CBE—Life Sciences Education
Vol. 10, 239–249, Fall 2011

Essay

Improving Graduate Education to Support a Branching Career Pipeline: Recommendations Based on a Survey of Doctoral Students in the Basic Biomedical Sciences

C. N. Fuhrmann, D. G. Halme,* P. S. O'Sullivan, and B. Lindstaedt

University of California, San Francisco, San Francisco, CA 94143-0523

Submitted February 14, 2011; Revised May 24, 2011; Accepted May 24, 2011
Monitoring Editor: Vivian Siegel

Today's doctoral programs continue to prepare students for a traditional academic career path despite the inadequate supply of research-focused faculty positions. We advocate for a broader doctoral curriculum that prepares trainees for a wide range of science-related career paths. In support of this argument, we describe data from our survey of doctoral students in the basic biomedical sciences at University of California, San Francisco (UCSF). Midway through graduate training, UCSF students are already considering a broad range of career options, with one-third intending to pursue a non–research career path. To better support this branching career pipeline, we recommend that national standards for training and mentoring include emphasis on career planning and professional skills development to ensure the success of PhD-level scientists as they contribute to a broadly defined global scientific enterprise.

INTRODUCTION

Forty years ago, the career trajectory of PhD-level basic biomedical scientists could be described as a linear pipeline. Trainees moved from doctoral to postdoctoral training, and, ultimately, to tenure-track faculty positions. As the number of trainees has outpaced the availability of academic positions, an increasing number of PhD-trained scientists have pursued paths outside of academia. These scientists are often described as "leaking" from the pipeline. Unfortunately, this metaphor perpetuates the negative perception that scientists who "leak" are outside the norm and represent failures within the system. In fact, today's PhD students and postdoctoral scholars commonly follow diverse career paths. Not only are PhD-trained scientists pursuing research careers beyond academe, but increasing numbers are leaving research altogether.

This is not new information—several national reports (National Research Council [NRC], 1998, 2005, 2011) and prominent articles (Golde and Dore, 2001; Teitelbaum, 2008; Benderly, 2010) have highlighted shifting career patterns of life scientists and challenges faced by those who do pursue the academic path. Consequently, promising new initiatives have been established in the area of trainee career development. However, most of these initiatives have focused on assisting young biomedical investigators as they transition to independent academic positions. A gaping hole remains; as a scientific community we have ignored the many trainees who will pursue nontraditional positions.

Our lack of action in this arena is shocking, because "nontraditional" career paths are not "alternative." Since 2001, fewer than 20% of PhDs in the biological sciences have been moving into tenure-track academic positions within 5–6 yr of receiving a PhD. In fact, the most recent data (2006) show only 14% of these PhDs in tenure-track positions. Forty-three percent were employed full-time in nonacademic settings

DOI: 10.1187/cbe.11-02-0013
*Present address: School of Medicine, University of Virginia, Charlottesville, VA 22908
Address correspondence to: Cynthia N. Fuhrmann (cynthia.fuhrmann@ucsf.edu)

(Stephan, 2012).[1] With increasing numbers of domestic and international PhDs being trained (Cyranoski *et al*., 2011), and research funding to employ and support them becoming tighter, the proportion of PhDs pursuing nontraditional career paths is likely to continue to increase. Students in these career paths need a broad set of skills to succeed in such positions (Smith *et al.*, 2002; Melin and Janson, 2006; Rudd *et al.*, 2008). Yet, graduate program curricula and federal training standards changed little in response.

To address this issue, those of us leading graduate education need to increase our awareness of when, and why, career choices are made. Career outcomes data for doctoral alumni are informative, but to design and implement doctoral-level career development curricula most effectively, we need insight into the career planning of current trainees, including the career paths they are considering, the factors influencing their career decisions, and the timing of when their career decisions are made. Both universities and funding agencies need this information to ensure the training being offered appropriately prepares these talented scientists for their future careers.

