America's Grad School Nightmare

How grad school is turning America away from science and jeopardizing the future of innovation

Chapter 0: Introduction

Introduction

Who I am

I was a graduate student at UCLA in bioengineering for four years, culminating in a PhD. I was shocked by the difference between my expectations of graduate school (for example, stipends are guaranteed), and the reality (well…it's complicated, but not really). Along the way I observed and experienced the many ways graduate school has gotten off track. I was compelled to write this book as a way to articulate the specific flaws in graduate education, to inform others, and to propose solutions.

Who should read this book

This book is for anyone in or considering graduate school in a technical field (science, engineering, math), anyone interested in how science operates or anyone curious about advanced degrees. I address the foibles of grad school and how it relates to education and science.

Why is this book necessary

I've written this book to inform about the realities of graduate school, particularly PhD programs, in the sciences and engineering. As the default track to prosperity for many disappointed undergraduate science degree holders, they deserve to know what they are in for. Additionally, I argue for some structural changes that might improve it.

Also, understanding of graduate science education and science employment is woefully lacking. In particular, the cultural understanding of PhD-track education in science and engineering is much less than it should be, certainly much less than the understanding of other advanced degree training such as medical and law. This leads to poor career planning by many students due to simply not knowing what PhD training in scienctific fields entails. Compare the public understanding of, for example, medical training with science training. Medical school and other medical training is a frequent topic of news articles and other cultural outlets such as television shows.

At any given time, there are roughly 100,000 medical students. However, there are over 450,000 PhD track graduate students in science, health and engineering. There is much less understanding in the culture at large of what PhD training entails. Many students simply end up in PhD-track graduate school in science simply by default, without an understanding of the specific nature of PhD training, which can result in disappointment, disillusionment and depression.

Also, I spend most of the book describing the many flaws of the PhD-track graduate school. Partly as an informational effort, but I also explicitly advocate for structural changes to improve the PhD degree. Much of what I argue has already been written down in various blogs and articles, but there has not, so far, been a book-length treatise.

Personal Advice for Prospective Graduate Students

Is going to graduate school a good idea? To answer this question, I'm going to quote from blogger Freddie DeBoer: almost certainly not. Graduate school is a long, hard slog and can have a downright terrible working environment. It's slow, it's arduous, and it's emotionally trying. If you have any other options at all, my personal recommendation is to explore them first before graduate school.

One simple piece of evidence about the worrying state of grad school is the attrition rate. The rate at which students drop out of PhD programs in the US is horrifying. Depending on the field, it can be anywhere from 30% up to 50%. Of course, we can't and shouldn't expect that every single person who enters a PhD program will finish, but these numbers are absurd, and a sign of a system that is deeply flawed and in fact surprisingly exploitative. Compare to other advanced degree programs, like medical school, where about 7% drop out, or law school where it's 10-15%.

http://www.thefacultylounge.org/2013/02/what-has-happened-to-law-school-attrition.html

The bad news is If you've gotten yourself a bachelor's degree in science, it's probably not worth as much as you thought it would be, and you might be forced into an advanced degree. While STEM (science, technology, engineering & math) majors are touted as a sure route to career success, it still depends greatly on your major. In particular, pure science majors (chemistry and biology especially) do not perform well in the job market coming straight from undergrad. I address this in more detail in my pamphlet, *5 Things I Wish I Knew About College Before I Went*. The typical job available to Bachelor's level science majors is a lab technician. So if you got an undergrad science degree and you'd like a higher career ceiling, you'll likely need some kind of advanced degree (Master's, Doctoral or Professional)

The good news is, if you decide to get a PhD, there is still some hope. The management structure of PhD researchers in scientific fields is unique among working environments. All of the authority regarding your employment and educational status is controlled by one person,

with very little to no oversight from above. As a result, *everything depends on your relationship with your research adviser*.

This means that choosing the right advisor is *incredibly important* and can be even more important than your choice of institution. Your adviser can be supportive, giving you the resources to succeed and the freedom to pursue your own project. Or, your adviser can be a tyrant in a lab coat, demeaning you for perceived failures, threatening to withhold pay, *actually* withholding pay, using graduation as a bargaining chip or threatening to (or actually) revoking your immigration Visa. The importance of your research adviser is all-consuming.

In my case, my research adviser was a mixed bag. While he was creative and tenacious as a researcher, and had adequate funding, his approach to managing students might be described as slash and burn. He never had the patience to either plan a good long-term project, or allow it to unfold. As a result, research direction was constantly changing, and blame for lack of progress was always placed at the feet of students. Strange and constantly changing demands on work schedule and availability were also in effect. While some students passed through this gauntlet unfazed, this approach turned me off to science forever. While I did well enough in terms of publication record, the petty, capricious, personal insults, the 10pm Sunday phone calls and the paranoid territorialism all made it impossible for me to imagine science was a career I wanted to pursue.

So what's the appropriate way to approach choosing a research adviser? The short answer is, get as much information as you can before deciding. Make sure that you get the chance to talk to some graduate students. When you interview for your PhD program or go for a visit day, talk to members of potential labs. Try to make sure you get candid input about what the department is like. Ask what the PIs are like. Ask about the stipend and ask about rent in the area. This sounds crass, but money matters.

If possible, try to find a program that allows for research rotations. Research rotations are typically 3-month 'trial' periods in three different labs in your department. This allows for you and the research advisers to make sure it's a mutual good fit. In addition, it's a way to learn many different lab techniques and styles of research. It can be scientifically enriching, and a great chance to avoid a huge mistake that may ruin your life for years. Departments that offer rotations also tend to be better organized and more supportive of students.

Chapter 1

Is there something wrong with graduate school?

Science is respected by society

In addition to the financial concerns outlined above which would motivate science degree-holders to pursue, graduate school, there is also the space that science occupies in the

public imagination. Science, as an abstract idea, and for some of its cooler products, is respected and revered. Indeed, science is one of the cornerstones that modern culture is built on. Who could imagine life without electricity, or fossil fuels, or vaccines, or telecommunication? In turn, scientists are some of our cultural heroes and people in general see science as a very positive thing. 79% of people asked by Pew Research said that science has made life better, compared to only 15% who say it has made life worse or more difficult. (http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/)

Individual scientists from the past also stand as icons. Isaac Newton, a physicist in the 1600s, appears on the currency of England. Among scientists, Newton's impact maybe the greatest of all. His theory of gravity has stood without any major changes for 350 years. His laws of motion as well, except for a small modification for objects at very high velocities, have lasted unchanged for more than three centuries. They describe, with the greatest precision, the flight of rockets and bumblebees, the mechanics of human athletes and cheetahs.

The pioneers of microbiology and vaccinology are idolized as well. Alexander Fleming, the discoverer of penicillin, was named one of the 20th century's 100 greatest people by Time magazine in 1999, and was voted one of the 100 greatest Britons in a BBC poll. Louis Pasteur's work is taught in high school biology courses. He did more than perhaps anyone else to convince the world that the germ theory of diseases was true. Jonas Salk is revered for his discovery of a Polio vaccine, as well as for his refusal to patent it, proclaiming, "There is no patent. Could you patent the sun?".

This is the pantheon to which undergraduate college students understand their science professors to belong. From this perspective, a contribution to science, whether major or minor, is a noble thing which will improve the world and last for the ages. Scientific research is a labor of love, born of boundless imagination and good moral character. It's not hard to understand how this kind of outlook would lead a student to choose to attend graduate school in order to make his or her contribution to science. *So what's wrong with graduate school?*

Graduate school is governed by an "unwritten trade-off" which is being abused

Graduate school is the method of entry for a career as a scientist. Any scientific job, whether in a for-profit company, at a research university or at a national lab, requires a PhD. As the gatekeepers to the scientific world, PhD programs have a responsibility to educate and inspire scientists. However, as the cauldrons of scientific discovery, PhD programs and advisers have an incentive to extract useful work from their trainees. This work contributes to existing scientific efforts and expands scientific knowledge, but significantly it also brings graduate departments renown and increased resources.

Because of this tension, there is an "unwritten agreement" that governs some of the decision-making about grad school. In return for accepting a relatively low but (supposedly) steady income and making a commitment of five years, you will have the chance to make your

contribution to the scientific canon, and finally receive a degree. You give up, at least for a time, the higher material rewards of the commercial world and commit to knowledge--absorbing what is known and striving to learn something new about the world. Ideally, a graduate student is given free rein to design and implement a project of their own creation which will answer some significant and fundamental questions about nature--helped along the way by a caring mentor. Framed this way, some will choose to take the tradeoff, shunning the crass profit-seeking of private industry for the unfettered pursuit of pure knowledge. However, it has become clear that this presumed trade-off (5 years of life for the ability to answer a scientific question, at a low but steady income) is becoming increasingly abused. For example, by institutions who no longer guarantee a stipend, or advisers who

Consider, in 2011, the academic journal *Nature* surveyed over 5,000 graduate students in the sciences. Among first year students, 73% were satisfied or very satisfied with graduate school. A further 19% were neutral while only 8% were dissatisfied or very dissatisfied. This level of satisfaction is high, but by 5th year, dissatisfaction increased from 8% to 26% and satisfied decreased from 73% to 50%. We can see that while grad students are initially optimistic, attitudes are tempered, likely because the reality of grad school does not match expectations.

http://www.nature.com/naturejobs/graduatesurvey/?question_id=38&filter_question_id=14&filter_answer_id=5&x=114&y=22#form.

Maybe grad students full of idealism and naivete are easy marks for exploitation. If you spend any time whatsoever talking to graduate students or in the academic blogosphere it's hard not to believe that something is dreadfully wrong with graduate school.

- "Science will fail because the System is running the scientists out of it." *-Lenny Teytelman, Ph.D. Cornell University; Postdoctoral Researcher, Oxford University, Oxford, UK & Author of 'Yes, Another Science Blog'*
- "In addition to the usual work-day schedule, I expect all of the members of the group to work evenings and weekends." *-Letter from Caltech chemistry professor Erick M. C Carreira to a lab member.*
- "I actually quit academic science after my PhD – I was sick of the stifling of creativity (in that particular career-track situation), the inherent sexism in the industry and the ridiculous expectations around a complete lack of work-life balance. … The lack of respect for other fields, careers and life goals is especially bad in traditional research science. I think it is so hard to succeed, and the commitment and sacrifice so great, that you lose sight of the value of any other choice." *-SM Morgan, Genetics PhD*
- "...anyone desiring to become a good organic chemist should be putting in a <u>minimum of 60 hours per week</u>. … <u>This is a bare minimum</u>." *-A memo from chemistry professor PG Gassman to all members of his lab.*
- "[Science Ph.D.] students have effectively become serfs." *-James D. Watson, famously credited with discovering the structure of DNA, at a talk on the state of science, 2007.*

- "I feel sorry for all my friends who will have to leave science too and still do not admit it to themselves, because this kind of denial of the obvious is really bad for one's health and happiness." *-Anonymous ex-academic, 'zinemin's random thoughts'*
- *https://web.archive.org/web/20100213174308/http://rezaghadiri.net/nature-of-phd-program-science*

Grad school and grad students in pop culture

Critique of grad school takes various forms. Bloggers and iconoclasts utter polemical and memorable quotes, and pop culture outlets make jokes.

The Simpsons has distilled the critique of grad school (and grad students) to almost perfect concision. In one scene, the son Bart, is holding a detached ponytail, aping a graduate student, saying "I was so bored I cut the ponytail off the guy sitting in front of us. [imitation voice] Look at me, I'm a grad student, I'm 30 years old and I made 600 dollars last year". In a line that encapsulates untold mountains of real-life grief, regret and rage, the mother, Marge, says "Bart! Don't make fun of grad students, they just made a terrible life choice." There are reasons *The Simpson's* has run for over 25 seasons, and that line was one of them.

While Matt Groening and his writers are probably most familiar with grad students in fields like English or creative writing, there is a big kernel of truth in the joke that applies to grad students in scientific fields as well. Not only is the joke largely true, it's true in multiple ways and indicts both grad students and the system they exist within.

First, grad school was a bad choice because it was a *miscalculation*, meaning the student made an error in judging the value of grad school relative to other pursuits. This is most likely for people who have entered a graduate program without looking at other options, or who know very little about it. Second, grad school was a bad choice because it was represented *fraudulently*, either implicitly (e.g. the abuse of the "unwritten tradeoff") or even explicitly (students are told they can finish a PhD in five years, or further back, that getting a STEM bachelor's degree is enough for a good career).

(https://www.youtube.com/results?search_query=simpsons+grad+students)

While jokes like these are meant in good fun, they do reveal a lot of the real issues with grad school.

Prestigious journal *Nature* identifies serious flaws in graduate education

Criticism of the current state of PhD education aren't coming just from TV shows, off the cuff remarks, isolated examples, or internet bloggers. In fact, many articles in one of the marquee journals in all of scientific publishing, *Nature*, have been devoted to investigating the

shortcomings of PhD science education. *Nature*'s survey has focused on two areas, mentorship and career readiness.

Mentorship in Science

Abusive bosses are ubiquitous--so it's no surprise to find out that they exist in science too. Take the article "Mentoring Mismatch" from Nature in 2006:

> "Paul's graduate supervisor stood beside his bench yelling at him about a failed experiment. Sadly, this was nothing new. But Paul knew that they had reached breaking point when he chased his supervisor into the hallway to continue the shouting match."

Unfortunately, this type of interaction with bosses is all too familiar to many people, in and outside of science. However, several factors can amplify the damage done by such relationships in a graduate student-adviser relationship. I will discuss many of these factors in more detail throughout the book and they include: the heavily skewed power imbalance between graduate student and adviser, the lack of screening or training for management ability of professors, the lack of oversight of personnel issues by upper management, and the disinclination of graduate students to leaving without a credential.

Very little value is placed on mentorship in science. To the extent that it does happen, it happens despite the existence of many other goals--such as publishing, seeking funding, and receiving awards to bulk up tenureship applications--which, by necessity, take precedence. To their credit, *Nature* attempted to argue for the importance of mentorship and lay out the standards by which it should happen. In 2007, *Nature* devoted a premier position--7 pages--in their journal to a feature about mentorship. They note that… "mentorship of young researchers … is perhaps the least remarked on of all the activities that take place in the lab. Indeed, there is no established definition of what constitutes good scientific mentoring.".

