ON BEING A SUCCESSFUL GRADUATE STUDENT IN THE SCIENCES

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The competition for jobs in academia and in top companies is intense. The jobs are there, but you have to stand out from the crowd. On any given year, there may be 10-20 new positions in your particular subdiscipline, and you can be certain that there are plenty of graduate students and post-docs around the country who have spent the past 5-8 years working day and night to show that they have the drive, imagination, and expertise to compete for these few positions. In addition, there are assistant professors who are looking to change jobs and against whom you must also compete. For each of those jobs there may be 75-250 applicants, depending upon how specific the search committee made the position description.

If you want to be in the group that is called for interviews, you must set up work habits early in your graduate career that will put you in a position to be competitive. Hard, consistent work will not guarantee that you will get an interview, but lazy, inconsistent work will just about guarantee that you will not get an interview in today's academic job market. If you want to spend your life doing research and teaching, you need to demonstrate that you are very good at it.

What follows is a set of recommendations for what I mean by a successful graduate student. These guidelines cannot make up for a lack of imagination in posing research questions and designing experiments to answer the questions. The guidelines simply indicate what you need besides a fertile imagination and a critical mind to be a successful graduate student with some hope of attaining a position in a major university or a major research organization. I don't mean to imply that everyone seeking a graduate degree should have their sights set on a university position or a research position within a non-profit organization, a government agency, or an industry. There are many alternative, productive lives, and the simple fact is that only a small subset of graduate students will eventually ever get the opportunity to work in a major research, or research and teaching, environment. But many graduate students view a combined research and teaching job as

[1] This treatise was developed as a supplement to the discussions I have with all new graduate students in my laboratory. It began as a few pages in the 1980s and has expanded in length over the years. Although I never intended it to spread beyond my own lab, it has taken on a life of its own, spreading over time by hand and email among colleagues in a number of countries. I continue to revise it from time to time as graduate life continues to change. The newest version is always on my lab website: http://bio.research.ucsc.edu/people/thompson

at least one possible way of how they may like to spend their lives after they leave graduate school. These guidelines are written with that in mind, and I wouldn't change any of them if I were writing them for any of the other possible alternative lives.

Set Goals.

Set long-term goals, monthly goals, weekly goals, and daily goals. If you do not, then time will just slip away. Each month evaluate your progress toward the goals you have set. If you are falling behind in reaching those goals, ask yourself why, then do something about it.

Learn self-discipline.

One of the clearest differences between successful and unsuccessful professionals in all fields is self-discipline. Set a schedule for yourself and stick to it. As a graduate student you must learn about your field of study in depth, set up a plan of research, carry out experiments, analyze the data or models, write manuscripts based upon the results, and participate in seminars and scientific meetings. To accomplish all this successfully, you must set up a schedule. Set a specific time that you will devote each week to reading new articles in journals. Set up specific times that you will work on experiments or analysis of data. Set a specific time that you will devote each day to writing (5-6 days each week), except during the peak weeks of your research and data analysis each year. Having a specific writing schedule will become especially important after your first or second year in graduate school, by which time you will continually have proposals and manuscripts that need attention.

Never catch yourself saying, I have not had time to set up the experiments (or read that important new paper, or analyze the data, or work on the manuscript), because these other things got in the way. You must set your priorities so that it is only the other non-essential things that don't get done on some weeks. Anything else is simply procrastination and excuses.

The problem of writing deserves special mention. Few scientists, or anyone for that matter, find writing easy. But there is only one way to get it done, and virtually every major writer who has commented on the problem has said the same thing: set aside a block of time each day and let nothing, absolutely nothing, interfere with that time. Some days, you may produce no more than a few sentences during several hours. Other days will be better. The important thing is to avoid the temptation to get up after half an hour of producing nothing and go to the departmental office for some coffee or pick up something to read. Do not let yourself succumb to the easiest cop out of all: I just do not have it today; I will try again tomorrow. Sit there and fight it out today, then do the same tomorrow, and the day after. If you are having trouble with the Introduction, then try working on the Methods section. Or think of one crucial sentence that you want to place in the Discussion. Keep at it. Eventually you will win.