Two prior studies have looked at doctoral student career preferences and how these career preferences change over time (Golde and Dore, 2001; Goulden *et al.*, 2009; Mason *et al.*, 2009). In a 1999 national survey of doctoral students in 11 arts and sciences fields, Golde and Dore found most students entered graduate school strongly considering a faculty career, but students reported a change in interest for this career path during their training: 35% of students reported becoming less interested in this career path and 21% reported becoming more interested (Golde and Dore, 2001). In 2006, Mason and colleagues surveyed graduate students in all disciplines across several University of California campuses, and learned that while 45% of men and 39% of women initially planned to become a professor with research emphasis, this proportion had decreased to 36% and 27%, respectively, by the time of the survey (1–7 or more yr after starting their training; Goulden *et al.*, 2009; Mason *et al.*, 2009). Data from these and other studies (Fox and Stephan, 2001) showed that career preferences vary significantly across disciplines. Therefore, to understand and address career development needs in the basic biomedical sciences,[2] we need to look deeply and specifically at the career preferences for students within this particular discipline.

In this paper, we show that large numbers of students in the basic biomedical sciences are considering career paths beyond academe—and even beyond research. This change in career preference occurs early in graduate school. We use the metaphor *branching career pipeline* to describe this substantial flow of PhD-trained scientists into various sectors of the workforce, and propose that this branching should be seen as a valuable opportunity for spreading science throughout society. To better support today's branching science careers pipeline, we recommend that national standards for training and mentoring place more emphasis on career planning and professional skills development to ensure the success of PhD-level scientists as they contribute, in a variety of science-related career paths, to a broadly defined global scientific enterprise.

STUDENTS ARE CONSIDERING A RANGE OF CAREER OPTIONS

We surveyed all basic biomedical sciences doctoral students at University of California, San Francisco (UCSF) to determine what career paths they are strongly considering, whether these preferences are different from when they started their training, and, if so, why. UCSF is the only campus in the University of California system that focuses solely on graduate-level training. The PhD programs in the basic biomedical sciences are ranked among the top in the nation, and admission is highly competitive. Therefore, one would anticipate that these students have a high likelihood of success in research-focused career paths, and a bias toward choosing research-focused careers.

The survey, distributed in spring 2008, is available in Supplemental Material 1. Four hundred sixty-nine students responded, corresponding to 62.3% of all basic biomedical science graduate students at UCSF (Table 1).

Respondents initially identified all categories of careers they were strongly considering. As expected, the vast majority of students (92.3%, $n = 432$) were strongly considering careers in scientific research (i.e., in academia, industry, government; Figure 1). Seventy-two percent ($n = 338$) of students included a traditional academic career path (i.e., as faculty with a significant portion of their time spent on research) among the career paths they were considering. When asked to choose only a single career (Figure S1 in Supplemental Material 2), only 44.8% ($n = 210$) of student respondents selected a traditional academic career path; 26.9% ($n = 126$) selected another scientific research career path, such as a research-intensive career in biotechnology/pharmaceuticals, a research career in government, or a non–principal investigator (non-PI) research career in academia (collectively, these three categories are hereafter called "other research careers"). While these numbers represent a general preference for research careers, they leave over one-fourth of students choosing non–research careers.

Indeed, 71.2% ($n = 333$) of all respondents were "strongly considering" at least one career path not directly involving scientific research (hereafter called "non–research" careers; Figure 1), and 27.9% ($n = 131$) selected one of these non–research careers as their top preference (Figure S1 in Supplemental Material 2). Among these career paths, the most popular choices were business of science, teaching- or education-related, science policy, and writing career paths. Given that graduate training is focused almost entirely on research, it is surprising that so many students selected a non–research career path as their top choice.

The fact that students were considering such a broad range of career options suggests they also have low confidence in their current career choice. Indeed, only 15.8% ($n = 73$) of students self-identified as "very confident" in their

[1]At 5–6 yr after completion of the PhD degree, the 43% of PhDs in the biological sciences employed in nonacademic settings include: 23% in industry, 9% in government, and 11% in other types of settings. In addition, 17% are employed full-time in non-tenure-track academic positions. Ten percent work part-time or are out of the labor force, and 17% are still in postdoctoral training. These data are from the 2006 National Science Foundation Survey of Doctorate Recipients, as analyzed by Paula Stephan (Stephan, 2012).

[2]We use the term "basic biomedical sciences" as defined by the NRC (2011): fields that "deal with the biological mechanisms that are ultimately related to human health."