To promote the issue of mentorship, they hosted a competition seeking out the best scientific mentors in Australasia, and, based on the results, they wrote what is maybe the most definitive guide of scientific mentorship in the modern era. They write that a good mentor should, be "a mentor for life", should have several personality characteristics including "enthusiasm", "sensitivity", "respect", and "unselfishness". It's reasonable to conclude that this article about mentorship was written because *Nature* believes that it's a topic which is sorely under-appreciated in the scientific community, and there's a lot more evidence of this which I'll delve into throughout the book.

http://blogs.nature.com/soapboxscience/2012/06/27/science-mentoring-mentoring-women-in-science
http://blogs.nature.com/soapboxscience/2012/06/28/science-mentoring-online-mentoring-for-improving-scientific-literacy
http://www.nature.com/nature/journal/v447/n7146/full/447791a.html

http://www.nature.com/naturejobs/science/articles/10.1038/nj7146-881a
http://www.nature.com/naturejobs/science/articles/10.1038/nj7126-453a
http://www.nature.com/nature/journal/v506/n7488/full/nj7488-399c.html
http://www.nature.com/naturejobs/science/articles/10.1038/nj7298-651b
http://www.nature.com/naturejobs/science/articles/10.1038/nj7487-257a

PhD training too focused/doesn't reflect reality of careers today

In April 2011, the prestigious academic journal *Nature* devoted an issue to the problem of PhD training. Mark C. Taylor wrote "There are two responsible courses of action: either radically reform doctoral programmes or shut them down." He argued that PhD training is too focused, "with curricula fragmented and increasingly irrelevant to the world beyond academia". Others echoed this and went further, saying that there are simply too many PhDs getting awarded and not enought jobs--certainly an understandable sentiment at the time.

A *Nature* editorial proclaimed described two possible solutions to the oversupply problem. The first is to simply reduce the supply: "They should get smart … data that reveal which types of science-related job are in short supply, and … then open the doors to more PhDs only where they are most needed." This would constitute a radical restructuring of PhD admissions, at least in the US, where the federal government has only very indirect control over the number of PhD students admitted. It is probably a poor idea for other reasons, not least of which is that such limits are almost definitely discriminatory and that PhDs don't operate as a credential, like professional licensing.

The second solution is to change PhD training so that degree-holders are able to pursue a wider variety of jobs. In the words of the Nature editors "Imagine *bright young things* entering a new kind of science PhD, in which both they and their supervisors embrace from the start the idea that graduates will go on to an array of demanding careers — government, business, non-profit and education" [emphasis mine]. Choice of language aside, this solution seems more pragmatic and in line with reality. Indeed, this seems to be the route that is being taken, de facto, since the number of PhDs awarded has continued to climb.

http://www.nature.com/naturejobs/science/articles/10.1038/nj7396-139b
http://www.leru.org/files/publications/LERU_AP_15_Good_practice_elements_in_doctoral_training_2014.pdf
http://www.nature.com/nature/journal/v506/n7486/full/nj7486-123b.html#/link-groups
http://www.nature.com/nature/journal/v472/n7343/full/472259b.html
http://www.economist.com/node/17723223?story_id=17723223
http://www.nature.com/news/2011/110420/full/472276a.html

Along the same lines, we are also seeing a torrent of articles from *Nature* about how academics can switch careers, not just away from academics, but away from science writ large. These types of articles show that, for multiple reasons, PhD-holders are seeking both non-academic

careers and *non-research* careers including careers related to finance, sales, non-profits, consulting, writing and more. *Nature* curated an entire series of essays by people who had transitioned out of science into a series of careers:

- "From science to politics"
- "From scientist to combining science and novel writing"
- "From PhD to patent attorney"
- "From PhD to PR"

and many more. Yet, students get little support from their programs to transition into any jobs, let alone these non-scientific and non-academic careers. This need, unmet by the academic departments and PhD programs, has become so large, that a variety of resources are being developed to meet the need. A recent *Nature* article highlighted the growing network of resources which .

http://www.nature.com/nbt/journal/v33/n7/full/nbt.3282.html?WT.ec_id=NBT-201507&spMailingID=49054967&spUserID=MTA3NTkxNzc1MjgzS0&spJobID=720999620&spReportId=NzIwOTk5NjIwS0

It's very telling that almost all of the efforts towards career prep have been taken either by administrators aligned with centralized university units such as a career center, by the students themselves, or even by independent consulting networks. Within the departments and <u>among faculty, there is no seriousness at all towards the issue of career preparation.</u> At this point, it's clear that the resources required for successful career prep are available, the awareness of these options is still lacking. While it's unlikely that the departments would devote significant resources to building more resources for students (which largely already exist), it behooves them to direct students toward these resources in some way.

http://blogs.nature.com/naturejobs/2012/04/12/career-transitions
http://www.nature.com/naturejobs/science/articles/10.1038/nj7365-501b
http://blogs.nature.com/naturejobs/2013/10/10/how-to-find-a-career-away-from-the-bench
http://pathwaysreport.org/rsc/pdf/ex_summary.pdf

These problems that Nature has called attention to which I discuss above are real and they are significant. However, these problems, and the way they are described in *Nature* are the tip of the iceberg--the situation is in fact much worse than it appears.

Nature, a rich and powerful academic journal (probably the richest and most powerful) would only mount such a significant editorial effort if it felt things had gotten so bad that the status quo was threatened. The real situation is much worse. "Poor mentorship", as I'll show, is a thinly veiled euphemism for sadistic abuse. "PhD oversupply" is callous indifference to graduate student welfare on the part of PhD programs. As I'll show, there are many problems, and the true causes, not even touched by *Nature*, are deeply ingrained. However well-intentioned these

efforts have been on the part of Nature, they address only the cosmetic symptoms of much deeper systemic problems with graduate school.

Graduate school: more like a job than it is like school

To understand the structural issues of graduate school, it's good to first understand what graduate school is. PhD programs in science and engineering are neither exactly school nor exactly like a job. School, as we generally understand it, consists of taking classes according to a pre-defined curriculum. In a science or engineering PhD program, however, course-taking accounts for generally between 10-20% of the total time and effort.

The remainder of the time and effort (80-90%) of graduate students is focused in a more job-like way. The student carries out tasks which benefit his or her employer, a university. In return, the student gets paid. Specifically, the student conducts research and teaches courses.

The university benefits from research by the generation of grant or sponsored research revenue. To support scientific research in universities, the federal government offers substantial monetary support. Several federal agencies offer this type of funding, especially the National Institutes of Health (NIH), National Science Foundation (NSF), Department of Energy (DoE), and the Department of Defense (DoD). In addition private companies and foundations also sponsor a significant amount of academic research.

Professors at universities are in charge of running their laboratories and securing this funding. In order to receive the funding, they must write lengthy, detailed and specific proposals for their research, which are evaluated in comparison to the other proposals received. Most proposals are denied. In order to be competitive, the professor must have a strong record of scientifically rigorous and interesting research. However, most often, it is not the professor conducting the actual research, it is the professor's direct reports, the graduate students.

Periodically, this research is reported in the form of scholarly articles. These articles are vetted by scholarly journals for scientific rigor and interest then posted online and in print. Both the student and the professor get credit for the work, as their names both appear in the list of authors. It is this record of publications that is critical to securing future grant funding. This is why the research function of graduate students is so important for professors and universities. Thus, it is the work of the graduate students which fuels the research revenue for the university.

Graduate students also act as teaching assistants. Typically, they compose and grade homework assignments and tests. They also lead discussion sections for classes where they usually go over example problems related to the content from the lecture sections. Lectures are led by professors, although occasionally a graduate student might fill in if a professor is away. Teaching courses is important to universities since it is the service they provide for their tuition-paying undergraduates.

In return for the research and teaching work which comprises the majority of a PhD program, a graduate student's tuition & fees are generally reduced or waived, and the student also usually receives payment in the form of a stipend, fellowship, or wages. The amount that PhD students are paid, if any, is typically between $15,000 - $30,000 per year, and seems to center around $25,000. PhD students in science and engineering are known for working long hours, sometimes reportedly in excess of 80 hours per week, although this can vary greatly and supervision is often sporadic. There is no conclusive survey of graduate student work hours, but a survey of postdoctoral scholars, who have very similar working conditions to graduate students, showed they work just over 50 hours per week on average.

Keys to the degradation of graduate working conditions

How has it gone so wrong? There are features of grad school which have given rise to the experience of modern day graduate school for science and engineering.

Power differential between graduate students and advisors

In a typical supervisor-employee dynamic, the supervisor necessarily has more power than the employee. One measure of how big the power gap between supervisor and employee is the pay ratio, that is how much more the supervisor gets paid than his or her direct report. Pay is a relatively good measure of power differentials, especially as it relates to how valued someone is by their organization. In that respect, it's clear that professors have an unusually large power advantage over their direct reports--graduate students.

There isn't a uniform guideline when it comes to how much more money a supervisor should make than his or her employees. In exceptional circumstances, supervisors can actually make less money than their direct reports. However, it is typical for supervisors to make at least 10% more money than their employees. According to 'Compensation' a textbook by Milkovich and Newman, 5% to 30% is normal as the ratio between the best paid hourly employee and supervisor. However, with grad students and professors, the gap is much greater. According to Glassdoor, the average Graduate Student Research earns about $26,000 per year while the average for starting professors (Assistant Professors) is $80,000 -- about 3 times more or a 207% increase.

Of course, there are many good reasons why a professor's pay would be that much higher than a graduate student's pay, but this gives us a general view of how much a professor is valued by their organization, and on the other hand how little a graduate student is. Without the existence of other structural correctives, the difference in the support given to professors and their grad students will inevitably lead to exploitation.

The degree is awarded on the adviser's say-so

To receive the actual PhD credential, students must select a committee of professors, one of whom is the student's adviser and boss. The student then prepares a written summary of their work (thesis) as well as a presentation (thesis defense). If the committee approves, a PhD is granted. This arrangement nominally distributes the power amongst the members of the committee, so that the adviser doesn't. However, in practice, the awarding of the degree is controlled almost entirely by a student's advisor, swelling the already expansive control wielded by the PhD adviser. In combination with the conveniently ambiguous nature of what the standards are for a PhD degree, this inevitably gives rise to insidious exploitation.

There is no standard for a PhD degree, no national governing body and no authoritative standards

Adapting to a changing world is a goal of many types of education. Mostly, this is facilitated by the action of national governing bodies: the American Association of Medical Colleges for medicine, the American Association of Colleges of Nursing, the Association of American Law Schools for law. With rare exceptions (nutrition, fish & wildlife programs) There is simply no equivalent for most fields of PhD study: biology, neuroscience, chemistry, physics or any fields of engineering. This means that as the world changes, PhD programs and the system at large may have difficulty adapting without a consensus on the goals for their programs.

There are no authoritative standards for what a PhD consists of, even within a discipline. Some PhD degrees may require the acceptance of a scholarly publication by a peer-reviewed journal. Some may specify a time minimums or limits. Some may require a thesis defense. The amount of coursework required by graduate programs varies from less than a year to more than two. These requirements are scattershot and often don't make sense even to the students and faculty within a program. There are simply no standards of any importance which are universally or even widely accepted, nor any way of enforcing them.

Most undergraduate degrees are accredited by accrediting bodies to certify that they meet minimum standards. This is also true of many post-graduate degrees like nursing, law and medicine. PhD programs are not accredited by any agency and there are no national governing bodies, nor any authoritative standards. While PhD accreditation exists, this is mostly used by marginal or non-traditional PhD programs such as those associated with hospitals or think tanks. Thus, paradoxically, *un*-accredited PhD programs actually tend to be better. The vacuum in standards allows poorly managed programs to decay under the radar. Given the relatively unique form of PhD training, standards might not be needed for every aspect, but the .

Lack of labor market fluidity

As we've discussed, for PhD track students in science and engineering, there is a tacit understanding (i.e. the "unwritten tradeoff") the that in return for conducting research which brings funding to the university, certain things are guaranteed in return. For example, tuition is waived, a modest salary is guaranteed, and that there is a reasonable standard and timeline for

achievement of the degree. However, as with all rules that aren't quite codified, there are departments and institutions that abuse this assumption. There is no codified salary guarantee at a systemic level (federal and state minimum wages do not apply to graduate students), and many individual institutions and departments do not standardize or guarantee any level of pay. Additionally, the 5-year assumption for time to graduation is roughly true *on average*, but many students take longer, 6, 7 and more.

All this might be sorted out by market forces, except for the stasis of the graduate student researcher labor market. Once you are in grad school, you don't have the same leeway to leave as with a normal employment situation. For students, the major value of grad school is in the attainment of a credential, and *none of that value is imparted if the degree is left halfway through*. In a regular job, the value to the employee is in the salary paid, which is delivered continuously. This means the graduate student labor force is more static than the labor force at large since there is a larger barrier to leaving. Thus there is less incentive for universities and academic advisers to provide good working environments.

Another way of characterizing this problem is *incomplete information*. When a student chooses a graduate program, they do so often with very little information about that particular program and what might make it different from other programs. This is mostly the same as other jobs, but there is less compunction about leaving a job if better alternatives are available. If a grad student leaves a program halfway through, they can't transfer to another one and pick up where they left off. Thus, they are often simply stuck toughing it out if what they thought was a 5 year commitment magically turns into 7. In terms of incentives, the feedback between graduate program quality and desirability is *temporally dislocated* from the decision to join that program. Thus, the recruiting of students is relatively unaffected by the actual reality of a program.

This lack of fluidity is exacerbated by the fact that the awarding of the degree is controlled only by a student's advisor. Thus not only is the reward of the graduate program concentrated into the credential, reducing the incentive for providing a desirable program, but the awarding of the credential is controlled by the one who directly benefits from the graduate student's labor. This further extends the time it takes to get a degree beyond what it would otherwise take, multiplying the negative effects of labor stasis.

Lack of accountability to upper management

Part of what allows science to work is that usually, professors/primary investigators (PIs) are allowed to pursue whatever scientific project they find the most interesting. In their choice of scientific direction, they are accountable to no one. This independence is a big part of why some describe position of tenure-track faculty as 'the best job in the world'. This lack of accountability in scientific direction is matched by a nearly complete lack of accountability in labor management practices.

Can you imagine a situation where a major corporation would hire a talented researcher to manage a research project, then allow them to hire a team of 10-50 underlings, provide zero management training and remove all accountability to senior management? I can't. However, this is exactly what professors in science and engineering departments do. Such an analogy is not perfect--universities are not the same as corporations and vice versa--but this situation begins to describe how bizarre the modern American academic laboratory is in the context of the broader working world.

