The Journal of Undergraduate Neuroscience Education (JUNE), Summer 2018, 16(3):A203-A209

ARTICLE
Demystifying Graduate School: Navigating a PhD in Neuroscience and Beyond

Linda K. McLoon[1,2] and A. David Redish[1,3]
[1]Graduate Program in Neuroscience, [2]Department of Ophthalmology and Visual Neurosciences, [3]Department of Neuroscience, University of Minnesota, Minneapolis, MN 55455.

The decision to apply to a PhD-granting graduate program is both exciting and daunting. Understanding what graduate programs look for in an applicant will increase the chance of successful admission into a PhD program. It is also helpful for an applicant to understand what graduate training will look like once they matriculate into a PhD program to ensure they select programs that will help them reach their career objectives. This article focuses specifically on PhD programs in neuroscience, and while we use our program, the Graduate Program in Neuroscience at the University of Minnesota, as an example, most of what we describe is applicable to biomedical graduate programs generally. In order to ensure that our description of graduate programs is typical of neuroscience graduate programs generally, we surveyed the online websites of 52 neuroscience graduate programs around the U. S. and include our observations here. We will examine what graduate schools look for in an applicant, what to expect once admitted into a PhD graduate program, and the potential outcomes for those who successfully complete their PhD in neuroscience.

Key words: graduate program, PhD

What Makes a Strong Application to a PhD Program in Neuroscience

Research

A number of years ago, our Graduate Program in Neuroscience at the University of Minnesota performed a statistical analysis of what correlated with successful completion of our PhD program. Consistent with more recent analyses (Weiner, 2014), we found that the strongest correlation was if the applicant had done research outside of the classroom setting. Given those results, at this point, our admissions committee will only consider applicants if they have some research experience. However, in our experience speaking to undergraduates, we find that undergraduates tend to underestimate how much research they've done. This issue of what counts as "research" appears to worry many applicants, who often feel that they have not done sufficient research to meet this requirement.

The most useful research experiences are not necessarily those which result in publications, or even those which find statistically significant answers. Rather, the most useful research experiences are those in which an applicant contributes to the research being performed, which involve grappling with questions which do not have known answers in the back of the book. These experiences are generally performed outside of a regular classroom setting, but a wide array of experiences can fulfill this research prerequisite. For example, an applicant might have done one or more summer internships in a laboratory. Others may have done a directed research project that was taken for academic credit but whose sole purpose was to perform independent research. Others may have done internships at companies. We often see applicants who have worked in laboratories or done independent original research projects in the context of their specific coursework during the school year. These courses are becoming more common, and these independent research-focused undergraduate classes can be great examples of independent research if the work provided the applicant with experience in doing research directly.

Some colleges do not have strong research opportunities available. Students in those situations should reach out to summer or other internship programs at other universities to gain that research experience. There are many such research programs. For example, the University of Minnesota runs a Life Sciences Summer Undergraduate Research Program (LSSURP) that provides such opportunities across many fields in the life sciences (including neuroscience). Many universities have Research Experience for Undergraduate (REU) programs available that are funded by the National Science Foundation (NSF). These programs usually pay a summer stipend and living costs as well as providing research experiences.

However, it is not necessary for the research to be done in a formal setting. What matters is that the applicant has some experience with direct research. Similarly, the duration of the research done is not as critical a concern as having had the experience of performing research at all. The key question is: *Does the student have real-world experience in doing research, and in spite of methodological difficulties and negative results in experiments, does the applicant still have a love for the scientific process?* It does not matter if there were no conclusive results, if the project was left unfinished, or if the project was not published as an abstract or peer-reviewed publication.

While coursework in a graduate program is important, the "real" work of a graduate student is to learn to do science. The research experience demonstrates to the admissions committee that the applicant has a realistic sense of what it is like to work on an open-ended problem, which takes innovative thinking about experiments and controls as well as understanding the need for patience with the scientific process. It is important that both the applicant and the admissions committee know that if admitted, the applicant will not be surprised by the focus of graduate school on independently performed research.

Personal Statement

The personal statement is one of the most important aspects of an application to a graduate program. There are three main areas that need to be included in a personal statement, and if these are inadequate, it will have a negative impact on the ultimate success of that application. First, and most importantly, a personal statement must make it clear why that applicant wants to pursue a PhD in neuroscience specifically. A broad flowery description about the applicant's interest in biology since they were 5 years old is not helpful. This statement is easier if the applicant has some laboratory research experience and can speak to why that research experience was motivating. A clear articulation of "why neuroscience" is imperative.