Table 1. Survey demographics and response rate

Students		Enrolled at UCSF	Responded to survey	% Responded
Year	1	138	84	60.9
	2	121	80	66.1
	3	142	88	62.0
	4	105	69	65.7
	5	114	58	50.9
	6	78	49	62.8
	7 or higher	55	21	38.2
	Unreported		20	
Graduate program	Bioengineering[a]	176[a]	67	38.1[a]
	Biomedical Sciences	135	88	65.2
	Biophysics	63	39	61.9
	Biological and Medical Informatics	32	21	65.6
	Chemistry and Chemical Biology	45	28	62.2
	Neuroscience	91	64	70.3
	Pharmaceutical Sciences and Pharmacogenomics	51	33	64.7
	Tetrad	160	122	76.3
	Cell Biology	—	39	—
	Developmental Biology	—	7	—
	Genetics	—	16	—
	Biochemistry & Molecular Biology	—	50	—
	Tetrad—focus not yet determined	—	10	—
	Unreported		7	
Gender	Female	368	249	67.7
	Male	385	205	53.2
	Unreported		15	
Ethnicity[b]	American Indian or Alaskan Native	—	1	—
	Asian	—	102	—
	Black or African American	—	10	—
	Hispanic or Latino	—	26	—
	Pacific Islander	—	8	—
	White	—	298	—
	Other	—	9	—
	Unreported		37	
OVERALL		753	469	62.3

[a] All graduate programs returned a response rate of more than 60%, with the exception of Bioengineering, a joint graduate program with UC Berkeley. The response rate for Bioengineering students (38.1%) is likely lower because 62% of Bioengineering graduate students identify UC Berkeley as their home campus and many of these students may have ignored the survey request.

[b] Respondents could choose more than one category to describe their ethnicity. Response rates were not calculated because ethnic categories were defined differently in our study compared with those on file through university enrollments.

current career choice; 29.3% ($n = 135$) of students were "fairly confident"; and the majority of students (54.9%, $n = 253$) were "still considering a range of options."[3] There was no significant difference in confidence between students choosing research careers and students choosing non-research careers ($p = 0.37$). Although students choosing to become a PI at a research-intensive institution were more confident than students not considering that career path ($p < 0.001$), they were still not very confident, with only 23.7% ($n = 31$) "very confident" in that selection, 38.9% ($n = 51$) "fairly confident," and 37.4% ($n = 49$) "still considering a range of options."

[3] In agreement with their self-reported degree of confidence, only 8.3% ($n = 39$) of respondents selected one career category when asked which careers they were strongly considering, and 91.7% ($n = 429$) of respondents selected more than one career category. On average, students chose 3.9 ± 1.9 careers from the 16 possible categories ($n = 468$). Although early-stage students generally chose more career categories than later-stage students, even later-stage students selected three to four career paths on average.

CAREER PREFERENCES SHIFT MIDWAY THROUGH GRADUATE STUDIES

How do career choices and confidence levels change during the graduate school experience? Although longitudinal data would be ideal, our data provide a cross-sectional view. When asked to choose a single career path, confidence in the chosen career path depended on the stage of graduate training ($p = 0.006$). A large change in confidence occurred between the first and second year in graduate school, with the number of students "still considering a range of options" increasing from 48.8% ($n = 40$) to 66.7% ($n = 52$; see Figure S2 in Supplemental Material 2). Uncertainty in career choice remains high