In the case that a graduate student is exploited in some unfair way (not paid, arbitrary extension of time to degree, etc), there is virtually no recourse to higher management. In some cases, there may be a pro forma venue to register complaints, but it's unlikely to lead to a positive outcome. Consider the institutional priorities at play. Graduate students are interchangeable cogs to the university. Recruiting more graduate students isn't difficult and isn't expensive. On the other hand, an established and successful research professor is a revenue-generating asset to the university who is difficult to replace. So in the case of a conflict between a professor and a graduate student, it's clear which side is most likely to get institutional consideration. . . .Additionally, Consider the case of Erick Carreira.

The effects of this lack of accountability are amplified by the stasis of the graduate student labor market. Mistreatment and poor mentorship by advisers have no repercussions on recruiting and so there is no feedback. Although some institutions may have procedures for reporting abuse or arbitrating conflicts, there is no effort to make them known to graduate students. Further, there is no accreditation process for PhD programs in science or engineering which might force upper management at universities to be responsive to graduate student issues.

My purpose here is not to describe all the ways in which the academic world at large is broken. That is a topic which is too broad for this book, and has been described by others better than I. Nor is my purpose here to just catalogue the heartbreaks and injustice that have befallen graduate students. In the chapters that follow, I will discuss how these two main factors (along with some others) shape the lives of graduate students and what can be done to improve the situation.

Chapter 2

Grad School Forever

PhDs Take A Long Time

PhDs take a long time, but is it too long, or required for a PhD level education? How long should a PhD program last? The time length of a PhD program depends on what the desired outcome of that program is. However, as I've discussed before, there is no consensus on what a PhD is or should be. There are different and sometimes competing priorities like developing new knowledge through research, gaining broad expertise in a topic area, learning research techniques and scientific writing and reporting. Each of these topics and more can take different amounts of priority depending on the particular program and adviser. As a result, while there is a vague general expectation that PhD's should take about five years, it varies dramatically. In extreme cases, it can take as little as 3 years, or as long as 8 years or more.

Undergraduate degrees can also take a long, and sometimes varying amount of time. But the requirements for undergraduate degrees are well-defined. A certain number of credits must be achieved. If progress to a degree has stalled, the issue can easily be delineated. For example, a student isn't passing their classes, switches majors too frequently and so forth.

Graduate professional degree programs, unlike PhDs, are generally fixed in duration and scope. For example, medical school is four years, law school is three years, dental school is three years. A clinical laboratory scientist degree is a one year program after a bachelor's degree. All these degree programs have explicit standards and expectations and have national governing bodies and seperate accrediting organizations. If an issue is found with time to degree, it is able to be addressed individually by a student or collectively by the governing body.

In contrast, there is no standard for the work required for a PhD degree. While the technical requirements of the degree are laid out by a university's policies, in practice these simply amount to: "Pass the oral thesis defence." The content, expectations and timing of the oral thesis defence (called dissertation or simply "defence") is not advised or overseen by any part of the university administration hierarchy. All of these matters are left entirely at the discretion of the thesis committee, and in particular, the committee chair/adviser. Certainly, the vagueness of this policy can be abused both by students and PhD advisers, and the result is that the degree ends only when both student and adviser agree that it should end, and inevitably, coming to this agreement ends up taking quite a long time.

So how long do PhDs actually take? According to statistics collected by the National Science Foundation (NSF), a PhD in science or engineering in the US takes about 6.9 years from the time that a student begins graduate school to the time that the PhD degree is completed (this would include any time spent in master's programs, for instance) for both engineering and life

sciences degrees. However, this measurement also includes time spent in graduate programs before the PhD degree, such as Master's or other programs.

Based on data collected by a separate nonprofit group called the PHD Completion Project, it's possible to calculate the average time taken only for the PhD degree itself. The PhD Completion Project reports the fraction of entering students that graduate each year, from which an average time to degree can be calculated. Based on this data it takes about 5.0 years for an average engineering PhD and 5.5 years for a life sciences PhD. This is a *long* time, much longer than any other graduate degree program, and as we'll see by comparisons to other countries, it's not at all clear that such a long PhD is necessary for productive research programs.

http://www.nsf.gov/statistics/infbrief/nsf06312/nsf06312.pdf
http://phdcompletion.org/quantitative/book1_quant.asp
http://www.theguardian.com/education/2007/oct/02/highereducation.postgraduate

PhDs Average About One Year Shorter in England

PhD degrees are clearly not treated the same all around the world. For example, the average time for a research PhD in the UK is about 4 years. This is a *full year* shorter than a PhD in the US would take. One year out of a 5 year PhD might not seem like a big deal, but that is the *average* value, meaning it applies in that amount to *all* PhDs awarded. Consider, all of the roughly 20,000 PhDs awarded in the US every year, take a total of 20,000 person-years longer than they would in the UK. 20,000 person-years. 250 lifetimes spent in needless toil. Every year.

Furthermore, the drop-out, or attrition rate in the US is much higher than the UK. Statistics on the US attrition rate were collected by the *PhD completion project,* a non-profit organization. The *PhD completion project* collected information about the percentage of students completing their degree at each year, from year 1 through year 10. By year 10, it can be assumed that a negligible fraction of PhD students would still be enrolled. Thus, the fraction that didn't finish a PhD degree by year 10 is the fraction which stopped their PhD studies. For physical & life sciences and engineering, the completion rate by year 10 is around 60% (life sciences = 62.9%, physical sciences = 54.7%, engineering 63.6%). So in the US, roughly **40% of entrants into** these **research-intensive PhD programs never finish**.

In England, information about PhD studies is collected by the Higher Education Funding Council for England (HEFCE), a government agency. They found, in a 2007 report, "PhD research degrees: update", that by year 10, for full-time research-based PhD programs, 83% of those who started degrees, finished them, indicating a drop-out rate of 17%, less than half the equivalent figure for the US.

European Approach to PhD Studies

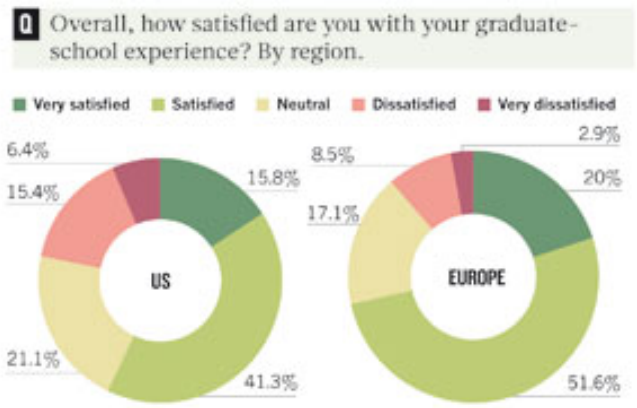
These differences in PhD length and attrition are significant, but looking only at these easily observable metrics masks deep differences in the overall approach to PhD studies between US universities and many European universities. The US approach is much more informal and 'hands-off'. US universities, as has been mentioned, devote very little institutional focus to the conduct of PhD programs.

The conduct of research and its direction is decided *ad hoc* by the research adviser, typically on a rolling basis throughout a PhD. Recruitment of PhD students is conducted *en masse*, without necessarily deciding on a research direction beforehand. Because many are expected to drop out, often many more students are admitted than can be handled by the available funding. Degree time length, which on average is longer in the US, is also much more variable. In the UK, nearly everyone finishes between year 3 and year 5, but in the US, it is a gradual increase in completion from year 3 to year 7 or 8, depending on field.

The 'European system' (inasmuch as there is a unified system), in contrast, is much more formalized. Some PhD positions are advertised in much the same way as a job position. For example, the University of Uppsala (Sweden) website has a page for its PhD program. The page very prominently announces 'Four Years of Study', and has a link titled 'Browse Open PhD Positions' which leads to individual postings for PhD positions. Looking at the UK, on the webpage for University of Manchester, the PhD positions are not listed singly, but the duration ('3-4 years') and stipend (GBP 14,057 per annum) are prominently advertised on the webpage.

In contrast, applying for graduate studies at US universities is much the same as applying for undergraduate studies. One applies for entry to a graduate program, but there is no direct link to a specific research project. Graduate studies websites for US universities rarely mention anything about stipend or study length. This information vacuum makes an opening for PhD advisers who want to take advantage, by paying very little stipend or holding students back to get more work out of them. Additionally, it allows lazy or unfocused grad students to muddle through their programs without planning for the future. Because the term of the PhD is undefined, kicking the can down the road "a few more months" becomes very easy.

So, which method is better, European or US? There are certainly tradeoffs involved, but it is very clear that in general, the European approach is more favorable for graduate students, while in the US, the approach is more favorable to institutions and advisers. This results in a more favorable way of life and working environment among European PhD students in comparison to the US. This affects who decides to pursue research careers which can have ripple effects on the long-term health of science and the makeup of the scientific workforce, an issue I'll cover in more depth later.



http://www.nature.com/naturejobs/science/articles/10.1038/nj7357-533a
http://www.manchester.ac.uk/study/postgraduate-research/programmes/list/06765/biological-chemistry-phd/programme-details/
https://www.uu.se/en/admissions/phd-studies/

http://webarchive.nationalarchives.gov.uk/20100202100434/http://www.hefce.ac.uk/pubs/hefce/2007/07_28/

How about the effect on research productivity? You may imagine, for example, that there is some negative impact of such a short PhD program on research productivity or quality. There are dangers in trying to quantify something like the quality of research undertaken, but one metric for research quality and quantity is the number of citations of research produced by each country. By sheer number of citations, the US is the clear leader. US research was cited 48 million times in the years 2006-2011, and the next closest is Germany with 10.5 million. However, on other metrics, the US is not the clear winner. For example, in citations per paper, which could be an indicator of research quality instead of quantity, the US is third to Switzerland and Denmark. Additionally, if you calculate citations *per capita*, the UK is clearly ahead with 0.19 citations per person vs. 0.15 for the US, while Sweden is much farther ahead with 0.28 per person. This could be an indication that better-planned PhD programs result in more publishable research, and at less cost. The US spends the most of any of these countries on R&D (with the exception of Sweden, which spends *slightly* more as a % of GDP), yet has proportionally less research to show for it.

http://archive.sciencewatch.com/dr/cou/2011/11decALL/
https://en.wikipedia.org/wiki/List_of_countries_by_research_and_development_spending

Faculty Advisors & Students Both Contribute to Long PhDs

The length of the degree in the relatively unconstrained US system is controlled by both the student and the professor. In other words, both student and adviser must be willing to end the study. The student must be willing to go through with writing and defending a thesis, and the

adviser must be willing to allow a thesis committee to be convened. There are reasons that both students and advisers may be reluctant to go through with the thesis defence. A student must be ready to give up the role of graduate student and move into the job market, while professors must be willing to let their most experienced researchers leave the lab.

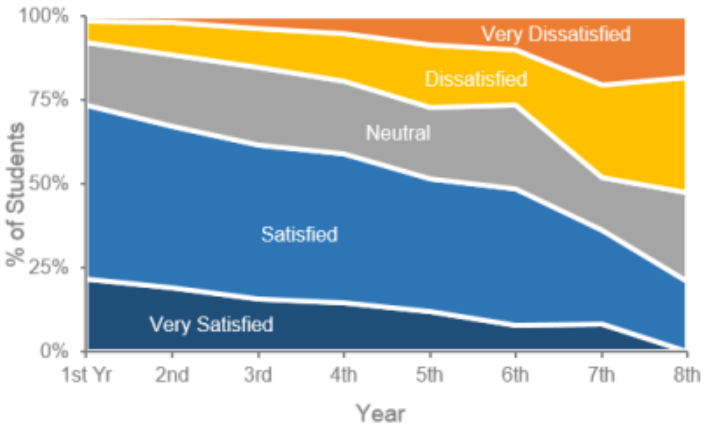
On the part of professors, a fifth or sixth year student is at the peak of their abilities after perfecting the techniques required for research. They can read and interpret scientific papers, they can perform research efficiently and formulate new hypotheses. In order for a PhD to be awarded, a faculty advisor must be willing to let the student go and allow a thesis committee to be convened for a thesis defense. This power inevitably leads to abuse. Professors put a hold on students' futures so that they will continue to do work for the lab and train new students. Since there are no standards for the awarding of a degree, and little chance for recourse by students to university upper management, professors are limited only by their own scruples in how long they wish to hold back a student.

For the students themselves, after five or six years as an academic, venturing from the relatively low stakes as a pawn in the ivory tower to the fast and furious world of business, or the uncertainty of attempting to begin one's own academic career, can be intimidating. This can lead to dawdling, feet-dragging and a general reluctance to move on, particularly if their experience in graduate school has been a positive one. Additionally, graduate students are motivated to put up with bad conditions in a PhD program longer than they would in a traditional job so that they can get the degree.

PhD programs take an agonizingly long time in the US, much longer than elsewhere in the world. Stern professors, uncertain graduate students and poorly organized PhD programs all contribute to the very long PhD programs observed in the US.

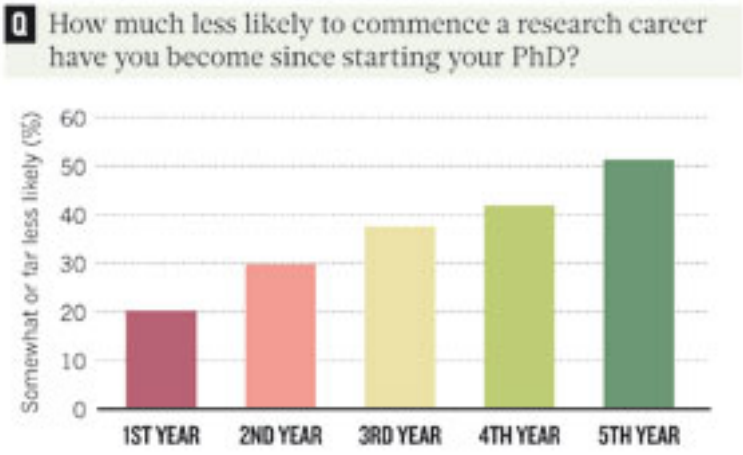
Neverending PhDs Take a Mental Toll

However, no matter why grad school is taking so long, there is evidence that the neverending modern PhD is burning out grad students and turning them away from careers in science. In 2011 a survey of over 5,000 science graduate students was conducted by *Nature*. In particular, the question "Overall, how satisfied are you with your graduate school experience?" showed a strong correlation with the year the students were with the 6th years and beyond showing an especially steep dropoff in satisfaction. As the average time to complete a PhD is about 6 years, it's clear that by the time students finish their degree, they've soured significantly to the prospect of a science career.



http://www.nature.com/naturejobs/science/articles/10.1038/nj7357-533a
http://www.nature.com/naturejobs/graduatesurvey

Another question that was asked in the same survey was about the likelihood of pursuing a research career. Year after year, PhD students became increasingly unlikely to pursue the degree. In the first year, 20% said they became less likely to pursue a research career than when they started the program, increasing to 50% at the end of the program.