Plan on long work weeks, but keep them productive.

There is no substitute for long hours if you are to accumulate the knowledge and skills necessary for doing innovative research, analyzing results, and writing papers. Some weeks (e.g., peak of field season, or experiments that require almost continual monitoring) may require 70 or more hours. During most other times, you should set a weekly schedule for yourself that guarantees you will make good progress each week. You will not be able to treat graduate school like a 40 hour a week job. It will take much more. The important thing, however, is not to just ‘put in hours’. Work hard and concentrate hard, and enjoy the work and concentration. Then set aside time to exercise and socialize.

Regard yourself and present yourself as a professional.

Don’t choose average graduate students and postdocs as your role models. Most of them will not end up with the kind of position you are hoping to attain. Aim higher, but do so with humility and respect for others.

Read broadly and critically.

Understand the broader context of your research. It is not enough to know the 100 papers most closely related to your dissertation topic. To do successful graduate work, you will want to have some familiarity with the wide range of subdisciplines that make up your field of research. To gain that familiarity requires more than taking some graduate courses. The best way to do this as a graduate student is to read a majority of the abstracts and introductions of every issue of the major journals in your subdiscipline. If you spend and hour or two on each issue of the several major journals in your field of study, you will be well on your way to getting the broad perspective you need. Place yourself on the eTOCs of the major journals.

Reading regularly through just a few journals is not enough. You will want to regularly thumb through other related journals and books to look for fresh ideas or approaches that could help make your research novel. Online data search routines are getting better all the time, and you should make use of these as well. Keep an eye out for major new books in your discipline.

Attend national meetings of one or more major scientific societies, and join those societies.

The papers presented at the national meetings of major scientific societies include the results that are currently in press or submitted to the major journals. By going to these meetings, you get to hear the newest results and you get a chance to talk with other researchers doing similar work. Initially, you will have nothing of your own to present. Go anyway, so that you can hear what others are doing. Talk with them about their research.

Join several of the major scientific societies in your discipline. It is part of being a professional. Scientific societies are more than the journals they produce. They are the voices for your scientific discipline. If we want scientists to have a say in the future of science, then scientific societies, and the meetings and outreach efforts they organize, are our best hope.

Learn how to write grant proposals.

Proposal writing is a fact of life in almost all major research positions. Early on, take every opportunity you can to read successful proposals (i.e., those that were funded) written by others. Ask yourself, what makes this a good proposal? Do the same with proposals that were rejected. Ask yourself, just what is it about this proposal that kept it from being funded. Help with the proposals being written in your own research group. Never try to write just a good proposal. Aiming for good is not good enough. At major granting agencies, often only 10-20% of proposals receive funding, and the percentages have continued to fall in recent years. You must use solid arguments to convince reviewers that this is a proposal that falls in the very top group. That group includes proposals that test major hypotheses, use up-to-date methods, show careful thought on experimental design, and provide a convincing case that the work can actually be accomplished during the funding period.

Design and carry out your research in a professional way that will help to minimize the chance of having your manuscripts rejected by major journals.

Science is a marvelously creative process: the posing of interesting questions, the design of models and experiments, the analysis of data, the interpretation and arrangement of results in tables and graphs, and the presentation of these questions, methods, results, and conclusions in the text are all part of the process. Every part of the process is important. Skimp at any stage and you are setting yourself up for not getting clear answers to the questions you posed. Moreover, you are setting yourself up for a rejection when you submit your work for publication.

Be prepared to have some of your manuscripts rejected. You will almost certainly have some disappointments when you begin to submit manuscripts based upon your research, unless you submit them only to obscure journals. The competition for space in the major journals is fierce. *Nature* and *Science* reject more than 90% of submissions. Many major journals within specific disciplines reject at least 66-70%. Remember those percentages at every stage of your research. Every time you think about settling on a more mundane question to answer, or reducing your sample size, or skipping an experiment that would strengthen your interpretation, remember that reviewers and editors of the major journals are looking for the small minority of papers that stand out from the rest. Editors of major journals search carefully for originality in questions, novelty in approach, thoroughness in carrying through on observations and experiments, and, finally, clarity and economy in presentation of the results. Continually ask yourself if you as self-critic find this method, this experimental design, this analysis, and this interpretation justified and convincing.