As noted above, the most important information in an application is the research done by the applicant. Thus, the applicant needs to provide a description of the independent research they have performed to date somewhere in the application. The research description should focus on the big picture: *What was the big question? What choices were made in the experiments? What controls were done? Why were the specific controls used?* The applicant should do this for each distinct research project. This shows the admissions committee how the applicant thinks about science; understanding the process is more important than if there were positive results.

The final part of the personal statement should state why they are applying to the particular program. A good way to show that the applicant has spent time looking at the specific graduate program and has thought about which programs were a good fit for their interests is by identifying programmatic strengths, such as the expertise of the faculty, or by identifying other specific or unique aspects that differentiate the program, such as, for example, our Itasca program [see below].

Finally, applicants should proofread their personal statements. Typographic errors, poor grammar, and other sloppy writing suggest an applicant who does not take the time or effort to ensure quality. It may seem silly to mention, but it is important to make sure that when mentioning programmatic strengths, the applicant should be sure that these are the programmatic strengths of the institution to which the application is sent.

Majors, Grades, and GREs

Neuroscience encompasses many different disciplines – from genetics and subcellular approaches to neural circuits and behavior. Most neuroscience graduate programs admit applicants with a broad variety of majors. Many of the applicants that we see majored in neuroscience, biology, or psychology as an undergraduate, but applicants with other undergraduate majors such as math, computer science, or physics have succeeded in our program. Many programs also admit applicants with degrees in the humanities, and we have found that many students with these broad backgrounds have succeeded in our program, some of whom only developed an interest in neuroscience after they graduated from college. However, successful applicants from the humanities need to have taken classes in the sciences before they apply to graduate school for a PhD in neuroscience.

The most important statement that we can make about grades is really in terms of the specific classes taken. While the major area of study is not critical, an internal survey of our program found that trainees were most successful in our PhD program if they had taken at least some biology, some physics, basic chemistry preferably through organic chemistry, and college level mathematics through calculus.

In our survey of over 50 graduate programs in neuroscience, most programs do not seem to have a strict GPA cut-off under which they will not admit someone; nevertheless, GPA is an important criteria being used by many admissions committees. While overall GPA is important, students who did poorly in their freshman and sophomore classes, but did well in their junior and senior years, can excel in their PhD training. Another example might be someone who had a very bad single semester or year due to extenuating circumstances, such as an illness of a death in the family. If one of these scenarios applies, it is imperative for this to be directly discussed in the personal statements that accompany a graduate program application. While most admissions committees do not explicitly rank schools, expected difficulty of the undergraduate program is usually taken into account when looking at grades, classes and GPA.

The use of the Graduate Record Exam (GRE) in making admissions decisions to a neuroscience PhD graduate program is a complex issue and has become controversial in recent years. Although many recent studies have claimed to suggest that GRE scores do not correlate with successful completion of a PhD degree in the biomedical sciences (Hall et al., 2017; Moneta-Koehler et al., 2017), other studies examining PhDs in more quantitative disciplines, including neuroscience, found that the portions of the GRE score are in fact correlated with successful degree completion (Willcockson et al., 2009; Olivares-Urueta and Williamson, 2013). In a large meta-analysis of GRE scores and success in graduate school, Kuncel and Hezlett (2007) found that both the GRE and undergraduate grades were effective predictors of important academic outcomes even beyond grades earned in graduate school. It should be noted that all of these studies have been performed on programs that took GREs into account when making admissions decisions and thus are based on biased data sets. Following this, some neuroscience graduate programs have elected to remove the GRE from their admission decisions, while others have decided to weigh it less in their decision-making. Most graduate programs recognize that the GRE score is just a tool, and one of many that admissions committees use to make their admissions decisions. Our graduate program, for example, is currently in the latter group—we still require it but are weighing it less than other factors such as the personal statement, classes taken, GPA, and letters of recommendation.

Letters of Recommendation

Letters of recommendation are some of the most important components of an application to graduate school. Who the student chooses to write for them and what those letters say are important factors considered by admissions committee members. The most important letters are those from research mentors with whom the applicant did independent research. A lack of letters from research mentors leaves open the question of the extent and value of that research experience. The best letters of recommendation are detailed and provide a clear indication that the mentor knew the student and can assess the student's potential for success. The mentor's comparison of the applicant's abilities relative to others with whom they have worked is particularly useful.