So what's to be done? And more to the point, who could do anything to change the status quo? There are no nationwide unions for graduate students, although there are some at various universities. The transitory nature of graduate student as a profession no doubt adds to the difficulty of political organization.

The NSF, as a major funder of science research is able to dictate some policies for institutions that accept funding from it. For example it requires some standards of research ethics. Thus, it wouldn't be completely out of the question for the NSF to require PhDs to end in, say, six years if it thought that would improve the nation's science education. A fourth year PhD student in

biology at Harvard Medical School, said of such hypothetical action by the NSF: “It could work, but I don’t necessarily think people would move on. Some would probably stay on as [postdoctoral researchers].”

Even without action on a national level, some departments are setting a standard they believe will improve their educational program. For example, the UCSF Biophysics Graduate Program has instituted a six year cap on PhD programs with the option to petition for only one additional six-month extension. A PhD student at UCSF said, ‘Some of the students aren’t happy about the requirement. They don’t feel ready to graduate after six years.’

I am absolutely convinced that the best single reform that could be made of graduate school is to put a time limit on the length of PhD training. There is some value in leaving PhD training open-ended. A time limit makes certain that PhD efforts will be focused and that the process is transparent while not dictating everything that will take place within that time.

Motivation in Grad School

Why is that time in graduate school takes so long, and is so mentally punishing? In some ways it is the intricate relationship between progress and motivation. In graduate school, projects are often highly individual--there is very little to buffer oneself from the pains of a bad result. In addition, PhD students often get intensely invested in their projects, making any setbacks both professionally and personally devastating.

When the work of months could be for naught, it can cause an immediate halt to progress. However, not only is progress halted in the moment, but keeping oneself motivated after a bad results becomes increasingly difficult. When motivation is lost, the ability to make progress is stunted, and the process is repeated. Thus, a string of bad luck with results can not only lengthen your degree by its effects in the moment, but also over the longer term, by its harmful effects on your psyche. This is true particularly if you are in a research environment that lacks the key elements of motivation.

Within the field of science, there is very little discussion of the practice of science, or in other words, a meta-discussion of science. Among the most prominent of the few meta-scientists that are also practicing scientists are Evelyn Fox Keller and Uri Alon. Uri Alon has written directly about the idea of motivation. In a paper called *How to Build a Motivated Research Group*, he writes that there are three components.

First, motivation depends on competence. In other words, your project must engage you at your level of competence. Too simple, and you find yourself bored by its simplicity while too complicated, and you are overwhelmed and cannot find a way to move forward. Second is autonomy. A major facet of motivation in scientific projects is the power to set and decide one’s own research project, rather than being forced onto something for reasons outside your control.

Finally, is social connectedness, which is a sense of being part of a group and that you can talk with people about topics not necessarily research-related, life etc.

Evelyn Fox Keller has written about the hostile and malicious environment she encountered as a physics graduate student at Harvard in the physics department in the 1950s. In a must-read piece of meta-science literature called 'The Anomaly of a Woman in Physics', she wrote about the dismissive attitudes from fellow students and instructors towards her ambitions for a theoretical physics career. We will revisit Fox Keller's story later in more detail, but for now, it is enough to discuss how her environment hampered here motivation. The environment certainly lacked social connectedness as well as autonomy. She mentions feeling very isolated from other students, who made a show of both fearing the curriculum as well as not betraying any difficulty with it. The exercises assigned to her, she mentions, were routine rather than broaching the broader questions she was interested in. In this way, her environment lacked social connectedness, autonomy, and did not engage her at the appropriate level. Missing on the three points of motivation, it's not surprising she switched fields into molecular biology. The attitudes and environments she describes exist in many institutions and fields and make completing a degree in a timely fashion more difficult than necessary.

Science can be inherently motivating. People pursue science because they see it as meaningful, but it can also be quite thrilling. There's really nothing quite like setting up an experiment and thinking "by tomorrow, the universe will tell me if I'm right." The feeling you get when the results come back how you wanted, now that, that is what keeps you going as a scientist. That's the feeling of being *motivated* to do science, and it's a very important and powerful feeling that fuels the curious and creative impulses that drive scientific discovery. Clearly, motivation is important for accomplishment of many types. In PhD programs, a lack of motivation can lead to longer times to degree, burnout, or dropping out. The problem of motivation is hard enough in the scientific field due to the personal ownership of projects and the unpredictability of results. However, it can be made much worse by the peculiarities and draining nature of academic culture, which I'll explore more in subsequent chapters.

The burden of 'story' for PhD theses

There are some particularities about expectations about academic culture which tend to exacerbate the problem of long PhDs. A major point of uncertainty is the standard which must be met for a PhD to be granted a degree. By default, the thesis committee looks for a satisfying scientific story. What exactly does this mean?

Scholarly research articles in academic journals have one main message to get across. In other words, scholarly papers should be 'narrow'. They investigate one particular phenomenon in detail. How particular? How about 'Development and Growth of the Brown Mouse'? Not even close. Try: 'Cytokine H-241 Has a Positive Correlation with Cerebellar Growth In the 2nd Week of Gestation in *Mus musculus*'. Completely made up, but we're getting pretty close.

Narrowness is a virtue in academic writing because precision is absolutely essential. For science to progress, communication between scientists must not be ambiguous. However, although scholarly papers are narrow, they must be deep. Experiments must be controlled, and alternate explanations should be ruled out. Multiple experimental methods or schemes should be used if possible. To help the reader navigate this depth, papers are written so that evidence is presented in a logical and appealing way. On the other hand, papers which present contradictory data, multiple messages, or isolated data are not generally accepted by academic journals.

This way of constructing scholarly articles is preferred for a number of reasons. For those reading it, it is easier to follow a paper with a relatively simple and appealing narrative arc. A paper tends to be better received if it is well-composed, predictable and believable. This is the best way to disseminate scholarly information to a broad audience and for posterity. I don't have a complaint with this method of constructing scholarly articles.

However, academics also look for 'story' in a graduate student's thesis. In an idealized vision of academia, a graduate PhD thesis is the culmination of all a student's work, building towards a grand conclusion about some branch of science. A model PhD thesis would have 3 or 4 narrow points to expound on, showing progression over the years towards what is sometimes called a 'complete story'.

When this complete story works well, it's great! [Example of an academic story (Annus mirabilis?)] A complete scientific story is intriguing and satisfying in much the same way that a fictional story is. There is a dramatic arc, in which some unexplained phenomenon is investigated in a number of different ways. After a few initial dead-ends, the right approach is found and in an intellectual and personal triumph, the scientist ultimately has an explanation for the unknown phenomenon. The presentation of the data need not even be in chronological, but can be in whatever order makes the best story.

Unfortunately this vision for what a thesis should be is arbitrary and unfairly hurts students. There are many reasons legitimate why students may not have a complete, engaging or coherent thesis story and none of them justify withholding a PhD.

A need to 'follow the money' reduces grad students' ability to tell a coherent scientific story

Funding is a constant issues in conducting academic research. Grants or other funding instruments are often awarded to conduct a specific project. Thus, if one grant ends and another begins, the project a student researches may change profoundly. It's an obvious result that of this kind of change of direction that it is much harder to tell a satisfying scientific story.

Funding agreements about topics which a company, for example, is interested in, are not necessarily of scientific interest, and the results gained may not even be publishable. With

funding always an issue, however, any money is good money, and compromises between the need for funding and pursuing the most interesting scientific questions have to be made. Long story short, “project-hopping” due to a source of funding drying up--or the need to maintain a different funding source--is a fact of life for grad students.

If a graduate student is shuffled from project to project to follow the money, they are unable to devote enough time to tell a classic academic story. That is--a story that follows a consistent thread, is narrow and deep, and is compelling to a thesis committee. Thus, two students with equal abilities and who exert equal effort will not necessarily end up with the same quality academic story.

The student who has had a predictable and steady source of funding is likely to have had the greatest opportunity to make significant progress towards a complete story which an academic committee finds acceptable. On the other hand, a student whose project has changed abruptly due to funding is less likely to have been able to complete a story which an academic committee will certify for graduation. This would amount to an arbitrary time penalty against students with unsteady or restrictive funding sources.

Students who perform high-risk research are punished by the standard of academic story

Choice of scientific research project involves trade-offs. It’s not uncommon that there is a trade-off between risk and reward. In other words, a project which is low risk is one which will likely work, have good results, but the significance of the work is not very high. In contrast, a risky project is one that is less likely to have good results, but if the work succeeds, it will make a more significant impact on the field. It’s not completely unlike horse racing. The underdog is unlikely to win, but the reward is great if you placed your bet on it.

On the whole, low-risk research is more student-favorable, while high-risk research favors the advisor. A student is typically most interested in a project on which she can make steady progress and which will lead predictably towards a ‘complete story’, and graduation. Generally, a student isn’t as invested in doing high impact work and getting noticed within the scientific community, especially if they’re not planning on an academic career. On the other hand, advisers need to get noticed in the scientific community, in order to make a name for themselves and get research funding. Thus, they have more incentive to engage in high-risk research. Even though any given student’s project may have a low chance of success, combining the efforts of several students on high-risk projects, an adviser might have a fairly good chance of success. And depending on their scruples, they may have no problem sacrificing their grad students’ time, as long as one of them comes through with a high-profile result.

In this way, a student may be kept from timely graduation, not by the strong-arm tactic of saying “no” to request for a thesis defense, but more subtly, by preventing the accumulation of positive results upon which to build a “complete story”. Ultimate authority over what project a student pursues lies with the advisor, since a student who doesn’t follow an adviser’s directives on what

project to pursue may simply be fired. In some cases, an advisor may allow a student to choose a project, particularly after the student has gained some level of mastery in the field. Depending on a student's personality and confidence, they may begin to push back against an advisor's plans when they see a more promising scientific path. However, it's also possible for an advisor to steamroll students into high-risk projects, with or without realizing that they're more than likely pushing a student towards a long, fruitless and emotionally taxing PhD.

There's always some conflict inherent in a supervisor-direct report relationship, but perhaps the dynamic described here indicates some issues with the extant expectations of the thesis defense and its "complete story".

Having a complete research story is not required to learn the tools of academic inquiry

Although there is no universal standard by which PhD student's progress is measured, in general, thesis committees look for the 'complete story' of results in order to determine when a student should be allowed to graduate. Is this really the best way to assign a PhD though? To rephrase the question, should progress be measured by the skills a student develops, her knowledge of the field, or contribution to science (i.e. a 'complete story)? To more fully illustrate this conundrum, consider the following situation.

Imagine two PhD students with very similar projects. Student A is studying protein A of the brown mouse while student B is studying protein B. Both students are attempting to characterize the role of their respective proteins in, let's say, the development of diabetes. Both students will characterize the protein, do experiments to determine what interactions they take part in and so forth. They will make a mouse model which has some modification to the protein, like a loss of function mutation, and see what happens to the mouse under different conditions relating to the onset of diabetes.

Now, let's say student A finds that protein A has a significant impact on the development of diabetes, while student B finds that protein B doesn't have a significant impact. Student A has a high chance of publishing an important paper about diabetes development, which would contribute greatly, or entirely constitute, an acceptable PhD story. On the other hand, student B would have a much smaller chance of publishing an important paper (or any paper), and consequently, does not have an important building block on which to construct a 'well-rounded scientific story'.

Consider, though, that both students have learned the same things. They learned the same research techniques, did much of the same background reading, used similar experimental design and carried out the experiments. The students constructed almost identical hypotheses and subjected them to the results of a, presumably, well-designed set of experiments. They expended the same amount of effort in the same span of time, yet, by a chance of nature, student A is much closer to having an scientific story acceptable for the purposes of a thesis defence. Although I don't see a solution to this problem, this effect has the potential to prevent

the graduation of students who are perfectly qualified on a skills basis, if not from a 'scientific-story-acceptable-to-a-thesis-committe' basis.

A lack of focus and structure contributes to stress and long PhDs

Stress is a necessary part of life. Without stress, there is no motivation to act. Yet, what is healthy and necessary in moderate amounts, is clearly toxic in large doses and over long periods of time. Adam Ruben writes that grad school is polarly stressful, in other words, at points it is lackadaisical, and at times it is like crunch time. So just what is the origin of stress in graduate school?

Some of the stress attributable to employment and work is related to its usually highly structured nature. A rigid adherence to working hours or vacation day policies can make it difficult for employees to deal with the various difficulties of life--a sick relative, a child in trouble at school, a flooded apartment etc. However, it's also possible for a complete lack of structure to contribute to stress. In the absence of clearly delineated job duties, and with a lack of oversight from upper management, for instance, there is no limit on the tasks that an advisor can order a grad student to do.

It's not always the pressure from a supervisor, though, that is most crushing in the absence of a clearly defined structure. In grad school, there are no definitive guidelines to follow, no rulebook, and no 'punch-out' time. Students can make themselves believe, with no one to guide them, that overwork is the most direct path to graduation, or whatever goal they may be pursuing. It's easy for a student in the thick of her PhD work to convince herself that every hour not spent in work, is another hour she must spend in her PhD program. While motivation to work is a positive and necessary thing, the tendency to overwork in grad school is omnipresent, and is often counterproductive, leading to costly mistakes or losing sight of the big picture and potentially more fruitful scientific directions.

It's a deeply destructive impulse, harming students' psychological and physical wellbeing, extending PhDs, hurting scientific productivity. It's motivated by a certain kind of feeling, combining despair in total uncertainty, of intense anxiety over scientific failure and a fear that it is related to one's own ineptitude. It's a feeling that is deep and bitter and yet often completely aimless, in its failure to motivate one towards any set of actions in particular. When a culture is saturated by people feeling this way, it's an unsustainable culture. One way to introduce some structure into a PhD program would be to set a time limit for PhD graduation.

Reform of Graduate School Length Would be Positive Step

As I've explored throughout the chapter, PhD programs are long, averaging over slightly over 5 years in the US according to The PhD Completion Project. As the years wear on, surveys show students become less satisfied and less likely to pursue careers in research. The time commitment takes a physical and emotional toll on grad students, but also discourages many

from pursuing research PhDs in the first place. It's not clear that such a long PhD is necessary or productive, with some European countries coming in a full year shorter, with comparable or higher research output. I've come to the conclusion that limiting PhD length would be a positive step, for students and institutions.