Check and recheck your data.

At every step of data collection, analysis, and writing, make sure your numbers are correct. You will make mistakes in recording numbers. The important thing is to find them—every last one of them.

1. Think about the numbers as they go into your notebook or onto your data sheets.

2. Check them, then recheck them, after you type them as data files into the computer.

3. Proof your data by printing out the typed data file and checking it against your notebook. Do not attempt to proof the data just by looking at the numbers on your computer screen after you have entered them. I have never found anyone who can proof data that way.

4. If you find mistakes, correct them and then print out another copy of the data file and recheck the whole data set again. It is very common to introduce new errors into a data file while making corrections, no matter how careful you are.

5. Repeat this process of proofing on paper, correcting the data file on the computer screen, and re-proofing on paper until you find no errors.

3-5 (alternative): The better modern alternative to this entire procedure is to enter all the data twice into the computer and then write an algorithm to catch mismatches. If you use this method, correct the mismatches and then run the algorithm again to make certain that all mismatches have been corrected and that you have not introduced any new errors while making corrections.

6. The next step is to choose the subset of data that you want to analyze. Check each printout carefully. Just because you think you wrote the program to eliminate all plants weighing less than 60g, do not simply assume you did it right. Check to make certain that you are using only the subset you want to include in the analysis.

7. Now you are finally ready to run your statistical analyses. Check each analysis carefully. Is this really the ANOVA model that you thought you were choosing after you finished pointing and clicking through all the boxes on your computer screen?

8. Check the numbers that you transfer from your printout sheet to the manuscript.

9. Check them again after you have finished the final draft of the manuscript. With all the deletions and insertions you have made while typing the manuscript, anything could have happened.

Go through this nine-step sequence with every analysis you perform. Remember, you will make mistakes and you must find them. If the numbers are wrong at any stage leading to the final manuscript, you are no longer doing science and you are wasting your and everyone else's time analyzing data with wrong numbers. You are doing research to get answers to scientific questions. You must make certain that the numbers are right.

Regularly ask yourself if you are asking important research questions or trivial questions.

It is easy to get caught up in little side questions that are personally fun to explore but are simply trivial. Every few months, sit for a few hours and think very hard about the direction of your research. Ask yourself, so what?

The answer to the question "What do you work on?" is not "I work on species x" or "I work on interactions between x and y".

How many times have you asked someone what he or she works on, only to have that person name a species, some higher taxon, some particular interaction between two taxa, or some small detail of a biological, chemical, or physical process as the reply? When you ask yourself that question, or answer it for others, you should be able to state clearly the major scientific question that you want to answer.

"Because it is poorly known" is not an adequate reason for choosing a dissertation project.

There is an almost infinite number of things that are poorly known. You must have a clear reason in your mind why, among the many poorly known phenomena in this universe, you have chosen a particular one for your research. Why is it a fundamental question?

Later on when you begin to write papers based on your research, remember that "because it is poorly known" is the least convincing justification for scientific study. Even so, it is probably the most common justification given in the introduction of scientific papers. If you have thought deeply about your research as you have worked on your dissertation, you will be able to write justifications for your work that go well beyond that very weak justification. You will be able to explain clearly how your work addresses a major scientific hypothesis, resolves alternative hypotheses, explains conflicting results found in previous studies, or unifies past results that seemed to be caused by separate processes.

Work on expressing ideas and results to colleagues and students.

You will spend much of the rest of your life trying to explain concepts, hypotheses, and results to others. The ability to do so will not develop miraculously. You must learn from experience how to get your point across in research seminars, in classrooms, and in meetings with people outside your discipline. If you want to convince colleagues that you have something important to say, you need to be able to keep them awake and interested during a seminar or a discussion. Think about how often you have been bored by having to listen to a speaker who wastes an hour of your time as he or she mumbles or reads to you—slide after slide—a disjointed talk that makes no important or interesting point. The same applies to giving lectures to students. With so many capable scientists competing for jobs, universities should be able to keep only those faculty who are both good researchers and good teachers. With the keen competition for jobs that now occurs, that is what will happen more often in the future.