Letters from other sources, such as athletics coaches or course directors, can speak to initiative, time management, ability to work under stress, and so forth; however, most admissions committees do not find these particularly useful, unless the course director can speak to exceptional academic achievement, such as an undergraduate shining in a graduate class. Least useful are letters from non-academic sources, such as faith leaders, employers, family friends, and the like. These letters cannot speak to the questions of success in a graduate program and have been known to detract from an application, because it implies that the student does not have sufficient academic mentors to provide the full complement of letters.

Should letters come from postdoctoral fellows or graduate students? In many large laboratories, the primary professor may not actually interact with an undergraduate research assistant very much. Instead, undergraduate research is often done under the supervision of a postdoctoral fellow or graduate student. While letters from senior postdoctoral fellows are acceptable to some programs, they are not for others. We advise the applicant to check with each program to determine if this is an issue for their admissions committee. Our program has accepted students with one letter from a postdoctoral mentor, but we found that these students were not eligible to be nominated for some university-level awards. Thus, there is a balance in having the letter come from someone who worked with the student directly but also having the letter come from a faculty member. We recommend that undergraduates in these situations get a single letter that is co-signed by both the postdoctoral fellow and the professor or senior mentor.

The Admissions Process

Most graduate programs in neuroscience use a two-stage admissions process. The first stage identifies a subset of students to invite for an interview/recruiting visit and then a subset of those students is provided offers. All graduate schools in the U. S. have signed the Resolution Regarding Graduate Scholars, Fellows, Trainees, and Assistants from the Council of Graduate Programs which says that students have until April 15th to make their matriculation decisions. In order to try to manage this, schools will admit more students than they actually expect to matriculate, and may place other students on a waitlist, trying to balance issues of getting too many students, producing a problem for budgets, or too few students producing problems of cohesion, and problems meeting the research needs of the program and university.

Interview and Recruiting Visits

Some graduate programs bring students out either singly or in small batches to visit their program, interview with faculty, and see what possibilities could come from matriculating into the program. Other programs bring students out all at once as a cohort in a combined interview/recruiting visit. Many programs combine this interview/recruiting visit with other program events; for example, we tie ours to our annual retreat. The method of organizing these interviews and recruiting visits is not particularly important, as the goal of these visits is the same – to provide an in-person look at the graduate program.

From the program side, the interview/recruiting visit allows the admissions committee to assess the fit of the potential students and to ask specific questions related to how they think about science. It is important for visiting interviewees/recruits to realize that graduate programs often have graduate students contribute to the governance of the program and provide input to the admissions committees. In our program, two current PhD students are full voting members of the admissions committee. Comments made during events where only graduate students are present do matter, and we have had a number of experiences where comments and behavior at dinners or other trainee-only events have led to rejection of the applicant.

From the visitor side, this is an opportunity to see what the program is like, as well as the living environment where the program is located. Important questions that applicants should consider include whether the students are getting the training and support that they need, whether the faculty members are engaged with the program, and whether there are faculty members to work with in the student's area of interest. Generally, applicants should recognize that their goals, interests, and research directions may change. Ensuring that a program can accommodate those changes is an important thing when choosing a PhD program.

Choosing the Right Program

Graduate school, like most of life, is about finding the right fit. Every student is going to have to use their own judgement to determine which graduate school is right for them, but we have some suggestions about issues to consider.

First and foremost, *are there a sufficient number of faculty members in their area of interest?* Importantly, students should recognize that interests often change, either with experience or time or discoveries, so the student should also look at what other faculty members are around, and what opportunities there are to examine other research areas. For example, *how collaborative are the faculty? What processes are in place if one needs to switch advisors? Does the program do rotations in different laboratories, or does the student have to choose an advisor immediately?*

In our survey of over 50 neuroscience graduate programs in the U. S., all but one admit students into the program as a whole, rather than into specific laboratories. Students in the majority of programs spend the first year rotating through three or four different laboratories in order to get a thorough exploration of advisors and potential research areas. Furthermore, because students are admitted to the program as a whole and not into a specific laboratory, there are processes in place to handle the (rare) situation when a student needs to switch their primary research mentor.

