perhaps a former fellow Post-doc or grad student works for the company, or knows someone who does. Don't be shy; pick up the phone, make an appointment, even if you know them only remotely. Most likely they will make time to meet you face to face and show you the type of work they are doing. Some companies give their employees even a premium if they help recruit talented former colleagues.

But the best way to figure out whether a particular corporate work environment is right for you is to spend some real time there. Many companies provide opportunities such as fellowship programmes that allow PhD/master's degree students to experience the corporate work environment.

Not Your Final Destination

It's often hard to leave an academic research post, especially once you have tenure. Moving from a corporate research career back to academia is difficult, though not impossible; only a handful of people make the leap, especially in more applied programs like engineering departments. At managerial level academia appreciates the corporate experience more. While it is difficult to return to basic science, once you are in the corporate world, it's relatively easy to branch out within a corporate setting.

After several years of R&D experience, many people are eager for take on new challenges. Many shift into management, production, sales, customer service, or intellectual property. A corporate lab might be an interesting environment to do research with a slightly different twist. It can also provide a step into new kinds of stimulating work later on.

A Career as a Management Consultant

Assisting corporate executives with their toughest decisions may not seem the most obvious career move for someone who has just finished – or is in the process of finishing – a science PhD But many consulting firms hire PhD's to join multidisciplinary teams to do exactly that, and new PhD's are often thrilled to work in such a novel and exciting environment, where facts and analysis play an important role. Being an example of a non-research related continuation of your career after your PhD we address here a number of dimensions of embarking in the world of management consultants.

Consultancy firms help company managers deal with all kind of issues and problems that arise within their businesses. Of course, companies have internal resources to address their problems. But corporate executives may decide that a certain issue calls for a team of external, independent problem solvers working full time. (See box for an example.) Typically, consultancy firms send in a small team of consultants to address the issue, supported by partners and expertise from the firm. Usually the team includes a leader responsible for running the daily operation, senior team members with several years of experience, and some younger team members – such as freshly minted PhD's – who are learning on the job.

Solving a corporate problem is not much different from solving a scientific problem. It requires data, a thorough analysis of the data, and a synthesis leading to the best possible solution. Finally, the solution has to be reported in such a way that the audience accepts the message and is willing and able to implement it. Those challenges are familiar to most scientists fresh from PhD programs.

There is one big difference: time. Time is money in the corporate world, particularly for the types of problems that management consultants are usually asked to solve. So it is essential to find the best possible solution within a given time frame, rather than a completely correct 'scientific' answer.

Consultancy Firms Hiring PhD's

Having a PhD is not a prerequisite to joining a consultancy firm, but quite a few management consultants do have a PhD track. For example, the Boston Consulting Group and McKinsey and

Company both have special entry levels for PhDs. Since your PhD research topic is probably of little value to the consultancy firm, you might wonder why they are willing to hire science PhDs with probably irrelevant graduate experience. Firms see problem solving is a key asset that PhDs have. Not just the analytical skills, but also the ability to structure a problem seeing both the big picture and the details driving it. Being new in a field and approaching a problem with and open mind – though fact driven - has something refreshing to an organization struggling with problems in developing and executing its strategy. When joining a consultancy firm your analytical and quantitative skills are probably adequate, while you have to catch up on skills and knowledge related to business, finance and economy. Firms have the experience that PhDs quickly learn the knowledge and skills the are lacking.

The Steep and Uncertain Career Path as a Management Consultant

Top-tier consulting firms generally have a fast career track; you are expected to move up to the next role within 2–3 years. What if you can’t, or don’t want to, make the next step up? In that case, most firms would advise you to look for opportunities outside the company.

Is this something to worry about? Probably not. Most former consultants say they learned a lot while on the fast track and received good advice on how to move on in their careers and on what to do next. ‘In the long run you are better off learning fast and moving on’ when your progress slows, says one seasoned pro.