So get all the experience you can get and learn from your mistakes. Watch carefully how others give seminars and lectures. Take the best from what you see in them and work out which of those techniques will work well for you. The structure of a good talk is completely different from the structure of a scientific paper. Your goal should be not only to convey information on your recent work but also to put that information into the kind of broader context that is not possible in a scientific paper. The most boring talks are those are nothing more than a description of the methods and an endless series of tables and graphs. Your audience deserves more than these details, as important as they are. The audience deserves to hear from you what these results mean in a broader sense and why they should care.

Finally, never read a talk to an audience. As Daniel Janzen (1980, Bull. Brit. Ecol. Soc.) once wrote, “If you, the person who knows more about it than anyone else, cannot remember something for 30 minutes, how do you expect me to remember it more than 30 minutes after the end of your talk?” When teaching a class you may need some notes in addition to your slides. But when giving a research seminar, you will have your slides to prompt you. Use either no notes or at most a one-page outline. And don’t cheat by piling so many words onto your slides that you are essentially reading the talk to the audience. No member of your audience wants to read slide after slide of bulleted text.

Remember that science is a social enterprise.

You cannot make much progress as a scientist unless you are willing to seek the help of others and, in return, give help whenever you can. The major questions in science demand expertise in ideas and technical skills greater than any one person can garner in a lifetime. You have to be willing to work with others if you want to get answers to anything more than the most mundane scientific questions. You cannot work in isolation. Take a look sometime at the collected letters of Charles Darwin (published by Cambridge University Press and expected to reach at least twenty volumes at completion). You will find that Darwin was constantly writing letters to colleagues requesting help and information, and offering it when asked.

Learn how to introduce others, and learn how to introduce speakers.

You will often need to introduce colleagues to other colleagues. Learn how to do it effectively with several brief sentences, so that they can immediately see where they may be some common ground for conversation. Learn also how to introduce speakers by listening carefully to introductions by others and developing a style of your own. Speak clearly and briefly about that person’s work and accomplishments. Don’t bother giving a list of the universities that the speaker attended as student. It is irrelevant information and shows a lack of preparation of a real introduction. The audience wants to know why it might be worthwhile to listen to this particular speaker talk on this particular topic.

You are part of a laboratory.

Your first responsibility as a graduate student is to get to know very well the research being conducted by others in your laboratory. You should begin by reading all the recent papers of your advisor and a good representation of the major older papers. You should then make certain that you know what everyone else in your laboratory is doing and why they are doing it. After all, you have chosen to work with your advisor and the others in that laboratory because their research is closest to your own interests.

Do not waste your time writing short notes for obscure journals.

Concentrate on finishing your major experiments, observations, or models and write them up as papers for major journals. There will be plenty of time later, if you want to collect together several small notes that will be of interest to only a few other specialists. Search committees are not fooled by a CV that includes half a dozen short notes in obscure journals but no major papers. It is crucial for you to publish papers; unpublished research is the same as research not done. But focus on publishing major papers that represent a solid body of work.

Once you have given your advisor a draft of a manuscript, assume that it will take at least several more months before you will be able to submit it for publication or include it in your dissertation.

Do not give your advisor a first full draft of a manuscript that is missing figures, tables, and sections of text. Be professional about it. Hand in a complete manuscript that is actually the third or fourth draft you have written and represents the best you think you can do with the paper. That doesn't mean that you shouldn't ask questions of your advisor while you are writing, or go over some trial versions of the Introduction and the Methods. You should. Moreover, you two should have gone over the major figures and tables and their interpretation before you started writing. But after that, take the advice and your own deliberations and put it together into a full preliminary manuscript so that you can both see the full flow of argument. Remember, you are making an impression on others every time you ask someone to look at a piece of your work. The impression you make is up to you. The draft of the manuscript that is finally submitted may have little resemblance to the one you first gave your advisor, but it is much easier for the two of you to move from one specific draft to another specific draft than it is to go from a nebulous, incomplete draft to a complete draft.