There is little organization of PhD studies at a national/federal level, so such a step is unlikely to come from there. However, even at the level of universities, departments, or individual labs, such a step could be part of a program to repair the culture of academia. A time limit of about 6, or eventually 5 years would allow some flexibility, but also protect students from the worst overreaches of abusive PIs and also encourage students to plan for the next steps in their careers. When the end date is known ahead of time, career preparation becomes a much more imminent priority. Additionally for students and advisers who wish to continue work beyond that time frame, a position as a postdoc or technician is always an option.

Graduate students have so little extrinsic value, no one keeps track of what they're doing

Chapter 3

Academy or Bust

Academic culture in graduate school is biased heavily in favor of academic career tracks over employment in other sectors. This bias exists at many levels. In particular, the practitioners of academic science, the faculty, want their students to follow in their footsteps in the academic world. At first glance, this might seem like a noble, even caring impulse. In reality though, it is often born of ignorance and self-interest, and can end up hoodwinking students of time and sanity. This attitude, despite its sometimes destructive effects has to a considerable extent, pervaded academia, often including the students themselves. While on the whole, this attitude remains de rigeur for students and faculty, in this area (the sometimes unhealthy prioritization of academic careers over), probably more than any other in this book, there is reason to be hopeful. There is a lot of movement in this area towards normalizing non-academic careers.

Academics Was Traditional Career Path For PhDs

After a lucky grad student finishes their PhD, what then? They're ready to move on, finally, to full employee status, but where? As one option, they can attempt to move into a career in the very system in which they spent so many years at the bottom of the ladder. They've spent years around the system, have learned its intricacies and idiosyncrasies. They feel comfortable in it and may even admire some of the researchers in their field. It's completely unsurprising for a new PhD holder to seek a career in academia. As an extension, it's not surprising that the academic career track became the default assumption.

For a long time, this arrangement worked out just fine. In the post war years (1950s & 1960s), as federal research dollars in the NIH & NSF boomed, universities expanded, and plentiful faculty positions were opened. In the 1970's, research spending stagnated, before again booming in the 1980's and 90's. Many of today's faculty began their academic career in this time period of abundance (1985-2000).

Since the early 2000s, the economics of research and universities have again changed dramatically. Start with research. The budget of the NIH, which expanded dramatically in the 1990s, has declined by as about 10% in real (inflation-adjusted) terms since 2003. The NSF has fared only a little better. Since 2003, the NSF has been essentially flat. In tough budgetary and economic times, the political choice of reining in spending growth in these areas is certainly understandable, and in this area, I differ from many others who see funding as the one and only problem in academia. I see funding levels as a problem, but not the biggest problem, for grad students today.

https://whyevolutionistrue.wordpress.com/2009/07/21/chris-mooney-on-nsf-funding/
http://themillercircle.org/2009/07/the-impact-of-national-institutes-of-health-nih-funding-on-the-health-and-economy-of-america/

http://www.faseb.org/Portals/2/PDFs/opa/2015/2.10.15%20NIH%20Funding%20Cuts%202-pager.pdf

The economics of universities themselves has also shifted. Academic careers, which traditionally were seen as a hybrid of teaching and research, are becoming increasingly bifurcated. Tenure-track faculty, who earn a (usually quite decent) salary, devote all of their time and energy to research--leaving teaching as essentially a parenthetical. Tenure-track faculty usually do have some teaching duties, but it is normally a maximum of one course per term--at least in the science and engineering departments in which I have worked.

On the other hand, teaching roles have largely been relegated to contingent laborers, somewhat euphemistically labelled “adjunct faculty”. Adjunct faculty are paid piecemeal, by course. Grad students are often pushed toward academic careers by their advisors and their environment, yet the jobs waiting for them are not, by and large, the glamorous research careers they imagine, but the low-status, insecure world of adjunct teaching faculty.

Current faculty have skewed, sometimes inaccurate views of job market

Many academic PIs have little knowledge or appreciation of life in the private sector. This is caused by a fundamental imbalance. While nearly all professionals have some exposure to the academic world from their time in college, many faculty have spent no time at all employed in or in contact with the private sector. This leads to many faculty holding incorrect and skewed beliefs about the character of work in the private sector and the motives of the people doing it. Often, these attitudes percolate down to, or are at least not challenged in, students and other academic workers who quite possibly have also never worked in the private sector.

Paradoxically, current faculty don’t have much contact with or insight into the current academic job market either. As it stands now, less than 1% of grad students will go on to become tenure-track faculty. The changes that have occurred in the academic job market are not necessarily visible to sitting faculty, who most likely got their job at a time when many more faculty positions were open and fewer people were applying for them, for example in the go-go periods of the 1970s or 1990s. Faculty may enter the job market occasionally to change institutions, but they do so with many advantages and do not compete with aspiring faculty for entry level positions. (Cheekyscientist.com)

Faculty want their students to pursue academic careers

Not only do faculty have an often incorrect view of the facts of job markets in favor of academics, but their motivations are skewed in that direction as well. In particular, faculty have both vain and material reasons to want their students to go along and become professors.

When a faculty’s trainees go on to their own academic research careers, it adds to that faculty’s prestige and influence in the academic community. It shows how their excellent mentorship

allowed people to succeed in their world, and how they attracted the most talented academic minds to work with them. Placement of a faculty's 'academic children' in faculty positions is itself a metric of success in the academic world. Faculty are often highly motivated by the perceptions of their peers, and the accomplishments of their trainees, as well as their own high-impact publications, are highly visible and often-discussed topics for comparison and competition in this world.

Having connections in academic faculty positions also redounds positively through peer review of publications or grant proposals. Although some journal editors or grant managers may try to avoid reviewers with direct connections, in some cases, the 'academic children' or others with close connections are the most qualified to comment on the scientific merits or demerits of a given paper or proposal. More generally, when one's acolytes work in the academic world, they often work on similar scientific questions. This raises the profile of a particular niche in the scientific community, leading to more funding and fame.

The combination of this self-interest with faculty with the overall attitude towards the private sector leads predictably to apathy and ignorance towards career paths in the commercial world.

Awareness of non-academic careers still not enough

Despite progress, PhD programs and advisers are still doing too little to raise awareness and respect for non-academic careers. These careers have often been belittled through the label 'alternative', as if someone would only turn to them if they had no other options. However, just as bad as the attitude of academic culture towards is PhD candidates' frequent lack of belief in themselves. This was highlighted by academics Fanuel Muindi & Joseph B Keller in an article for *Nature Biotechnology*:

Often, we hear common refrains from colleagues: "What else can I do? Do I have necessary skills to move outside academia? Which industry fits me best? Will I have the support from my department and research advisor in pursuing jobs outside the academe?" These are just a few of the myriad questions they face. Unfortunately, some trainees may simply lack the information necessary to make an informed decision about their post-training careers.

Academic peons like graduate students are very insulated. Countless lives have been shattered by the mindless pursuit of academic positions--sometimes simply because someone doesn't believe they're able to do anything else.

Academic institutions are making an effort to increase awareness of career paths for their PhD students. Interestingly, these efforts are mostly being spearheaded outside of the academic departments, but through universities' career centers or by students themselves. Additionally, a suprisingly well-developed network of outside organizations are helping PhD students connect with careers outside academics. A notable example of these is CheekyScientist, a network of consultants that PhD students can join for a fee, which has stellar recommendations.

The plight of post-doctoral scholars

The path to a tenure-track faculty position, although narrow, still exists. Generally, to become a faculty, you must first bulk up your resume with a post-doctoral researcher position. Post-doctoral researchers ("postdocs") are nominally independent researchers who take a position in an established lab to help themselves gain a footing in the academic world. The position is meant to be an opportunity for advanced training for PhD holders who are looking to advance in academics. Ideally, postdocs learn about how to become tenure-track faculty from their department's faculty and may even take on some management and mentorship role themselves. The National Academy of Sciences articulates what the role of postdoc should entail in their report *The Postdoctoral Experience Revisited*:

The postdoctoral experience is first and foremost a period of apprenticeship for the purpose of gaining scientific, technical, and professional skills that advance the professional career.

The reality of the postdoctoral scholar is that they are not independent researchers, but usually carry out a set role in ongoing projects. In practice they are not receiving any meaningful training, but are instead simply a convenient source of contingent labor to fill in the gaps when grad student recruiting fluctuates. They are more well-trained than grad students, but more expendable as well, since there isn't the promise of a credential to keep them from leaving.

While I'm focusing this book mostly on the experience of graduate school, understanding the fate of postdocs is vital to appreciate the full scope of graduate school since so many who earn a PhD end up doing post-docs in sometimes quixotic quests for academic positions. A steadily increasing fraction of PhD holders are going into postdoc positions immediately following their graduation. In 1986, the fraction of PhD holders entering a postdoc position was about 26%, and it has increase to 2013 when it was about 40%. As 'postdoc-ing it' becomes more and more common, paradoxically, faculty positions remain sparse. Simple arithmetic indicates that either people are postdoc-ing longer and longer, or moving from postdocs to positions outside academia, rather than into tenure-track faculty position.

As widespread as postdocs are becoming, their salaries are far below average for PhD-holders. They earn an average of $45,000 per year (via Glassdoor). According to *Revisited*, PhD holders who work in other positions earn **40-200% more**, depending on field. Also in *Revisited*, the National Academy call for an increase of the NIH postdoctoral fellowship to $50,000 per year (it hasn't happened).

Reading *Revisited*, it's painful to see the authors avoid confronting the economic reality of the postdoc position. They steadfastly (foolishly) cling to the notion that postdocs ought to be getting additional research training. This is just not happening, and no amount of reports will change the incentives at play. Postdocs don't require any skills beyond that they used in graduate school. They don't perform any management role, they are restricted from applying for

grants under their own name, and they still (like graduate students) are not even technically employees. At best, a postdoc is a 1.5x graduate student. They may be able to do work a bit faster, but are fundamentally no different from graduate students. They plan experiments, conduct experiments and make powerpoint summaries of the results which they report only to their direct supervisor. Interchangeability with graduate students (whose pay is kept low by preventing labor fluidity) is the fundamental reason for the low salary of postdocs.

http://www.nature.com/naturejobs/science/articles/10.1038/nj7126-453a

Why is this a problem?

So far, I've made the case that the academic environment and advisors often steer students toward academic careers. But why, exactly, is this such a big problem?

There are a couple of reasons:

http://www.nsf.gov/pubs/2005/nsf0504/nsf0504.pdf

- Students implicitly trust their advisers as mentors

Implicit in the words "student/advisor relationship" are connotations of a relationship based on mentorship. In this conception, the advisor has a benevolent attitude towards a student, putting the student's interests, while not necessarily first, at least on an equal footing with their own. Students, particularly early in their PhD's, may be operating under the assumption that this is the case. Thus PhD students are notably vulnerable to suggestion by their advisers.

Even by the time a PhD student graduates, they are typically almost complete naifs when it comes to the world of employment and jobs. Typically, they have held no full-time employment, except perhaps as a summer job during high school or college. Instead they have spent the first decade or more of their adult life on college campuses, the second half as a student/employee hybrid. So the word of a professor, whom they often trust implicitly, as mentors and good scientists, carries weight in lieu of their own experience. Interestingly, professors are often little-more experienced in the world of job-seeking, having typically only worked in academics, at one or a small handful of institutions. In fact, they can be even *less* apprised of current trends than their students, since it has often been years or decades since they have had contact with the job market. Trusting the advice of someone who is in an authority position, but is not necessarily well-informed is a mistake. But even worse, some advisers may intentionally abuse the implicit trust their students place in them. As I've mentioned earlier in the chapter, faculty have a vested interest in their students becoming research faculty to spread their academic empire.

Giving unearned trust to employers and supervisors is a mistake many people might make early in their careers, not just PhD students. However, the typical non-academic boss/employee

relationship is readily thought of as potentially adversarial, with opposing interests. It may do well for PhD students to think of their advisor as a “boss” with their own set of interests, rather than a “mentor” who is always out to help them.

- This leads to missed opportunities, wasted years, bitter hearts, regrets and hatred of science

It’s always dangerous to make decisions based on faulty information, or when you harbor significant biases. This is particularly true of decisions about big life decisions about education, career, relationships, family and so forth. If you get these big decisions wrong, it can not only waste years, and prevent you from getting where you want, but also inflict significant psychological damage.

The internet/blogosphere is littered with accounts of one-time PhD students who, for one reason or another, blindly pursued academic careers until they had to declare bitter defeat. Often, this is based on a misinformed dichotomous view--for instance, that everyone working in the commercial world is an unfulfilled, profit-hungry drone, while academics are noble warriors, pushing the boundary of knowledge. A student’s pre-held beliefs can certainly play a role here. After all, they decided to enter academics as a PhD student. However, their advisors, and the academic environment more generally, can further influence their thought processes.

A Google Document listing 86 separate online essays of researchers leaving academia for greener pastures elsewhere, a list of so-called ‘quit lit’.

https://docs.google.com/spreadsheets/d/1OODoiZKeAtiGiI3IAONCspryCHWo5Yw9xkQzkRntuMU/edit#gid=0

The typical “quit lit” story goes something like this. A student begins their PhD studies with hopes of one day becoming a research faculty at a major university. As they progress through their academic careers, they encounter more and more difficulty. Throughout the course of their PhD, they necessarily put up with the vagaries of scientific discovery, but also the arbitrary and sometimes abusive demands of their advisers (with no supervision from upper management), the ambiguous requirements for graduation and a lack of structure in their program. These difficulties take their toll, but rather than reconsider their commitment to academics, this student doubles down. Maybe they tell themselves that once they get into a postdoc, they’ll have their own project and really be able to talk with their professors on an equal footing.

When they finish their PhD, they get a postdoc position without too much difficulty. However, instead of their own project, maybe they find that they are playing a bit role in a pre-existing project. And instead of being treated as an equal with worthy opinions, they are treated by their new boss as a convenient, low-investment, source of labor to push their own projects forward. Despite these further setbacks, the academic ambition is unabated. Maybe they are able to

push out a lousy paper or two in their postdoc and in year 2 or 3 of the postdoc, begin furiously applying for academic positions.

This is when ambition truly begins its disastrous collision with reality. While the student's publication record could be decent, even verging on respectable, they are simply getting no traction with their job applications. What the departmental search committees are looking for is applicants with high impact publications in "glam" journals--a few publications in society journals isn't going to cut it. And while the applicant may have been doing sound science for almost a decade, they haven't taken the strategic approach of weaving it together into a catchy story, so that when someone mentions their name, they immediately think "oh, that's the X guy/gal". While our hero has spent their career dotting the i's and crossing the t's, what is really required is a sloppier, catchier approach.