To learn more about management consultancy most firms organize business courses or master classes for potential hires. In a programme, typically lasting a few days, you get to work on a real problem, supervised by consultants. It is an excellent way to gain an appreciation of the thrill of the job, or to realize that it's just not your cup of tea.

Applying for a job at a management consultancy is not much different from applying for a job anywhere else. Try approaching someone in the company you know, or someone one of your colleagues or friends knows. Follow up with an application letter that states your interest and willingness to work for the company. The initial interviews – which usually are with recruiters – are likely to be conventional interviews in which you talk about your skills, your career history, and your ambitions, and ask questions about the company.

Your next round of interviews may include working on a case study with one of the company's consultants. You receive information about a particular problem and, with help of the interviewer, plan a problem-solving approach and try to crack the problem on the spot. Interviewers are aware that you aren't an expert, so they'll focus instead on general skills and the progress you make on the case. Since this is quite different from a normal interview, consider doing a practice case upfront. Firms' Web sites often provide examples of case studies. But 'the best piece of advice I can give candidates is to get a good night's sleep and be fresh,' suggested one recruiter.

Companies Care

Although the years of lifetime employment are over, most companies really care about your career, perhaps for very selfish reasons. Academic science still follows the tournament model, with all but the most accomplished researchers often feeling taken for granted. Once you've survived and earned tenure, your academic freedom allows you to do whatever you like – but this changes little; outside your narrow research world, still no one has to care. Companies, in contrast, often treat their people – especially their knowledge workers – as their biggest assets. They invest in developing, training, and retention to nurture and keep the staff they need to meet their strategic objectives. This holds true for research driven companies, consultancy firms and most other private organizations hiring PhDs.

In summary, although working in a corporate research lab or as a management consultant are quite different entry jobs for a newly minted PhD, they have quite a few aspects in common. Pulled out of your academic research comfort zone you will learn very different ways of working, requiring you to work further on your skills and knowledge base. You will encounter quite different parts of society with all its pro's and con's. Continuation on the academic research track is often perceived as a choice for life. The entry jobs in a profit organization are often a first step in a career that can branch out in many unexpected directions.

Your first assignment as a management consultant

Because management consultants deal with a variety of problems, there are no 'typical' assignments. But here's an example of the type of assignment you might get as a new hire at a consultancy:

The company HighTech is losing market share on its main product because last year a competitor introduced a superior product. To survive, your client needs to regain its market share by improving the performance of its main product – its primary moneymaker. This means expanding the company's research and development (R&D) effort.

On top of that, HighTech has a breakthrough technology in the works, but it has to be launched in time for the 2012 holiday sales. But the new product has big technology uncertainties and these, too, require a lot of R&D effort.

It is up to you and your team to analyse HighTech's current position, evaluate the major technology challenges, consider the options, and decide whether and how to pull additional money from the market (loans or stock issuance, for example) to finance these options. You'd better hurry because Hightech is losing money every day and will be bankrupt by next spring if the recovery plan doesn't succeed.

Chapter 23
Exploring Not-for-Profit Organizations

How wonderful it is that nobody need wait a single moment before starting to improve the world.

– Anne Frank

Perhaps you've decided not to pursue a career in academia, but you're not sure about jumping into an industry job, either. Have you considered the nonprofit sector?

If you're passionate about a particular issue, mission-driven, and – in addition to your passion for science – desirous to improve the state of humanity and the world, you may be a perfect candidate for a job with a nonprofit. This article aims to give you a sense of the breadth and range of the possibilities open to you and a general sense of what nonprofits have to offer.

Where to Start

Not just soup kitchens and humanitarian aid, nonprofit organizations focus on nearly every issue you can think of: environmental protection, biomedical research, health care, education, international aid, disaster relief, science policy, and science awareness, among countless others. In the United States alone, more than 12 million people – some 9% of the workforce – are employed in the nonprofit sector.