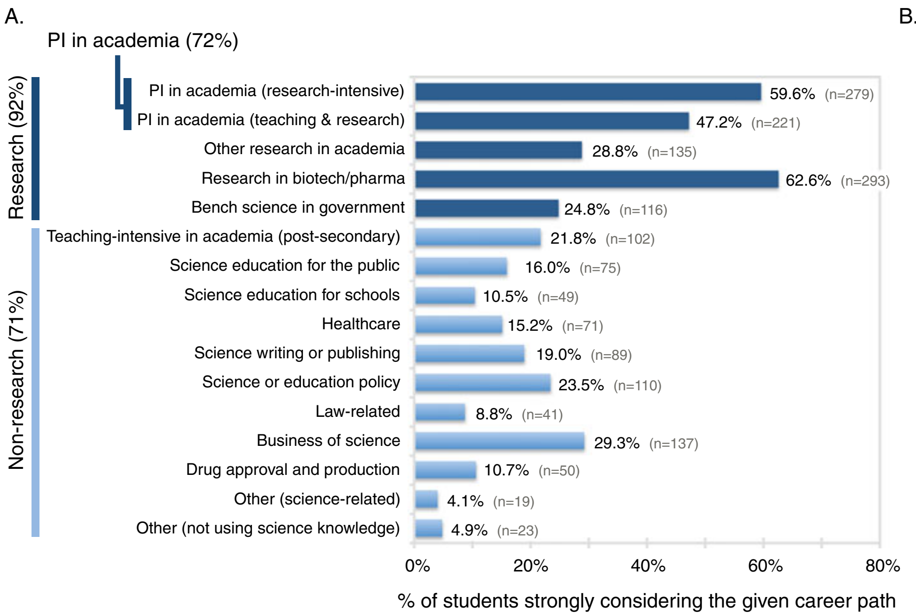

Figure 1. Graduate students are strongly considering a range of career options. (A) The bar graph shows the percentage of all student respondents who chose each category as one of the career path categories they were strongly considering (respondents could choose more than one category). Overall, 92% of students were strongly considering at least one category of research careers (represented by bars in dark blue), with 72% of all students strongly considering becoming a PI at a research-intensive academic institution and/or a PI with a balance of teaching and research. Seventy-one percent of all students were strongly considering at least one category of careers that typically do not directly involve performance of research (labeled as "non-research" careers and represented by bars in light blue). (B) As illustrated in this Venn diagram, many students (63%, $n = 297$) were strongly considering both research and non–research career paths.

(61.4%, 61.8%, and 55.2% for third, fourth, and fifth years, respectively) until students approach the expected time of graduation (sixth or later years, 33.3%, $n = 23$). How do we explain the drop in career choice confidence during the second year of graduate school? At UCSF, students take courses and rotate through labs during their first year. In June, most students choose a thesis laboratory. Therefore, at the time of this survey, second-year students had been working in a thesis laboratory full-time for 8–10 mo. This time afforded them plentiful opportunities to observe and interact with senior students, postdoctoral fellows, and faculty, and to more fully experience day-to-day academic research.

The drop in confidence between the first and second year was followed by a significant change in career choice between the second and third year (see Figure 2). The percent of students selecting a research career path as their top choice dropped significantly, from 80.0 to 65.9% ($p = 0.001$; Figure 2A and Table 2). Specifically, this was due to a drop in interest for PI positions at research-intensive universities, with a decrease during the transition from first to second year (from 41.7% to 35.0%) followed by another, sharper decrease during the transition from second to third year (to 25.0%; Figure 2B).

When interest in the research-intensive PI track decreases, one might expect a corresponding increase in interest for other research careers. However, student interest in other research career categories remained relatively stable (Figure 2B and Table 2). Instead, interest in non–research career paths increased (from 20 to 34% between the second- and third-year classes). Within that broad category, the percent of students choosing a career path in teaching or science education did not change significantly (Table 2). However, interest in non–research career paths outside of academia (the business of science, science writing, healthcare, science policy, law-related, and drug-approval and production) did increase, from 15.0 to 29.5% between the second- and third-year class ($p = 0.006$ when comparing early- and late-stage students). In summary, the shift in students' career choices can be described most succinctly as a decreased interest for becoming a PI at a research-intensive university, and an increase of interest in non–academic, non–research career paths. These data are consistent with those described for PhD students across all disciplines in the University of California system (Mason *et al.*, 2009).

In addition to a decreased interest in the traditional PI track as a top career choice, students also tended to eliminate the PI track from their inclusive list of career paths being "strongly considered." While 89.3% ($n = 75$) of first-year students included the PI track (research-intensive or with a balance of teaching and research) as a career path they were strongly considering, this percentage decreased sharply between the second- (87.5%, $n = 70$) and third-year (67.8%, $n = 59$) classes. Within this broader PI career category, there was a more pronounced drop in consideration of PI positions at research-intensive institutions (from 75.0% in the second-year class to 55.2% in the third-year class) compared with the drop in consideration of PI positions with a more even balance of teaching and research (from 56.3 to 44.8%).