In desperation, the student jumps to another post doc, hoping they'll get lucky with a high impact paper, but they run out of luck and despite their best efforts, remain unable to get that academic job they were hoping for. The one-time ambitious student has been thoroughly defeated. By now, our intrepid hero has spent probably over a decade in academics (~6 in grad school and a total of maybe 5 in postdocs), feeling like a failure and at rock bottom. Finally, painfully, they begin to question their unthinking dedication to an academic career. But now, years have been lost in beginning a career transition. Not only is time lost, but letting go of an ideal, tightly held for so long, is psychologically devastating--and someone so wiped out by such an experience, may be incapable of adapting themselves to a new career for some time.

This is the harvest of a one-track mind on academic career tracks. This attitude comes from faculty, students and the overall ambience of the academic space. It's simply not a realistic to expect a faculty position, and a failure to adjust one's expectations in the face of reality can be an absolutely catastrophic life-ruiner.

- What can happen when PIs attack -- PIs fast-track the graduations of those planning on academic careers --stall those who aren't -- Some students may hold themselves back out of a perceived need to publish more

Interestingly, the prioritization of academic careers (Chapter 3 topic) can lengthen the time to PhD (Chapter 2 topic) in multiple different ways. First, when it's the advisor's opinion, they can knowingly or unknowingly alter the course of their students' degree progress depending on whether they plan to pursue academics. Second, when students hold the opinion, it can hold them back from graduation because of a desire to publish more or get a better letter of reccomendation from their advisor.

PIs might attempt to impart the attitude of academic superiority to their students. This can take many forms, some benign, but some potentially harmful. If it simply takes the form of counselling a student on their experiences in academics, then so be it. However, it often goes beyond simply making the case for academic career track--it can take forms which are more

personal and potentially negative. This could be by acts of omission, for instance, prioritizing degree progress for students who are interested in academics, while ignoring students with other career plans. This effectively puts students with academic plans on the fast track, relegating the other students to stagnation and a slower graduation. However, it can get even more blatant and intentional than this.

Ambition for an academic career path can also constrain graduate students due to their need to get letters or a desire to get more papers. To get an academic career, publishing record is of paramount importance. So a student may delay graduation because they think they can publish a couple more papers if they stay around for a year or two. The students may be right that this will help their ability to get an academic career, but at the cost of massive time investment for uncertain return. For students who are interested in an academic career, they are forced to toe the line their PIs set out for them scientifically, and professionally in order to maintain good will for letter writing.

How is it changing?

At the beginning of the chapter, I mentioned that there was good reason to be hopeful about PhD students adjusting career expectations. And indeed, out of all the issues raised in this book, I think this one has the greatest reason for optimism. Partly, this is just because of the nature of this particular issue. This issue can be solved simply by a PhD student changing his or her own attitude. This is not so for the time to graduation problem, or the lack of a management chain of command, or other aspects of the material situation of graduate school.

The expectation of academic career paths can be changed by adjusting *one's own* outlook, without relying on the system to fix itself. And there is good reason to believe lots of people are changing their outlooks. There definitely seems to be an increasing realization among grad students and universities that non-academic careers are viable, respectable options. This is reflected in the number of resources that have emerged for students wishing to pursue non-academic careers.

First, high-profile academic publishers, particularly *Nature*, have devoted much of their heavy-hitting editorial focus in the recent past to just this issue. *Nature* sends out a weekly newsletter of its recent publications. In its "Jobs & Career" section, scarcely a week goes by when one doesn't see an article about leaving academia or finding non-academic jobs. This not only reflective of a realization, at high levels within the academic world, that the current attitudes are untenable, but will itself go a long way in further transforming the fabric of academia.

Take for instance, a recent series of articles about how to change careers. In 2012, *Nature* published a series of 13 articles about how to change careers away from academics. Here is a list of some of the articles in the series:

- From science to politics

- From PhD to scientific conference organizer
- From chemist to company founder
- From PhD to patent attorney
- From academia to business entrepreneur
- From journalism to science and back again
- From science degree to PhD to postdoc
- From PhD to PR
- From a science degree to teaching and film-making
- Changing PhDs and exploring science writing

These articles not only show that it is realistic, but also potentially desirable to switch from a life as an academic in grad school, to the life in other career endeavors. While this kind of career jump is not necessarily easy, this kind of visible demonstration that others in the academic world have done it, is incredibly motivating for a PhD student investigating considering alternative career options. This series of articles, along with all the other articles I highlighted in Chapter 1, show that there is some real reasons for hope, by the fact that high-level scientific publishing is putting some real editorial heft behind these movements. This is both a sign and an embodiment of the movement to recognize non-academic career paths as acceptable.

Second, universities, are offering more career development workshops for graduate students than ever before. One famous example of this is the Stanford Biodesign program. This offers several classes for graduate-level students in science, engineering, business and medicine. The core of the program is Biodesign 374, a two-term, project-based class which looks for solutions to unmet needs in the medical world. The ultimate goal of the course is to generate intellectual property, which Stanford claims, that can be used to develop and commercialize medical devices. Ideally, the class is a win-win. The University gets a cut of the profits, and the students get experience in areas that might be useful for starting a career that isn't in academics. This particular class turned out to be a hit--and many other universities all around the country are now replicating this program.

http://www.stanford.edu/group/biodesign/cgi-bin/bme-idea/

Another example of these career development programs is the UCLA Business of Science Center. This program states explicitly, that "The mission of the Business of Science Center is to prepare scientific, engineering, law, medical, and business students for non-academic careers…" They offer courses like MPHARM 287 Exploring Entrepreneurship, in which students compete in a venture competition. Additionally, they offer BIOENGR M233, a "MedTech Innovation" course based on the original Stanford course.

Students themselves are also leading efforts to gain the transferable skills needed for non-academic careers. A recent article in *Nature*, interestingly enough, detailed how students are beginning to lead these programs. For example, the BALSA (Biotechnology and Life Sciences Advising) Group at Washington University of St. Louis. This student-led and -created

group assigns volunteer students to a client-based business question, especially relating to life sciences and technical areas. Read the original Nature article for more examples of student-led career development groups. Although it lists several, it is likely that every university with a significant number of PhD students has one of these groups, or will soon. These types of groups empower students to show the kinds of skills and habits that can make PhD studies worthwhile: technical knowledge, making sense of data, presentation skills and maybe most important tenacity.

http://www.nature.com/nbt/journal/v33/n7/full/nbt.3282.html
http://www.nature.com/nbt/journal/v31/n10/full/nbt.2706.html

It's interesting to note that all these resources are coming either from students themselves from central university units like a career center, and never from the academic departments. This fact is inextricable from the notions explored in this chapter, most pervasive in these departments, that academic careers are superior. Why should a professor bother with the career prep of his students if they're just going to go into commercial industry anyways? In some ways this bias is built-in, for all the reasons I've already mentioned. But the way this attitude plays out in today's connected global economy is regrettable and ultimately unsustainable, a theme that we'll explore more later.

Finally, students themselves seem to be pursuing resources even outside the university to help themselves succeed as well. A large number of services, networks and resources in this area have been formed. The CheekyScientist network is the largest and most prominent example of such an organization. Cheeky Scientist markets itself as a network for PhD students interested in industry jobs. Cheeky Scientist Materials feed on a deep and justifiable strain of bitterness in graduate students: "You can't do meaningful work in a broken system.", "Professors have too much power over you and often abuse this power." read some of its materials. Bitterness notwithstanding, the Cheeky Scientist network has thrived, serving "50,000 Academics Who Are Now Successfully Becoming Industry Professionals".

The founder Isaiah Hankel, has written extensively about his own unenviable grad school experience in the materials on his website. In one post, titled "Why You Need To Leave Avademia", he wrote: "The idea of getting on food stamps as a PhD student seemed completely ridiculous at first. … My academic advisor was treating me very badly and was refusing to let me graduate."

These materials on the CheekyScientist website tell us two things. First, that Isaiah Hankel had a bad time in graduate school. Second, and more importantly, that he is banking successfully on the fact that this kind of writing, laced with bitterness and grievance, has resonated powerfully with tens of thousands of one-time academics. This second fact paints a sobering portrait of PhD studies that surveys, numbers and statistics just never quite capture.

http://cheekyscientist.com/leave-academia/

Recognition of Non-Academic Careers for PhD Holders is Critical for the Continued Relevance of PhD Degree Programs

Pursuit of PhD degrees is done partly because of the intrinsic rewards of research, but also, certainly because of the opportunities that are made possible by obtaining the degree. In the past, this has typically meant opportunities to enter the academy. However, that model is no longer tenable. As I've mentioned before, there is significant information asymmetry when it comes to graduate school. In other words, potential graduate students have not much idea about the realities of graduate school and also the potential career opportunities. Thus, there will tend to be lag time between the realities of career opportunities for graduating PhDs, and their effect on the choices of incoming PhD students. And this is probably part of the reason why the ideal of an academic career has stuck around for so long, even though it is no longer realistic for everyone, nor the only way to go. However, when the tables turn, and the common wisdom about PhD becomes that it's a road to nowhere (as it has begun to) the damage will be long lasting. If you believe, as I do, that scientific research is important, and that PhD studies have some redeeming value, this is a problem.

Clearly a change is needed. In this chapter, I have outlined what kind of change and and shown how that change has already begun. To buttress and expand the appeal of PhD programs, the idea that a PhD can confer many, diverse and valuable skills is needed. The notion that a PhD opens the door to a variety of desirable careers is paramount. The way to revitalize PhD programs is not to close the gates of the ivory tower and double down on academics, but to open the doors to new possibilities and new futures.

Chapter 4

Graduate Student Serfdom

- "[Science Ph.D.] students have effectively become serfs." -*James D. Watson, famously credited with discovering the structure of DNA, at a talk on the state of science, 2007.*

Grad students occupy an unusual niche that no one understands, making them particularly susceptible to holes in the system

Graduate students tend to get pushed around a lot. They often work long hours. PhD students are usually, though not always, paid for their labor. However, even graduate students paid for their work are at a disadvantage compared to other workers. Graduate students are not considered employees under federal labor laws, and are therefore not entitled to minimum wage protections, unemployment benefits and have reduced legal recourse, for example to wrongful termination or wage theft lawsuits. While graduate students are probably not best considered employees, there is no equivalent set of labor protections for grad student workers. As such a small group relative to the labor force at large, it is unlikely that sufficient political pressure could be exerted to get such protections at a federal level. While overall, most PhD students might be paid at a fair level under reasonable working conditions, the fact that this group has no legal recourse allows for a small but significant subset to get paid very little and work under terrible conditions.

In the first chapter, I mentioned how labor stasis in graduate school is one of the root causes of many of the problems discussed in this book. Graduate students are much less likely to leave a position than a typical employee under similar conditions, since they get none of the benefit of the degree, while a typical employee gets rewarded continuously over time with their salary. This becomes more true as more time is spent in graduate school. In this way, graduate labor stasis enables these poor working conditions since PhD students are less likely to leave an unfavorable working environment. The six-year PhD makes it possible.

A lack of upper management supervision allows PIs to act however they like. While quite often this hands off approach works fine, very often, things don't go so well. Academic lore, and more recently the blogosphere, is replete with unbelievable stories about the 'PI from hell'. 60-hour work weeks, Saturday morning meetings, withheld pay for perceived poor performance, forced religious attendance and more. However, university upper management takes such a lax stance on working conditions that these situations are never even detected. Even sexual harassment, which is taken very seriously in large bureaucratic organizations, is often swept under the rug or ignored. Nearly anything goes in the management of PhD students. Institutional opacity and a thorough-running inability to care about these issues are the fragrance that infuse academics, particularly at the top. Since PhD students are not likely to leave, and when they do, are mostly considered interchangeable, upper management has basically no stake in these events, and so therefore deploys very little resources to control these situations.

PIs' ultimate lever of control is the degree award

'Graduate *school*' is a misnomer. For many programs, the course requirements aren't a serious component. They are meant to be dispatched as quickly as possible, hopefully within the first year, so that you can focus on what really matters, research. The graduate student performs research projects for the principal investigator (PI), and in return, gets paid. There is no doubt that the PI benefits from the labors of the graduate students, in the form of additional publications, leading to more grants, leading to tenure, pay raises, etc. This sounds exactly like the *quid pro quo* of traditional employment.

And it's true, graduate students are effectively, though not legally, low level employees of their principal investigators. PIs have at least as much power over their students as bosses do in the private sector. They have the power to fire--i.e. stop paying--their students. Threatening to fire a student is a last resort, though, and probably the threat alone is enough to harm any kind of a productive relationship. And if a PI fires a student, who's left to do the science? It's just not the ideal mechanism of control.

However, there is an additional lever available that makes PIs' control over their students even more complete. It's said that sometime during the 1300's, European university culture changed dramatically. It ceased to be the case that you advanced by challenging your teacher, but instead by spreading their teachings. Why did this happen? The invention of the credential. Universities began awarding credentials, and as a result, students followed the demands of their teacher until the credential was awarded. The dynamic is not so different today.

In academic institutions, a PhD is awarded on the basis of the recommendation of a thesis committee. With research of 'sufficient' academic weight, the committee decides to grant a PhD. In theory, the committee format should dilute the control that any one member has over the student. In practice, only one member's vote matters, and that is the committee chair who is also the student's PI. The thesis defense is a formality. The mere fact of having scheduled it with the PI's permission is enough to elicit congratulations from colleagues.

The power wielded by the PI in controlling when a PhD is awarded can have widely varying effects on a student's professional future. For a PI who is understanding and gives consideration to requests from students, there can be positive results that come from the unilateral authority to grant a PhD. Consider, a PhD student near the end of her program gets a job offer, but must be ready to start in a month. An adviser who is considerate of his students' goals would make it possible for the student to take the job. Alternatively, PIs who are only mindful of their own gain, would see fit to deny the student's request since they benefit from the continuing work of the student.

The new normal for twenty-somethings in the industrial world is to switch jobs every two to three years to seek out additional responsibility and reward. Although the lack of loyalty from

employers to employees is much decried in the private sphere, its corollary is increased *churn* and opportunity for job-hopping. A PhD program is the opposite of this.

Although a student always has the option to walk away from a PhD program, in reality, additional considerations often prevent that from happening. A fifth year PhD student already has so much skin in the game that walking away is really only considered in the most dire of circumstances. Acquiescing to a seven-year PhD is less painful, seemingly, then walking away at five with nothing. Circumscribing this bit of game theory, there is the difficulty of explaining a five year resume gap with no degree to show for it. So, PhD students end up pretty locked in, and this opens the door to coercion along the lines of “oh, I really don’t think you’re ready to graduate yet”.