If you don't wish to stray too far from the bench, you can seek research jobs at the many well-known and well-funded nonprofit organizations dedicated to biomedical research; examples include the Howard Hughes Medical Institute (United States), the Fred Hutchinson Cancer Research Center (United States), and the Monash Institute of Medical Research (Australia).

Numerous smaller nonprofits, such as the Robert Packard Center for ALS Research and the Australian Stem Cell Centre, to name two, have a specific biomedical focus. Some midsized nonprofit organizations that hire biomedical researchers include SRI International (a nonprofit scientific research institute focused on innovative technologies) and the Institute for OneWorld Health, the world's first nonprofit pharmaceutical company, both based in California. These small and midsized organizations attract excellent researchers who are passionate about their work and committed to research in areas typically neglected by profit-making companies.

If you've decided to pursue a career outside the lab but would like to stay in science, then the nonprofit sector has many options for you, including, for example, working in science education for an organization such as the Society for Science and the Public, as an outreach coordinator for the American Association for the Advancement of Science (the organization that publishes *Science* Careers), or as a programme officer at the Alfred P. Sloan Foundation. PhD scientists in agricultural or environmental sciences may choose to pursue a career at one of the many nonprofits active in the developing world, such as The Nature Conservancy and Earthwatch Institute.

Advantages

There are many issues to consider before starting on a career path in the nonprofit sector, including your personal and professional career goals. Here are a few of the advantages:

- *A wide range of excellent and compatible colleagues.* Nonprofits often have their pick of the brightest and most dedicated candidates, many of whom share your values. Staff members typically have a passion for their work and are committed to effecting social change. The result in many cases is an atmosphere of passion, teamwork, and collaboration.
- *Excellent opportunities for professional growth.* Due to the lower staff-to-project ratio in many smaller organizations – and often a flatter organizational structure – you may be assigned several projects and a wide range of tasks, offering you a better-than-average opportunity to strengthen your skill set.
- *Flexibility.* Compared with a corporate enterprise, for example, nonprofits may offer more flexibility in setting and achieving goals, establishing benchmarks, and setting strategies for meeting the organization's mission.

Disadvantages

Like any sector, nonprofits have some potential downsides:

- *Lower salary.* Most but not all nonprofits pay salaries lower than those in industry. This is especially true of advocacy organizations. But there's a wide range across the nonprofit sector, so don't let this particular issue discourage you.

- *Higher employee turnover.* There are many reasons for employee turnover in the nonprofit sector; burnout is high on the list, particularly if the organization is understaffed and you are required to multitask. Staff members may leave for better paying jobs, to switch sectors, or to return to school. Often, the smaller nonprofits lack professional-development tools aimed at retaining employees.
- *Limited opportunities for career advancement.* At smaller nonprofits, like most small organizations, upper management is very stable, so you might have to switch to another organization to advance in your career.
- *Structural differences.* If you thrive on hierarchy, discernable targets, and clear deliverables, small and medium-sized nonprofits might not be for you. Organizational clarity may be lacking, as these smaller nonprofits strive to fulfill their missions with limited staffing and resources. In larger and better funded organizations, these differences from industry tend to be less pronounced.
- *Fundraising.* Depending on the type of nonprofit, much time will be spent raising funds and writing grants.

One big advantage for many is that nonprofit organizations, whether large or small, are committed to their mission, not to shareholders or to maximizing the bottom line. This philosophy, however, may lead to an organizational structure and management style that, for better or worse, can create tensions and obstacles regarding the best way for the organization to meet its mission and goals.

Is Nonprofit Right for You?

How will you know if working in the nonprofit sector is right for you? Understanding yourself and your personal and professional goals is a first step. If you're passionate about a particular issue, and you like the idea of giving back to the community or making the world a better place to live, then a nonprofit organization may be the perfect place for you to launch your career.

Whether you're considering a job at a particular nonprofit or looking for a nonprofit organization to work for, you should, as in any job search, thoroughly research the organization while keeping a few sector-specific issues in mind as you explore your options.