Is this change in career preferences gender-specific? Interestingly, our analysis showed no significant difference in the percent of men (27.8%) or women (28.9%; $p = 0.79$) who selected a non–research career path as their first choice. There

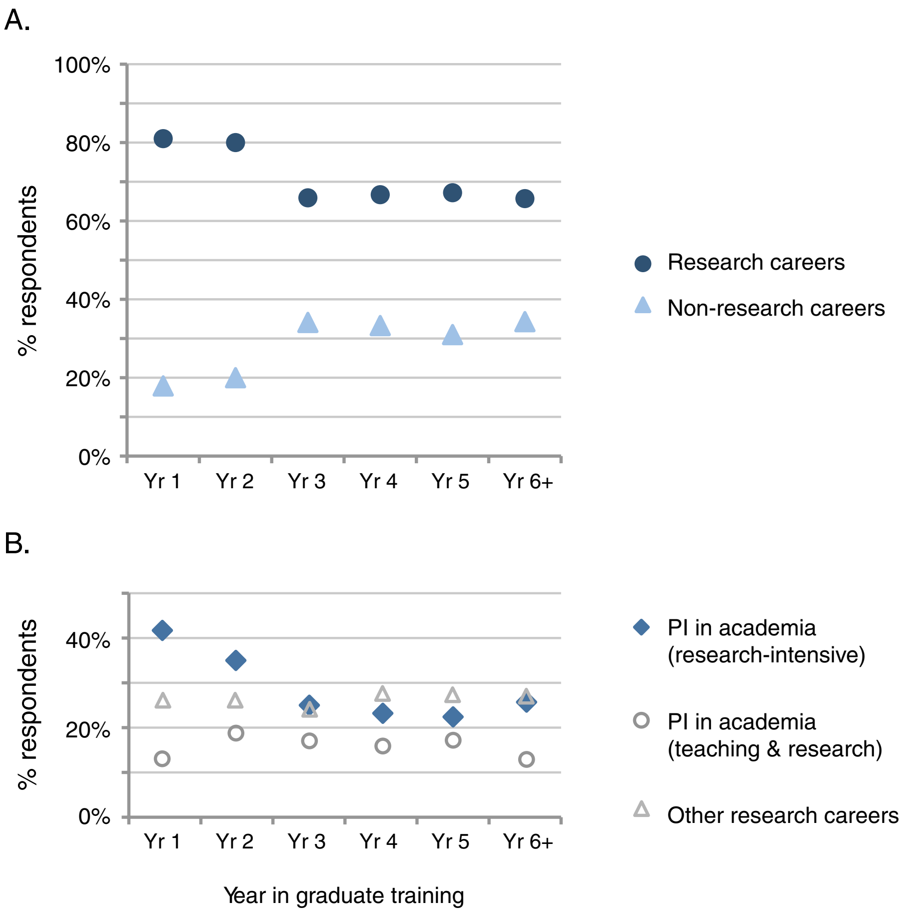

Figure 2. Early in graduate school, some students lose interest in becoming a PI at a research-intensive academic institution. (A) The percentage of students in each cohort who currently would choose a research (dark blue circles) or non–research (light blue triangles) career. Between the second and third year, there is a steep drop in interest in research careers. (B) Within the broad category "research careers," the only career choice that showed significant change was that of being a PI at a research-intensive academic institution (blue solid diamonds). Values and statistical analyses are given in Table 2.

Table 2. Current career choice as a function of year in graduate school

Current career choice	Year 1 $n = 84$ %	Year 2 $n = 80$ %	Year 3 $n = 88$ %	Year 4 $n = 69$ %	Year 5 $n = 58$ %	Year 6 and higher $n = 70$ %	p Value[a]	Year 1 and 2 $n = 164$ %	Year 1 and 2 n	Year 3+ $n = 285$ %	Year 3+ n	p Value[a]
Research career	81.0	80.0	65.9	66.7	67.2	65.7	0.067	80.5	132	66.3	189	0.001
Non–research career	17.9	20.0	34.1	33.3	31.0	34.3	0.051	18.9	31	33.3	95	0.001
PI at a research-intensive institution	41.7	35.0	25.0	23.2	22.4	25.7	0.047	38.4	63	24.2	69	0.001
PI doing teaching and research	13.1	18.8	17.0	15.9	17.2	12.9	0.897	15.9	26	15.8	45	0.986
Other research careers	26.2	26.3	23.9	27.5	27.6	27.1	0.995	26.2	43	26.3	75	0.98
Teaching and education	2.4	5.0	4.5	8.7	8.6	7.1	0.51	3.7	6	7.0	20	0.14
Other non–research careers[b]	14.3	15.0	29.5	23.2	22.4	25.7	0.12	14.6	24	25.6	73	0.006

[a]There is a trend toward significance for change of career choice from year to year ($p = 0.067$ and 0.051 for change in interest of research career paths and non–research career paths, respectively). Most of this change in career choice occurs between the second and third years of graduate school. This is evident when data are grouped for early (years 1 and 2) and later-stage (year 3 and above) students.