Graduate Students Have Few Rights, and No Guarantees

Graduate school is definitely more like a job than ‘school’ in the usual sense. But it’s also not a job in some important, structural ways. There is some precedent for the notion that graduate students deserve the protections that are common to all employees--see the supreme court in 1972. (*Adelphi University and Adelphi University Chapter, American Association of University Professors*) However, graduate students who are paid for conducting research are not classified as employees by their universities. Instead, euphemisms such as “Academic Apprentice Personnel” (AAP) are used. As a result, some of the basic protections of labor law like minimum wage and unemployment benefits aren’t extended to graduate students.

Some graduate programs standardize PhD student pay for their departments, and some don’t. Some publish their salaries online and some don’t. There’s no national standard. Unfortunately, too many potential PhD students don’t think about money, or think it’s gauche to ask about stipends. And unfortunately, they can fall through the cracks, ending up with less than a living wage, or nothing at all.

Tradition Creep

It might be a truism that any tradition not formally enforced will eventually be abandoned out of opportunism. One example, the US Senate filibuster as a truly last ditch effort, meaning most legislation would pass with a simple majority. Mostly, the filibuster would be used in only truly desperate, last-ditch efforts, and they required senators to stand before their legislative body and speak. In 1975, the senate introduced rules that allowed for a ‘virtual filibuster’ in which senators could invoke cloture, to filibuster a bill, without physically needing to stand before the senate. The new rule required a three-fifths majority to break cloture.

For a while, little changed, and cloture was still invoked relatively rarely. For the moment, tradition, and a respect for the lawmaking process, prevented . However, the low cost of invoking cloture, and the strategic advantage it conferred, by making a 60% majority necessary to pass a bill, gradually eroded the traditional hesitance to invoke cloture. By the mid-2000s,

filbustering, even on routine bills, became commonplace, effectively raising the bar for passage of legislation from 50% to 60%. Thus, the minority party was always able to prevent passage of legislation, provided they had .

The traditional filibuster, which once existed as a safeguard to democracy, was abandoned out of of rule change for expedience. The old traditions, probably imagined as sufficient safeguard by the senators serving in 1975 during the rule change, proved no match for the relentless march of self-interest.

https://en.wikipedia.org/wiki/Filibuster_in_the_United_States_Senate

PhD Admission 'Battle Royale'

A tradition that many graduate PhD programs follow is to guarantee all admitted PhD students a funded position in the department. Many departments make this guarantee ecause it is what is expected, but also probably believe that it will allow them to recruit talented students and foster a healthy environment. This guarantee allows for peace of mind in the students, since after all, committing to a graduate school program is no small decision. Many students move across the country or across the world upon admission to a graduate program. Thus, a guaranteed funded position makes life more predictable for admitted students. This fosters an environment of stability and trust, and a reputation that inevitably follows.

However, a small, but substantial fraction of graduate programs have decided to abandon guaranteed funding, and institute what I call a 'battle royale' policy. For the admitted PhD students, they may or may not be notified of this policy ahead of entering graduate school, and may or may not move across country under the impression that they are guaranteed funding. What happens once the PhD students are enrolled is an all-out brawl for the limited number of funded positions.

Funding decisions in this context are usually made by individual faculty, who decide to grant funded positions in an independent, ad hoc way based on who they believe will effectively carry out their research program. As a result, students must get a funding commitment very early on, either before the beginning of classes in the first year, or early in the first year of the program. It is unlikely that a funded position would become available after that point. For the lucky students who get funded positions, tuition charges are covered, and a stipend is also paid (more on this later).

So what happens to the poor souls who end up without a funded position? They are charged tuition, certainly for the first academic term. This can amount to up to $10,000 in many cases for only one term, particularly if out of state charges apply. Students, who feel ashamed at not getting a funded position, and wanting to salvage something from their misadventures in graduate school, may even stay for a Master's degree totaling one or two years, ending up costing tens of thousands of dollars. All this for unaccredited college courses, likely not much

different than what they learned in their undergraduate degree. I don't know how this can be described except as a vicious, risible scam.

The battle royale policy seems closely linked to engineering programs, rather than those in the basic sciences. This is partly driven by the perceived desirability of an engineering Master's degree for general career prospects. In some programs, entering PhD and Master's students are tracked together. Some engineering departments exploit this by overadmitting substantially for this combined track, distributing a limited number of paid positions by opaque means and tracking the rest into the Master's bin, charging hefty tuition along the way.

Factors allowing for 'battle royale'

What allows this to happen? There are a few factors that allow this to happen. First, in comparison to normal employment situations, there is little to no legal protection for graduate students. In normal employment situations, a new prospective employee is likely to get the formal protection of an offer letter or equivalent document. This document has significance in legal proceedings where an employee can fight against unfair treatment such as changes to terms of employment, or outright retraction of employment offer. In contrast to this formalized procedure, admission to a PhD program never, or rarely, includes a formalized listing of tuition remission or stipend amounts. This is true *even if* the admitting department does provide funding for all admitted PhD students. Stipends in guaranteeing departments, while usually adhered to, are often done so in an informal, internalized way with little transparency.

Closely linked to the lack of formal acknowledgment of funding intentions from the university, there is, as was alluded to earlier, a profound asymmetry in information and commitment between PhD student and admitting department. The department has all the information about the availability of funding, the presence or absence of a funding guarantee, the likelihood of funding, the level of funding, funding mechanisms and other relevant information about life in the department. The student, to the degree they are aware of any of this, are likely relying on second-hand information and without perspective on how these factors will affect a half-decade or more of their life spent in the department.

Further, the commitment a graduate department has to a PhD student is non-existent. PhD students are admitted en masse, making little distinction between individual students. The process often does not even include an interview, resulting in a fungible mass of laborers, who are paid very little. The students, on the other hand, make profound commitments, including terminating existing employment, moving across the world and more. This asymmetry of commitment means departments have much more power in dictating the terms of study--after a student has committed, there is no leverage.

All of this, of course is made worse by the two key factors I identified in Chapter 1, the static nature of the graduate student labor force, and lack of upper management presence on issues of graduate student treatment. As usual, a static labor market weakens feedback mechanisms

that might otherwise correct these problems. Mistreated graduate students are unable to leave, without throwing away years of life and effort. Upper management might presumably have a stake in issues which will affect the long-term success and culture of the institution. I have no doubt that if the various deanlets wanted to make mistreatment of graduate students a priority they could. However, the realities of graduate student life are so far removed from their perception that the abuses are either never seen or not believed to be common.

Battle Royale Forms a Vicious Cycle With High Attrition

The battle royale policy is a reaction to, but also probably contributes to the high levels of attrition in US research PhD programs. As I've touched on earlier in the book, attrition for PhD students is high. Only about 55% of students who begin a PhD actually finish it, less for certain majors. Why invest a guaranteed stipend in a student who probably won't finish anyways? By the same token, when admitted PhD students who may have believed they had a solid research position find out that they are fighting over spots in a lifeboat, they may just give up.

Engineering vs. Basic Sciences

Among the technical research departments offering PhD programs, there is a distinction between the basic sciences and engineering departments. Basic sciences encompass physics, chemistry and biology departments. Physics tends to have its own sort of culture, along with Math and astronomy. But chemistry and biology make up the core of academic culture. Basic science departments tend to have a more traditional view of scientific research. The research programs tend to be more older, more developed and comfortably inhabit a corner of the scientific world. They don't reinvent themselves overnight to chase the latest trends. Additionally, basic science departments, especially those in biology and the life sciences, tend to have a more humane and benevolent attitude towards their students.

Engineering departments encompass anything with 'engineering' in the title, including civil engineering, electrical engineering, chemical engineering and so on. These departments tend to be newer, more entrepreneurial, and more willing to adapt and change identities. The research doesn't necessarily fit into traditional categories and tends not to ask fundamental, but applied questions. Additionally, it tends to be the engineering departments that most push the boundaries of funding schemes for PhD students. In particular, the battle royale policy seems to be mostly concentrated in engineering departments.

What do grad students actually get paid

Is there a good way to get a handle on what graduate students are actually getting paid around the country? The best that I have found is the salary aggregator and workplace review website Glassdoor. Glassdoor pegs the average salary for 'Graduate Student Researcher' at $28,420 (2014). This number is well below the average for full-time workers in the US ($41,000), but I

don't find this number particularly outrageous, since there are a few other benefits of being in graduate school.

First, graduate students are eligible for loan deferment, delaying the the accumulation of interest on prior education debt. Second, graduate students may get health insurance benefits worth a couple of thousand dollars per year which aren't included in the base salary. Finally, I have already mentioned that I believe graduate school to be a trade-off. The trade-off is: accept a lower salary in return for the chance to pursue pure knowledge. The aggregate number for pay reported by Glassdoor is a living wage, and I don't think it's outrageous that the average graduate student researcher earns around $28k.

So it's not the aggregate that's outrageous, but rather the outliers. The fact that there's no guarantee for pay means that many stipends may fall well below the national average. The survey conducted by *Nature*, unsurprisingly, confirms that in fact, many graduate students get lower than the average, sometimes alarmingly so. For example, graduate students in the US who originate from other countries report a tidy bell curve of salaries, centered around $25,000. This roughly correlates with what we know from Glassdoor, and the fact that these students originate from other countries indicates that they are likely PhD students. (data is not available for native-born PhD students in the US. For all students attending *any* graduate school in their country of birth, there is a large fraction reporting no stipend, likely because of a high representation of Master's students, who typically receive no stipend.)

However, closer analysis shows that 28% of these students receive less than $21,000 and over 10% receive less than $15,000. For science PhD students who often work full time and more, that level of pay would fall below the federal minimum wage of $7.25/hr. The status of graduate students as 'not technically employees' means that federal minimum doesn't apply and this would all be perfectly legal.
http://www.wagehourinsights.com/higher-education/when-are-student-assistants-employees-under-the-flsa/

Working hard? Hardly working.

Although in some ways reflective of the US attitude towards work in general, in many academic labs there is an especially strong desire not to be perceived as not working hard enough. This results in many graduate students working long, but often unproductive hours.

It's hard to pinpoint decisive evidence of this tendency to unproductively overwork in grad school. There are no surveys of hours worked for grad students. There are no nationwide societies or unions of grad students which might track such concerns. Although extensive surveys of graduate students are undertaken by the NSF, they don't include questions on working hours or working conditions. However, the idea is everywhere in academia. It's a constant undertone in every US lab I've ever heard of. Further, the idea is pervasive throughout

cultural and social media outlets related to grad school. Thus, let us undertake an "anthropological study", of sorts, of the working habits and culture of grad students.

Let us start with the longstanding webcomic, *PhD Comics*. A 17-year project of Caltech neuroscientist Jorge Cham, *PhD Comics* (also known as *Piled Higher & Deeper*) has been satirizing the lives and habits of graduate students since 1997. It has a lot to say about the work habits of graduate students.

Dr. Cham has written over 1,700 comics about characters who occupy various positions in academia from grad students to post-docs and professors. He often finds humor in the long, futile hours spent in research and away from family and friends. One example of this is a series of strips about a support group for "grad school widows". That is, significant others of grad students who are "widowed" becauses the objects of their affection spend too much time in lab. In one strip, a character says in the first panel: "I try to be supportive and encouraging to my husband about taking his time to graduate…" which continues on the second panel as the character becomes noticeably agitated "...but he spends all day surfing the web or sleeping!!" This notion of aimless, extended work hours is a constant theme in *PHD Comics*--and in grad school.

http://www.phdcomics.com/comics/archive.php?comicid=1773
http://www.phdcomics.com/comics/archive.php?comicid=409 (Grad Student Widows)
http://www.phdcomics.com/comics/archive.php?comicid=784 (Oh Yeah)
http://www.phdcomics.com/comics/archive.php?comicid=1078

Another cultural outlet devoted to making light of the lives of graduate students is the Tumblr account "What Should We Call Grad School". The Tumblr account consists of animated GIFs accompanied by short titles which are meant to describe or resonate with some aspect of graduate student existence.

One post is titled "When I Make a Mistake on My Experiment at 2am". The GIF features a robot-like figure which cries and then collapses onto the floor and falls asleep. This illustration of the counterproductivity of greatly expanded work hours is almost too perfect.

http://whatshouldwecallgradschool.tumblr.com/post/120877021316/when-i-make-a-mistake-on-my-experiment-at-2am
http://whatshouldwecallgradschool.tumblr.com/post/117934700808/6th-year-of-grad-school
http://whatshouldwecallgradschool.tumblr.com/post/116844958892/trying-to-leave-work-early

This culture, as always, is set at the top by the PIs. Another example, this time from real life, is a typed letter on Caltech letterhead from a Professor Erick Carreira to a lab worker named Guido. The letter is now infamous for the sentiments it espouses, but is revealing of a deep-seated lack of boundaries in academic culture. Excerpts from the letter:

*"...I expect all of the members of the group to work evenings and weekends. ... I have noticed that you have **failed to come in** to lab on several weekends and more recently have failed to show up in the evenings. … I expect you to correct your work ethic immediately. ... I receive at least one post-doctoral application each day from the US and around the world. If you are unable to **meet the expected work-schedule**, I am sure that I can find someone else as an appropriate replacement for this important project."* (Emphasis mine)

(http://www.chemistry-blog.com/2010/06/22/something-deeply-wrong-with-chemistry/)

I have chosen to emphasize key phrases which show that the Professor's concern is not with research productivity, which in fact is not mentioned at all in the letter, but with hours present in the lab. The culture of long, unproductive hours is not unique to graduate school, but in an environment which is nominally about mentorship, learning and discovery, it's a glaring inconsistency.

Is there another way?

However, it's not at all clear that such long hours are necessary or even helpful for scientific output. On the other hand, it's certain that the culture of long hours and low productivity are powerfully destructive to curiosity and discovery. Further, they push a lot of people out of academics. Uri Alon is a world-renowned systems biologist and an advocate for a saner, more creative scientific work philosophy.