First, look carefully at the organization's mission statement, which you can almost always find on its Web site, to decide whether its mission is one you're passionate about (or, at a minimum, one you can believe in). Next, look at the organization's staff profiles to see if the type of people it employs fits your skills and career ambitions. Finally, take a look at the annual report to see what kind of operating budget the organization has and how funds are allocated. This information will give you crucial clues about how the organization goes about achieving its mission, the type of people it hires, and the stability of its finances. Try, if possible, to contact someone who works for the organization, or a former employee, to get a better sense of its structure, culture, and day-to-day operations.

Once you make it to the interview stage, no matter the size or renown of the organization, ask some key questions to get a better sense of the organization's operations and how they treat their staff:

- What is the structure/hierarchy of the organization? How are decisions made and communicated to the staff?
- Does the organization encourage teamwork and collaboration, or do staff members work independently on projects?
- What opportunities are there for advancement within the organization and/or partner organizations?

- What kind of training will I receive? What opportunities exist for professional development?
- What are the organization's short-term and long-term goals?
- How is the organization funded and what type of operating budget does it have?

The answers to these questions may help you align your possibly idealistic expectations with how things really work. Even if the organization is doing excellent work to improve the state of humanity, you can be sure that petty grievances, turf wars, and other aspects of interpersonal friction will be present – just as in any profitmaking corporation or bureaucracy-laden government institution.

Finally, ask yourself: Am I passionate about the organization's mission? Is this a place I would like to come to work every day? Do the organization's goals and objectives fit with my own interests and values? Do I see this as a first step in a career progression of increasing responsibility?

The nonprofit sector isn't for everyone, but for many, particularly those making the transition from academia, the values and culture inherent in the nonprofit world may offer an exciting and rewarding career choice.

Swinging from Branch to Branch on the Career Tree

When starting out in your post-PhD career, the system may seem to be rigid and inflexible. PhDs looking back on their career usually notice that they have actually been swinging through the career tree quite a bit. Here is what the members of our team decided to do once they'd obtained their degrees:

Saving an old master painting: epilogue – career tracks with a touch of art restoration

When starting out in your post-PhD career, the system may appear to be very rigid and inflexible. PhDs looking back on their career have noticed, however, that they have actually been swinging quite a bit through the career tree. Here is what the members of our team decided to do once they had obtained their degrees:

As a child *Isabel* was fascinated by paintings, in particular the Old Master paintings in which some of the figures were mysterious and barely visible. Having studied chemistry as an undergraduate at university, she still wanted to do something with art. She learned about the scientific aspects of art restoration at a chemistry conference on polymerization processes. Then she embarked on her PhD programme as discussed elsewhere in this book. As the end of her PhD period drew closer, Isabel began to realize that it was time to start looking for a job. Unfortunately, she fears that the chances of finding one in the field of art restoration are slim, especially for a chemist. So what to do? Isabel made an attempt to analyse what she liked most about doing a PhD. After some discussions with friends, Isabel realized that she appreciated in particular two aspects of her PhD programme. First, she enjoyed using multiple analytical techniques (x-ray, mass-spectrometry, IR imaging,. . .) to come to scientific conclusions about the nature of the paint pigments. Second, she liked interacting with experts outside the world of natural sciences, who put the scientific results into a broader context (the art historians' perspectives were essential for obtaining a complete picture of the original painting). She liked working with real masterpieces of art, but it was a less essential part of her work. But once she had in mind her two favourite aspects of the research, no particular job came to mind. One night, she watched a forensic series on television. Isabel realized that a job in such a laboratory was actually a perfect match for someone with her ambitions. To Isabel's surprise her professor knew the head of the analytical research department and he arranged for Isabel to meet with him. During that visit Isabel learned that they indeed used a wide range of analytical techniques at the forensic lab, most of which she knew already how to perform. Furthermore, she found out that the interactions with non-scientific experts, such as police inspectors, was an important part of the job, and for solving criminal cases. Now that she was well motivated and prepared, Isabel applied for the job. Five years later, she is head of the analytical services department of the forensic laboratory in her state.