Do not give the other members of your dissertation committee a draft until you and your advisor have agreed that the manuscript is now in sufficiently good shape for the other committee members to read.

Do not assume that you can hand in a draft and get a response a week later. The faculty on your committee have dozens of commitments. It may take at least a couple of weeks to get a response to each draft you hand in. If you ask for a hurried response, you will get back either no comments or a few superficial comments. Moreover, you will have left an impression that you wait until the last minute to get things done and do not really care about getting their thoughtful comments.

By the time you and your advisor have been through several drafts, and your committee has reviewed a draft, it may have been several months from the time you first handed your advisor the initial manuscript. Plan accordingly. If you plan to defend your dissertation in April or May, your advisor will need to have seen initial drafts of **all** parts of your dissertation by January (yes, January) and most parts of it earlier than that. That will allow sufficient time for the two of you to go over several drafts before handing the manuscripts to your committee. Yes, I know that it doesn't always work out that way. But that doesn't matter. What I am suggesting here is the process that will help you hone your dissertation so that it stands out from the crowd.

Under no circumstances should you simply hand your committee members all the chapters of your dissertation for the first time a month before your final defense. They may ask you for additional statistical analyses or they may suggest major changes in interpretation. You must allow time to make the changes or to sort out differences in interpretation.

Begin exploring possibilities for postdoctoral positions at least 1 1/2 years before you finish your dissertation.

Most positions in major universities now state in their advertisements that postdoctoral experience is preferred. Even if the job announcements do not state such a preference, someone with postdoctoral experience will have a competitive edge. The problem is that postdoctoral money is hard to come by. If you are lucky, someone may have a position available on a new grant and have no one specifically yet in mind for the position. But researchers often either have someone in mind when they submit proposals that include a postdoctoral position, or they have at least a short list of potential postdocs in mind based on conversations they have had and letters they have received over the past year or so. You will want to make sure you are on that list.

Some other postdoctoral fellowships are available through NSF, NIH, and NATO, NERC, ERC, and other agencies associated with various research councils worldwide. And be sure to look for funding opportunities offered by private foundations. In most cases, you will have to convince someone to be your sponsor, and you will have to write the proposal. The proposal will take time to develop, and you must allow enough time to work through several drafts with your sponsor before the proposal is submitted. Do not expect to contact someone suddenly in October and get much cooperation in submitting a proposal for a December 1 deadline. The kind of person with whom you will want to work as a post-doc is already busy, and you should allow sufficient time to get responses.

The basic unit of correspondence is three.

When you write to others for advise or ask one or more colleagues to read a manuscript, always thank them after they have responded. The basic unit is three: you write (or ask), they respond, and you write or call back. This is not just part of being a professional. It is part of being a decent person. You may agree or disagree with their comments, or their advice may not have solved your problem, but you have a responsibility to let them know and to thank them for their comments. Imagine how you would feel if someone wrote to you asking you to spend a couple of hours reviewing a manuscript. You devote precious time to this favor, send back your comments, and wonder what the person thinks about what you have written. But, instead, you hear back nothing. You feel used. Would you ever agree to spend your time helping out that person again?

Remember that the purpose of doing research is to get answers to interesting and important questions about how the world works.

In the process of doing all the things I have recommended, remember why you are doing them. If the answer is simply to get a degree that will get you a job that looks attractive, then you will not be able to maintain the schedule necessary both now and once you obtain a position. If you do not enjoy the process, you are setting yourself up for a most unsatisfying life. Just putting in time and trying to follow these guidelines as a formula is not enough. You can maintain this time-demanding schedule only if you deeply enjoy the full process of posing scientific questions, designing experiments, analyzing results, getting some answers, writing up the results for other scientists, and discussing both your results and theirs. You must want in your bones to know the answers.