He has hosted a series of "theory lunches" in which he invites academics to join him in a discussion of various scientific topics. One of these theory lunches was held on Friday, May 16th somewhere in Boston. His talk ended up on YouTube, and I've excerpted from it:

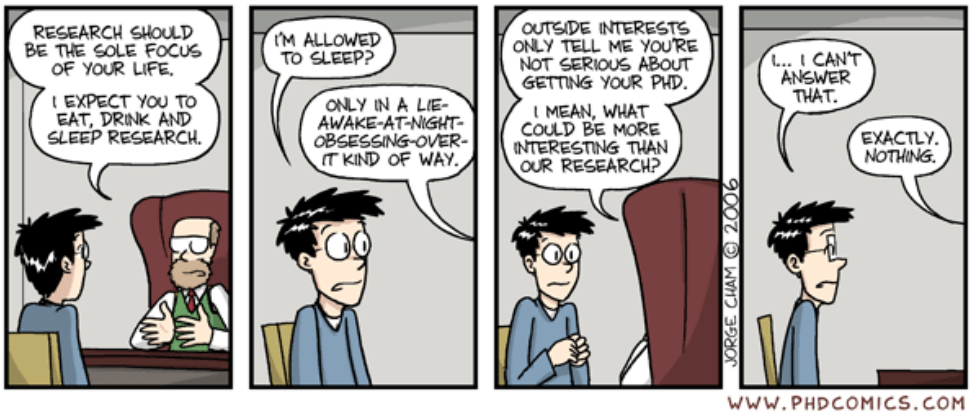
"But when we think about our scientific profession, we spend 10,000 hours learning math, biology and physics, but not one hour, usually, talking aspects of the scientists' lives here--the practice of science. So, it's under the table. That doesn't mean it doesn't exists--it just means it's not discussed. What are the implications? ... It's not valued in our profession, for example, how good a mentor you are, how many postdocs' lives you burned to get a result [there is laughter, but Uri's face is serious]. It doesn't matter for promotion or getting grants. It's not valued in our profession."

https://www.youtube.com/watch?v=iJsOSxD2XUs

I've seen firsthand the disregard that Prof. Alon mentions and it applies equally to graduate students. Prof. Alon has made it a mission to promote better mentorship, giving talks at academic conferences and even for general audiences at venues like TED. For that, I commend him.

Codification of disregard for graduate students

As we've seen, the culture of long hours comes from the top. Even beyond that, there is a desire by PIs to control the lives of their students, even outside of their expansive work hours. Again there is little conclusive evidence of this--but the notion is everywhere in academics. From *PHD Comics*:



Chats surprisingly like this one happen frequently between PIs and their underlings in real life as in fiction. However, it's not just informal chats like these where PIs claim ownership over students' personal time. Universities and PIs have gone so far as to formally claim the right to police their students' personal lives in written university policy:

From Stanford University Research Policy Handbook 10.6: Relationships Between Students (Including Postdoctoral Scholars) and Outside Entities:

" It is, however, appropriate for students' academic advisers to monitor their academic performance, and if inadequate, to inquire about the students' outside activities and to recommend that students reduce or terminate their outside commitments."

(https://doresearch.stanford.edu/policies/research-policy-handbook/non-faculty-research-appointments/relationships-between-students)

It's remarkable that academic advisers would seek such a level of control over graduate students, who aren't even their full employees. It is unlikely that even an employer would seek such control over their subordinates. This policy betrays a profound lack of respect on the part of PIs and administrators for the autonomy and independence of graduate students.

PI abuse

Isaiah Hankel, founder of the Cheeky Scientist Association, has written extensively about the abuse he endured from his PI. On cheekyscientist.com, he writes:

‘ “I’m the boss, get it? Do what I say or get out of my lab.” I can’t remember how many times my academic advisor said this to me. He didn’t just say it to me. He yelled it.’

Such high-strung antics may not be uncommon in the very highest halls of power in fields like high finance. However, when the stakes are lower, and in an atmosphere that is supposed to include mentoring. Again, there is no oversight of the management style of professors. Nor are professors ever screened for or trained in management skill. They either make it or not purely on the impact of the research they publish.

Hankel went on to write:

“The following year my advisor did everything he could to push me out of the lab and prevent me from graduating. He pitted others in the lab against me, deactivated my key card, and tried taking my name off of papers in press. He yelled at me and threatened me on a weekly basis. I had to have multiple meetings with my Department’s chair and with various Deans just to get my degree.”

This level of abuse is above average but not unheard of.

(http://cheekyscientist.com/academic-advisors/)

Sexual Harrasment

http://www.theatlantic.com/science/archive/2015/10/sexual-harassment-geoff-marcy/410089/
http://www.huffingtonpost.com/entry/grad-students-sexual-harassment_us_57714bc6e4b0dbb1bbbb37c7
https://www.theguardian.com/commentisfree/2013/aug/09/academia-winning-sexual-harassment-complaint

The abuse of graduate students and other academic workers can go beyond bad work environments, long hours, withholding pay and the overall casual disregard I’ve described so far. It can extend to sexual harrassment, in the form of unwanted sexual advanced or other behavior from supervisors. It’s understandable that these cases don’t always get publicity because of reluctance to come forward etc. However, universities also put these concerns under wraps to protect their reputations.

One recent case that did eventually get publicity is the case of Geoff Marcy, an astrophysics professor. In 2015, an investigation by UC Berkeley found that had sexually harassed multiple women in events spanning at least a decade. In fact, this pattern of behavior stretched back at least as far as 1995, when the San Francisco State University sexual harassment officer reported getting complaints. The 2015 case developed over the weeks following the investigation and outrage grew to the point where Marcy resigned all of his academic positions.

Sexual harassment happens in workplaces of all kinds. However, there are some factors that can make it particularly egregious and burdensome within the academic context.

First, it seems that there is a general ability for people in general to see companies, especially big companies, as a ‘bad guy’. This comes from media portrayals and a general consciousness of these companies as powerful organizations willing to harm individuals to protect their interests. However, universities tend to be seen more positively, as places of aspiration, learning, growth and personal fulfillment. Thus, it can be harder to build the sort of media attention/public outcry against a university to prosecute the sorts of in-depth investigations that are required for attention to be paid to these cases.

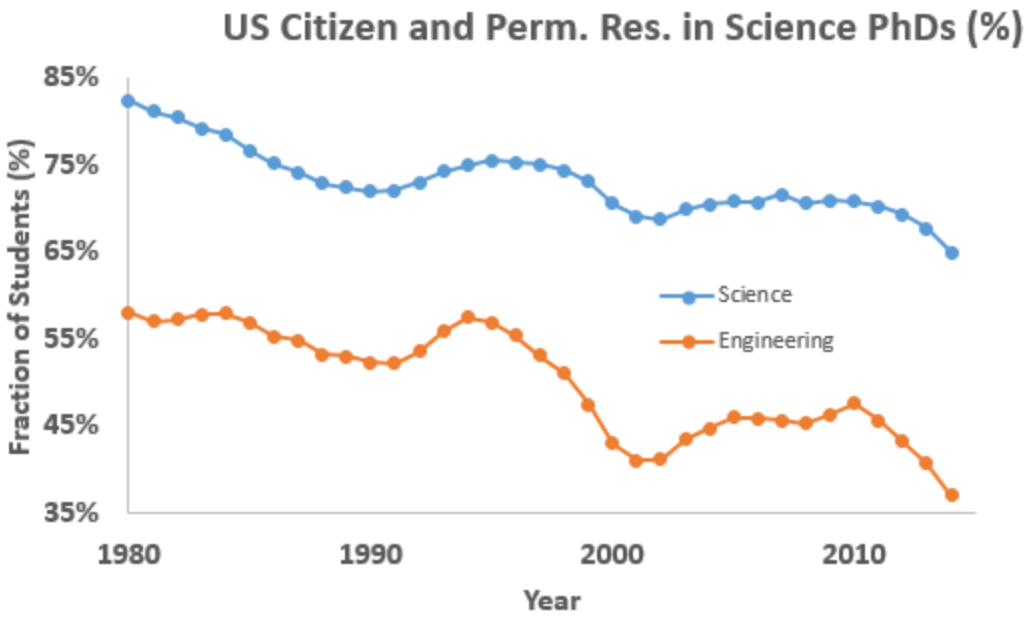
Secondly, as I addressed earlier in the book, there is a massive power disparity between graduate students and advisers. An individual graduate student has almost zero sway within a university, while a faculty are important, significant contributors to revenue. Faculty often make 3-10x more in pay than their direct reports, the graduate students. A power disparity this dramatic between direct reports and supervisors is less common in other sectors. In an allegation of mistreatment against a faculty by someone low-level like a graduate student, there can be enormous pressure within university management to hush it up.

Chapter 5

Graduate School and Immigration

General Trends in Foreign Students in the US

Perhaps the most consequential factor in the macroeconomics of graduate school in the sciences in the US is the continued increase in the proportion of foreign graduate students. This trend is most pronounced among graduate students in engineering. In 1980, the proportion of full-time graduate students in engineering in the US who were citizens or permanent residents was 58%. By 2011, it had dropped to 43%, and by 2014 it was 36%. In the basic sciences, the numbers were 81% in 1980, and 65% in 2014. (NSF Graduate Student Survey 2014, tables 7 & 8)



In the popular press, this is often taken as a sign of weakness in the American engineering or science education system. Quite the opposite is true however. American engineering bachelor's degree holders are among the best-positioned degree-holders in the job market. While 14% of the american labor force at large is foreign born, only a modestly higher percentage, at 19%, of bachelors degree-holding professional engineers are foreign-born--compare this to the 64% of PhD students in engineering who are foreign nationals.

An alternative explanation is that American-born bachelor's degree-holders find the meager rewards of graduate school to be not very compelling in the context of a job market which pays quite well, particularly for engineering degrees. Further, their relative competitiveness vs. foreign-born engineers is higher in the context of industrial work, where the job requires a higher degree of collaboration with English-speaking co-workers. In contrast, academic work is highly

independent, requiring little contact or co-operation with co-workers. Thus, the weaker language skills of foreign-born engineers is less of a disadvantage in the academic world. Probably the most significant factor though, is the fact that student visas are unlimited, and can often act as an entryway into the United States.

The US as an Immigration Destination

The US remains a highly popular destination for international migrants. 150 million adults worldwide (http://www.gallup.com/poll/153992/150-million-adults-worldwide-migrate.aspx) would move to the US if they could--more than 6 times higher than 2nd place UK. That's 23% of adults globally who would leave their country if they could, and 2% of *all* adults worldwide. However, the reality of US immigration policy is that there's almost no way in, unless you happen to be quite wealthy. The big exception to this of course, is education, and in practice that means graduate school in science and engineering. It's possible to get extended, and in some cases, effectively permanent residency in the US through the student visa system. Student visas are quite easy to come by, and unlimited, with no quotas.

The Visa Process

The appeal of graduate school for foreign students is strongly driven by the underlying structure of the US immigration system. H1-B visas are granted to foreign workers for jobs which can't be filled by American workers. H1-B visas are frequently in the news, usually because of arguments over what the cap on H1-B visas should be (currently it is 65,000 per year). Foreign students who come to the US for graduate studies don't have to worry about such a cap, because for F-1 student visas, there is no cap, no quota.

After graduation, there are several methods for students to stay in the US. For postdoctoral scholars at universities.

The F-1 visa, which all foreign students obtain, allows for a 12 month extension of the F-1 after graduation under an "Optional Practical Training" (OPT) provision. An additional 17 to 24 months is available for F-1 holders who graduated with a STEM degree. This grants about three years to any foreign masters or PhD graduate in which they are free to legally work for any US employer without any additional approval.

Additionally, many PhD graduates are eligible to apply for the O-1 or extraordinary alien visa, which is meant for 'the individual who possesses extraordinary ability in the sciences, arts, education, business, or athletics'. Anecdotally, this visa is granted to researchers whose Google Scholar citation count exceeds 50.

Finally, is the green card process, which finally allows for permanent legal residency in the US. Many PhD graduates begin this process as postdoctoral scholars

https://www.uscis.gov/working-united-states/temporary-workers/o-1-visa-individuals-extraordinary-ability-or-achievement
https://www.uscis.gov/green-card/green-card-through-job/green-card-through-job-offer

Without judging the merits of these programs one way or another, they provide a path, more or less, to work and live in the US upon completion of a graduate degree program. This is hugely consequential for the incentives at play for foreign PhD students.

Grad School Is Becoming Ghettoized

I don't advocate a cap on F-1 visas. Science has long benefitted from the spirit of international collaboration, and that remains one of the few true bright spots having to do with academic science in the US. But I do think that the lack of a cap has facilitated the erosion of working conditions in academic science. This is perhaps partly because foreign students aren't aware of the realities of academic science in the US before applying and enrolling. More likely, it is because their residency in the US is contingent on retaining student status.

This means that they have an additional incentive, or carrot, to put up with grad school that US citizens don't. Despite all the pain, graduate school is often a road to essentially permanent US residency for foreign students. In 2011, the 5- and 10-year stay rates of foreign-born earners of PhDs in science and engineering at American institutions was 68% and 65% respectively. In other words, of the US 2006 class of graduating science and engineering PhDs, 68% of those who are foreign born were still in the US in 2011. A slightly lower fraction, 65%, of the cohort of 2001 PhDs resided in the US in 2011. Thus, by a variety of routes, graduate school is often a path to long-term immigration.

As I've described throughout, the work conditions in graduate school are cratering. At the same time, the chart above shows that US citizens are fleeing the academy. Thus, in a way not so different from farm labor, science, and particularly academic science is becoming ghettoized as American citizens flee due to the poor pay, working conditions, and reduced legal recourse. While career prospects might be brighter for PhD scientists than farm laborers, it can require a decade-long odyssey, struggling through a 5+ year PhD as well as one or more postdoctoral positions.

https://www.uscis.gov/eir/visa-guide/f-1-opt-optional-practical-training/understanding-f-1-opt-requirements

Susceptibility to Fraud & Abuse

The sad truth is that foreign-born graduate students are probably much more vulnerable to an abusive system of graduate education than native-born students. The desire for adults worldwide to come to the US is real and massive. With that kind of an animating force, foreign-born students are more willing to put up with the difficult realities of graduate studies in

the sciences. The benefit of finishing a science or engineering PhD is just so much greater for foreign-born students in comparison to native-born. The chance of staying in the US without a finished PhD is certainly much lower. If they get a bad or abusive boss, there are just fewer options for recourse. Quitting becomes much more costly when so much of your future is at stake. How much can you really do to protect yourself from someone who controls not only your paycheck, but also your continued residency in the country you want to live in?

In addition to straightforward abuse of foreign graduate students, there is abuse of the student visa processes by new 'universities'. These fake universities exploit the affordances made for students, such as the F-1 visa and OPT status. Buzzfeed investigated an institution called Northwestern Polytechnic University. They found that its student population is 99% foreign and they have no full time instructors. The main function of NPU, it appears, is as a conduit for foreign labor in Silicon Valley.

As universities continue to evolve, it's likely that the line between legitimate and fraudulent will become increasingly difficult to parse. As pressures creep in from online courses, budget cuts, and an increasingly unwieldy bureaucracy, the university lobby will have to more forcefully defend their special visa statuses.

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