An important consideration on picking an advisor is not only the research area of the advisor, but also the training and personal style of that PhD mentor. In our graduate program, we have 8-week rotations to give a student and an advisor sufficient time to determine if they can work together well. The duration of laboratory rotations varies between programs, but generally most programs have between 2 and 4 during the course of the first year. Choosing a PhD thesis mentor is not generally an issue of advisor quality, but rather one of style. *Should the student and advisor meet daily? Weekly? Monthly? Is the goal a thesis that is a hoop to jump through on the path to another career or is it a magnum opus on which one will build a reputation? How are manuscripts written? How does the laboratory decide which projects to do?* These questions do not have right and wrong answers, but a mismatch between styles can potentially make it difficult to complete the degree.

There are several other considerations. The applicant should examine the curriculum. *How comprehensive or specific is it? Does it cover what the student wants to have as their baseline/background?* Applicants should also look at publication requirements and expectations. *Are students publishing first author papers?* Trainee funding should also be evaluated. *How are trainees supported? Is funding guaranteed or not?* Part of the consideration relative to trainee funding is whether the program has training grants to help financially support students—these can include National Institutes of Health (NIH) T32 grants, and National Science Foundation (NSF) Research Traineeship (NRT) and Integrative Graduate Education and Research Traineeship (IGERT) training grants. Training grant support from NIH and NSF is a good measure of how the PhD training program is viewed by external reviewers. It is also useful to see if the trainees are successfully competing for fellowship awards. This speaks to the quality of the graduate students as well as the quality of mentorship from their thesis advisors and the program.

Other issues to consider are the environment and social climate of the program and the career paths the program's graduates take. In terms of social climate and environment, we suggest asking whether the trainees know and support each other, and whether the faculty members know the trainees. Science is increasingly a collaborative venture. Evidence could be the presence of co-mentored trainees, as well as research publications that are co-authored by members of the graduate program. Other evidence of the environment of a PhD graduate program is to determine how integrated the PhD trainees are in program decision making and leadership. *Do they serve on committees, and if so, what are their roles?* Self-reflective programs generally include multiple voices in making program decisions. This also speaks in part to mentorship of trainees, as participating in program governance provides the PhD trainee an opportunity to develop leadership skills.

In terms of outcomes, it is important to recognize that career goals change, but we recommend programs that provide opportunities for a variety of career paths. Importantly, programs should have processes that enable students to succeed in academia and elsewhere. As we will discuss in the following section, post-graduate paths for PhD trainees have always included a mix of academic and non-academic careers. This was also the recommendation of a workshop held by the National Academy of Science (IOM, 2015), and in fact reflects the actual career choices of individuals who received their PhD in neuroscience (Akil et al., 2016). Importantly, the career-space that our current graduates will face will look very different from previous generations. In particular, it will look very different from the previous generation when there were very few academic jobs available. The current career space is broader than it used to be, including some jobs, such as internet-related positions, that did not exist a generation ago. Furthermore, neuroscience academic jobs are opening up as baby boomers retire and universities invest in neuroscience. Whatever the student's goal is, we recommend looking for programs that provide career facilitation support for a variety of outcomes, because, as noted above, career goals may change with experience.

While many students and many programs will look at time-to-degree as a criterion for program quality, we feel that this can be misleading. No one has ever asked us how long we took to get through graduate school. One way to think about graduate school is to realize that graduate students in neuroscience programs get paid to go to graduate school – being a graduate student in neuroscience is a job, and one that should provide a living wage in the area that one will be living in during one's time in graduate school. The main problem with students taking too long to complete a degree is that it may indicate deeper problems in a graduate program, for example, when students are not graduating because their technical skills are needed in a laboratory. These situations are rare, but extremely long durations (e.g., 8 years) can be a sign to look for when making a decision. However, the difference between spending 4.5, 5.5, or even 6 years in graduate school is simply not important relative to the duration of a scientific career. In fact, there is a case to be made that taking an extra year to get additional publications can be a wise choice for students going into academic careers, since fellowships, awards, and other granting mechanisms, such as individual NIH postdoctoral training grants (F32) and individual NIH Pathway to Independence (K99/R00) awards, and the faculty level "early stage investigator" identifier at NIH, are based on date of graduation. Furthermore, few reviewers normalize number of papers by time spent in graduate school.