After obtaining his PhD in physics *Yousef* accepted a position in the R&D department of a multinational oil company. After a few years of basic research on oil derivatives, he moved to the consultancy branch of the same multinational. Now he is responsible for in-house advice on regulatory affairs, together with a lawyer and a marketing consultant. When asked whether working on a PhD was a valuable investment Yousef always replies: 'Yes! In particular the skills I learned from structuring and solving complex problems within an interdisciplinary team turned out to be very valuable'.

Initially, *Peter*, a talented art historian, did not want to pursue an academic career. After a short Post-doc he joined a leading ICT company. Although he was working on demanding and complex problems, he missed the exploratory nature of basic research in art restoration. At an alumni event his former supervisor mentioned that there was a starting position available in art history at a nearby university. Peter went to the job interview and suggested to the search committee that they hire two assistant professors rather than one, and that the additional assistant professor have an analytical chemistry background. The university liked the idea and contacted the dean of the natural sciences department. With some extra money from an art restoration foundation they set up this unique interdisciplinary team. Peter is enjoying his new job and is happy to be back in the world of art history and restoration and working again with the chemical side of this challenging field.

Chapter 24
Lessons Learned

The first step in the acquisition of wisdom is silence, the second listening, the third memory, the fourth practice, the fifth teaching others.

– Solomon Ibn Gabirol

This book describes numerous situations that graduate students will commonly encounter as they work towards their doctorate. Starting from your very first day in the lab, to the beginning stages of your post-PhD job search, to the day you receive your degree, we've tried to offer you sage advice on how to handle particular situations as they arise. Although individual circumstances are never the same for everyone, we aimed to give you some general guidelines about what we believed would help you make the most out of your years in grad school. Most of the advice we focused on is of a practical nature and dedicated to the problems typically encountered by most PhD students. If you glance back through the various chapters you will notice that we have tried to suggest a general strategy for tackling particular problems. In may seem paradoxical, but usually similar actions are required to solve inherently different problems – no matter what stage of learning and life you happen to be in. And the good news is that many of the skills you learned during your PhD years, regardless of the topic of your thesis, will be useful in later stages of your career.

In this final chapter we summarize, in general terms, the key lessons we hope you have learned. Perhaps the two most important, and the ones that run through all the chapters like a common thread, are *proper planning* and *good communication*. If you've recognized the importance of these two skills and have managed to put them to good effect, you have probably come to the end of your graduate study with a sense of accomplishment, as well as pride in yourself for having successfully survived the course. In fact, the strategies you have acquired in learning how to master your PhD will be useful in every job you have from here on. To repeat a statement that we included in the introduction: former PhD students claim that the communication, planning, and problem solving skills they acquired during their PhD research are as useful to them, if not more, as the actual content that went into their thesis.

Planning Is Essential

Scientists tend to be skeptical by nature. It goes with the territory. So many of them claim that you simply cannot plan science. Research, after all, has a life and rhythm of its own. So some feel that trying to plan your time in the lab is a wasted effort. Indeed, you can not plan the outcome of your scientific efforts. But we still believe in the importance of proper planning (and this includes time management) and that good planning will maximize your chances of getting the most out of your time in the lab. There's more to grad school than research. All kinds of 'fringe activities' will take up your time and pull you away from the lab bench. Attending conferences, discussing work, preparing presentations, reading the literature, searching the Internet, and handling your e-mail, are all essential activities. With proper planning you can optimize the results of those fringe activities so that you spend as little time as possible on things that are essential, but take time away from your thesis research.