Additional Resources

The Society for Neuroscience provides useful resources to undergraduate students interested in a PhD in Neuroscience. One resource is the online training program directory that offers graduate program information on more than 75 top neuroscience graduate programs in North America, and provides a short summary of the characteristics of each program (e.g., number of faculty, student demographics, and research areas) along with a link to the program of interest. A second resource is available to prospective students who are able to attend the SfN annual meeting. Known as the Graduate Student Fair, it offers an opportunity for prospective students to meet face-to-face with representatives of many graduate programs.

The Gap Year Question

In recent years, we have seen that increasing numbers of applicants are taking a gap year between completion of their undergraduate degree and entering graduate school. We have not seen any correlation with success in graduate school from a gap year, and the Graduate Program in Neuroscience at the University of Minnesota does not require such a gap year. However, other neuroscience graduate programs have begun to require it. The gap year itself can vary, but often the recent college graduate enters a formal postbaccalaureate or “postbac” program, such as the one at the NIH, works in a laboratory, and participates in specific programs designed to increase readiness for graduate school. Many applicants have taken one or more years off from formal education to do research in an academic, government or industry setting. Whether a postbac year is useful or not is very much an individual choice.

There are two cases where a postbaccalaureate experience can be helpful for admissions into a neuroscience PhD program. One is when the undergraduate GPA is lower than a 3.0 or the student does not have the requisite science-related coursework. The other is when a student does not have sufficient research experience. Structured programs, such as the one at NIH, can be helpful in these situations. These postbac programs can provide an experience that is valuable for those students with limited research experiences. They can also provide opportunities for students who decide to transition to new fields late in their college career or after completion of their undergraduate degree. However, as noted above, in our experience, students underestimate their research experience and take gap years unnecessarily. To summarize, additional research training after a bachelor’s degree is not necessary for successful admission into a graduate program in neuroscience for the vast majority of applicants, nor does it appear to correlate with successful completion of the PhD.

What Trainees Can Expect During Their PhD Training in Neuroscience

A neuroscience PhD is a research-focused degree. This means that the student will spend the majority of their time as a PhD trainee working on research that can be published in peer-reviewed journals. However, that journey can look quite different from program to program. Most programs work through some structure that is a combination of coursework and early research exploration in the first years, punctuated by a written preliminary exam, followed by a thesis proposal, thesis research, and a thesis defense. In almost all of the programs we surveyed, the student is paired with an advisor that is the primary research mentor.

Throughout this section, we will use our program as an example and we will note where it differs from others. However, the general timeline is similar between programs.

Year 1

In August before our “official” school year actually starts, we provide a month-long hands-on, state-of-the-art research experience for all our incoming PhD students at a research station owned by the University of Minnesota at Lake Itasca at the headwaters of the Mississippi River. This program is unique in our experience relative to other programs, and it (1) provides a neuroscience background experience for students coming from diverse intellectual backgrounds, (2) binds the class together into a cohort which helps to provide a strong support system during the transition to and experience of graduate school, (3) begins the trainees on a journey from student to colleague. They then return to the Twin Cities to begin their formal year 1 experience.

In the majority of neuroscience graduate programs, students spend their first year doing two to four laboratory rotations with faculty who participate in the neuroscience graduate program and complete a set of core classes. The four core classes we require are Cell and Molecular Neuroscience, Systems Neuroscience, Developmental Neurobiology, and Behavioral Neurobiology. Other programs require other classes that might constitute a “minor” in a secondary subject, such as pharmaceutics or computational methods. At the end of the first year, many programs have students take a written preliminary examination that is focused on the integration of the material taught in the core first-year classes. Generally, programs use this sort of examination as a check to ensure that students have integrated the knowledge from their first-year classes. Students in most neuroscience graduate programs also take a class that provides training in research ethics, writing experiences, and other important non-academic components that will be necessary for a research career. Starting in the first year, it is typical that the program directors have annual or semi-annual meetings with every trainee in the graduate program. In later years, a thesis committee will also meet semi-annually with students to provide oversight and mentorship. Some programs we surveyed have separate committees that monitor student progress in the PhD program independent from the mentor and thesis committees. We advise looking for a program that will provide the trainee with regular evaluations and clearly defined milestones to help the student complete their degree in a timely manner.

Year 2

In year 2, students in the majority of graduate neuroscience programs have settled into a laboratory and are working towards writing their thesis proposal. The thesis proposal is usually the basis for the “oral preliminary exam.” In our program, we have students write their thesis proposal in the form of an NIH NRSA (F30 or F31) grant proposal which helps train students to write grant proposals.