Every now and then it helps to take a step back and look at your world with an impassioned eye. If you can honestly assess the productiveness of everything you did, you may realize that you could probably have skipped a good fraction of those activities (the 80/20 rule). Truly wise planners know how to stay one step ahead of their problems. By reflecting on what went wrong in the past, and being honest about what might go wrong in the future, you will be able to take appropriate measures that will save you a lot of time. Therefore, we have repeatedly suggested that you identify the potential hurdles you might have to leap over, and pitfalls that you need to avoid. For instance, during your monthly progress review. Once you have identified potential problems you can consider alternative approaches for obtaining the result you want.

People with a more chaotic approach to projects (perceivers in MBTI terminology), often find that things do eventually work out the way they want in the end – despite their lack of good planning. This may work only if your actions, and yours alone, are required to obtain the result you want. But doing a PhD always requires the help of others to a greater and lesser extent. So teamwork is essential and getting people to work in harmony takes time and effort. Very few people will start marching to the tune of your drum, even if you think that's the best way to proceed. You have limited power to change the behaviour of others, so in order to ensure that they deliver on their promises, you will have to plan carefully and be realistic about lead times for all the things (and the list is long) that are not under your control. Of course, for a plan to be successful, you will need to communicate the planning to others. This brings us to the second valuable skill that we hoped you have picked up and refined along the way.

Communication Creates Harmony

Even if it's just your name that appears on the spine of your printed and bound thesis, remember: you are part of a team. You might not find that your team mates are active or visible at all times, but they are there. From librarians to roommates, from undergraduate students, to your supervising professor, they all contribute to your research in one way or another. Share your good news with others (celebrate your success), and ask for help and advice if you are making less progress than you expected. Be able to admit it if you don't know the answer to something. Ask questions. Listen to the answers. If you have an open attitude and make clear what you expect from others and what they can expect from you, your years as a graduate student will be more productive, not to mention much more pleasant.

Misunderstandings that arise from a lack of communication are the source of many conflicts and much unhappiness. Solving conflicts is essential to moving forward with your team. The first step in solving interpersonal problems is communication. A key aspect of good communication is active listening, a skill that is also of great value during job interviews and meetings. As you make steady progress in your project, you might forget to communicate frequently. When work needs to be done, it may seem to you that talking, and especially listening, is a waste of time. But it's essential to keep communicating your progress, as others might have interesting suggestions to speed up your research or to redirect your experiments a bit, so that the scientific value of the results is bigger. A plan not communicated with your team is bound to fail. The converse is also true: communication that is not planned loses much of its value. Of course you already know that you have to prepare in advance your presentations at conferences and group meetings, but your yearly evaluations, as well as any other meetings you have with your thesis advisor, will have a bigger impact if you are thoroughly prepared beforehand. Think how important something as trivial as a proper subject line is when you write an e-mail. Words carry a great deal of impact. A well thought out subject heading will have a much better chance of being acted upon by the receiver. So it is with talking and listening to the members of your team.

A Final Thought

The research and effort that go into earning a PhD requires hard work, dedication, and the ability to recover quickly from setbacks. This may all seem like a lot of hard work and no play, but working on a scientific project also has many upsides. Enjoy and celebrate your successes – such as the occasion when you're the first person to obtain novel data about a particular topic and are able to draw conclusions from it. Doing science in a research institute is a job, certainly, but it's a special one. Some even say that it's a calling. You're surrounded by young, hard-working and ambitious people. So don't forget that there are also many opportunities to have fun with your fellow students. You're all in this together, so don't be afraid to inject levity and humour into the day-to-day seriousness of your work. A PhD programme is much more than getting results and writing a thesis. It's a period in your professional life in which you acquire many new skills and make professional and personal contacts that will last a lifetime. Allowing yourself to master those skills, as well as have fun in the process, is the sagest advice we can offer.

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Dr. Patricia Gosling obtained her PhD in Organic Chemistry from the University of Nijmegen, The Netherlands. For several years she ran her own communications consultancy with a focus on science journalism and medical writing. A US native, Dr. Gosling has lived and worked in the Netherlands, Germany, Malaysia, and Switzerland. She currently works in the Scientific Publications department of a leading biotechnology company.

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