Many programs have students take other elective classes throughout their second and sometimes even into the third year. In the second year in our program, students take one more required class, Quantitative Neuroscience that covers statistics, programming, and experimental design, but that then completes their class requirements. These types of quantitative classes are being introduced in many neuroscience graduate programs in response to the rigor and reproducibility issues that are being raised in the scientific literature and expected to be discussed as part of grant submissions to the NIH.

Most neuroscience graduate programs also have a teaching requirement. In our program, this occurs in the second year. Programs require different amounts of teaching, so this is a good question for the applicant to ask when they are interviewing. Many graduate students are interested in careers that include teaching as well as research, and additional teaching experience is important. We provide extra opportunities for teaching, where the trainee might run discussion sections or give course lectures. Often, these "extra" teaching experiences are paid beyond what the student receives from their stipend. For those interested in a more teaching-centric career, these experiences are very important. We recommend the applicant ask about how teaching expectations of the graduate students is handled in the programs to which they are applying.

Year 3 and Beyond

In the subsequent years, PhD trainees continue to do research, write and publish papers, present their work at conferences and in colloquia, and proceed on the journey to graduation. Graduate neuroscience programs generally have trainees meet with their thesis committee once or twice a year to ensure that they stay on track to graduation. The final stage, of course, is the thesis writing and thesis defense.

Presentations and Outreach

A key factor for a successful science career is the ability to communicate one's discoveries, both to fellow scientists and to the public at large. In our program, students are required to present their research annually to the other faculty and students in the Graduate Program in Neuroscience. These presentations are opportunities to learn how to present work to a friendly audience who will push one scientifically, but still provide positive support. In our experience, students are often very nervous giving their first colloquium, but confident by the time they are ready to defend their PhD thesis. The final PhD defense is a public presentation in which the student presents and defends their research. The specific aspects of the PhD defense are accomplished in different ways amongst PhD graduate programs; however, in the end, all PhD programs require that the student be able to publicly present their research in a comprehensive and cohesive manner as well as field questions about their research.

In addition, neuroscience graduate programs provide many opportunities for outreach beyond the scientific community, although most do not require outreach explicitly. Typical types of outreach in many programs include volunteering to present science at K-12 schools, Brain Awareness Week programs sponsored by the Society for Neuroscience, or science museums as examples. We have found that these opportunities provide students learning experiences in how to present scientific data and ideas to a broader audience. Not surprisingly, the ability to present ideas to a broad audience translates very well to communicating scientific results to other scientists as well.

It's a Job

We have found it useful for students to think of graduate school as a combination of college and career. Students should not have pay out of pocket for their PhD program. Most neuroscience graduate programs not only pay students a stipend but also provide tuition and health care benefits. For some trainees, conceptualizing graduate school as a job rather than as continued school can be important for dealing with family pressures to "get a job" rather than "continue in school."

Where to Go from Here

Fundamentally, the goal of a PhD program is to teach the student how to think critically and how to determine if a new discovery is real or illusion. An undergraduate program is usually about how to learn from books and from teachers, how to determine if the text in front of you is trustworthy or not, and how to integrate knowledge from multiple sources. A graduate program is about how to determine if the discovery you just made is correct when there is no answer in the back of a book for you to look up. In practice, this means learning how to ask questions that are answerable, how to design appropriate controls, how to interpret results and integrate them into a scholarly literature, and, importantly, how to communicate those discoveries to other scientists and the public as a whole.

These skills are useful in a variety of careers. Much of the discussion of graduate school outcomes has suggested that graduate programs are designed to produce faculty for colleges and universities and bemoan the fact that (1) there are too many PhD trainees and not enough faculty jobs, and (2) that many students are forced into "alternative careers." Both of these statements are wrong when one looks at the actual data.

First and foremost, we wish to point out that there should be no such thing as an "alternative career" — graduates should go towards a career and not away from one. We tell our students that we want them to do something important, whether that is becoming faculty at a research institution, teaching undergraduates at a liberal arts college, contributing to industrial research, analysis, or translation, becoming a writer and making research findings accessible to other scientist or lay audiences, or making policy in a governmental or non-profit setting.

Second, the complaints seen in many of these publications do not take into account very important demographic trends. Current students will see a very different world of faculty jobs than their professors did. Simply put, understanding the faculty situation requires considering the baby boomers (q.v. ACD biomedical workforce data). In 1980, a 35-year-old young professor was born in 1945, while a 65-year-old was born in 1915. This means that the generation of senior professors in 1980 consisted of those who had survived two World Wars and the Great Depression, while the junior professors were baby boomers. With the blossoming of investment in science after WWII, there were lots of jobs, and the baby boomers filled them quickly. Mechanisms were developed for new professors to get initial NIH grants to help them set up their laboratories (q.v. NIH History of new and early stage investigator policies). In contrast, in 2000, a 35-year-old was born in 1965, and a baby-boomer born in 1945 was 55, in the prime of their scientific career. There were fewer jobs and few funding mechanisms that focused on providing assistance for new, young investigators. In 2018, that baby-boomer born in 1945 is nearly 75 years old and likely retiring or retired. Thus, based on our own university as well as checking sources online such as Science Careers, there are faculty positions in neuroscience open all over the country. In addition, there are now specific programs at NIH to help new faculty get grants and transition into becoming successfully funded faculty quickly.

In practice, this has meant that there are many faculty positions for those who want them, at many different types of academic institutions. An undergraduate student who wants to take the next step into a PhD program should be encouraged to do so. PhDs have always gone on after their PhD to contribute to science in many ways. A recent survey published in Nature found that a scientific PhD had high value in the United Kingdom and Canadian job markets (Woolston, 2018). In fact, when we look at the distribution of careers our graduating students have taken since graduation, we find that the vast majority (96%) are engaged in important, science-related jobs.

However, the essential benefit of a PhD is that it teaches one how to think critically about the world around them. Life is long and careers are long, and the needs of both society and technology changes. It is critical to remember that many of the jobs people are doing today literally did not exist when we (the authors of this paper) were in graduate school. For example, it is now possible to make a living running an educational website on scientific topics that gets millions of hits per month, reaching thousands of school districts around the country, but when we (the authors) were in college, the internet didn't exist. A well-designed PhD program will prepare its trainees for whatever career they chose.

We cannot imagine the world 30 years from now, but we can state that PhD-trained scientists will not only be able to handle these changes but will in fact invent many of them. Huge technological innovations now allow investigators to see many individual neurons inside the brain, control the properties of neurons experimentally, to see effects of individual channels and proteins within a neuron or glial cell, and to observe the effects of these manipulations on behavior. Neuroscience is making amazing discoveries in the fundamental science of how the brain functions and the clinical and practical consequences of those discoveries. Simply put, it is an amazing time to be a neuroscientist.

REFERENCES

Akil H, Balice-Gordon R, Cardozo DL, Koroshetz W, Posey Norris SM, Sherer T, Sherman SM, Thiels E (2016) Neuroscience training for the 21rst century. Neuron 90:917-926.

Hall JD, O'Connell AB, Cook JG (2017) Predictors of student productivity in biomedical graduate school applications. PLoS One 12(1):e0169121.

Institute of Medicine (IOM) (2015) Developing a 21rst century neuroscience workforce: Workshop Summary. Washington DC: The National Academies Press.

Kuncel NR, Hezlett SA (2007) Assessment. Standardized tests predict graduate students' success. Science 315:1080-1081.

Moneta-Koehler L, Brown AM, Petrie KA, Evans BJ, Chalkley R (2017) The limitations of the GRE in predicting success in biomedical graduate school. PLoS One 12(1):e0166742.

Olivares-Urueta M, Williamson JW (2013) Pre-admission factors and utilization of tutoring services in health professions educational programs. J Allied Health 42:74-78.

Weiner OD (2014) How should we be selecting our graduate students? Mol Biol Cell 25:429-430.

Willcockson IU, Johnson CW, Hersh W, Berstam EV (2009) Predictors of student success in graduate biomedical informatics training: introductory course and program success. J Am Med Inform Assoc 16:837-846.

Woolston C (2018) Science PhDs lead to enjoyable jobs. Nature 555:277.

Received April 05, 2018; revised May 01, 2018; accepted May 07, 2018.

The authors thank Drs. Robert Meisel, Timothy Ebner, Paul Mermelstein, Stephanie Fretham, Kevin Crisp, and Neil Schmitzer-Torbert for comments on an earlier draft of this manuscript.

Address correspondence to: Dr. A. David Redish, Department of Neuroscience, 6-145 Jackson Hall, 321 Church St. SE, University of Minnesota, Minneapolis MN 55455. Email: redish@umn.edu