[b]"Other non–research careers" includes careers in the business of science, science writing, healthcare, science policy, law, and drug approval and production. Some columns may not add to 100% because respondents who indicated "other science-related careers" were not included in the bottom half of the table.

was a significant difference, however, in interest for becoming a PI at a research-intensive institution (21.3% of women would choose this path, compared with 39.5% of men, $p < 0.001$). The latter finding is consistent with prior studies of UC students across disciplines (Goulden *et al.*, 2009; Mason *et al.*, 2009). However, the decline over time in interest for this career path was not gender-specific; similar to both the Mason and Goulden studies, both genders in our study lost interest in this career path over time.

Do postdoctoral scholars show similar trends in career preference? We simultaneously surveyed postdoctoral scholars at UCSF (see Supplemental Material 3), and found postdoctoral scholars were more likely to prefer a research-focused career path (89%). Postdocs were generally more confident in their career choice than students, but still had low confidence (with 37% reporting they were "still considering a range of options"). Although 20% indicated their career preference had changed since beginning their postdoctoral training, this change was not apparent in our analysis of career choice data: There was no significant change in aggregate interest for each career category when tracked across years of postdoctoral training.

WHY DO STUDENTS MOVE AWAY FROM THE ACADEMIC PI TRACK?

What factors caused students to so radically change their career aspirations? Others have shown across disciplines that a variety of factors come into play, such as workload expectations, difficulty in getting research funding, competition within academia, low availability of jobs, loss of interest in basic research, and increased interest in other careers (Rice *et al.*, 2000; Golde and Dore, 2001; Austin, 2002; Bakken *et al.*, 2006; Goulden *et al.*, 2009; Mason *et al.*, 2009; Roach and Sauermann, 2010). In our study, 31.0% ($n = 143$) of students stated their career choice had changed since they began their graduate training. Seventy-nine students provided reasons for moving away from the academic PI track, most describing multiple reasons (hence, the percentages that follow do not add to 100%; see Supplemental Material 4 for examples). Of these, 91% ($n = 72$) described negative perceptions related to this career path. Thirty percent ($n = 24$) referenced inadequate quality-of-life or work–life balance, 22% ($n = 17$) referenced the competition or stress associated with trying to succeed within an academic position, and 24% ($n = 19$) anticipated difficulty in getting research funding. Nineteen percent ($n = 15$) mentioned the length of training required or competition to get academic jobs, and 11% ($n = 9$) mentioned low salary during training or in the job. Twenty-five percent ($n = 20$) wrote they disliked the tasks required of being an academic PI, such as grant writing and project management, and the slow pace of research. In contrast, only 24% ($n = 19$) of these students provided a positive reason for change, such as learning more about other career options or discovering a new skill or interest in the course of their graduate education.

These data suggest role modeling by faculty, and even postdoctoral scholars, had great impact on graduate students' perceptions of academic careers, for better or worse. Positive and negative effects of role modeling have also been described for doctoral students in the physical sciences (Paglis *et al.*, 2006) and across all disciplines (Austin, 2002; see discussion below, "Data Highlight Discipline-Specific Influences on Career Choice"). These and other studies support that career decision making is an important outcome of socialization during doctoral training (reviewed in Antony, 2002). In our study, students observed and formed perceptions of the quality of life that PIs achieve, and the challenges they faced in funding a group's research. They saw the challenges postdoctoral scholars faced in attaining academic positions. They experienced their own frustrations with the process of doing research. Their shift in career choice reflected a desire to find a different career option that more closely fit their own professional and personal goals.

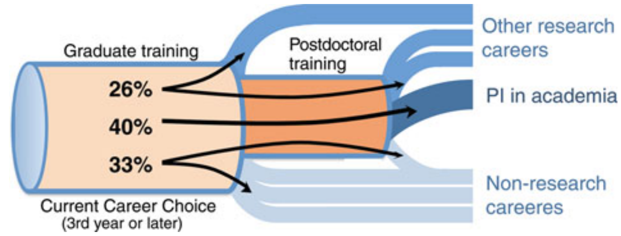

Figure 3. Graduate student career preferences predict a branching career pipeline. This diagram illustrates the branching pipeline model, describing the career trajectory of PhD-level scientists. The central pipes represent graduate (light orange) and postdoctoral (darker orange) training. Black arrows represent the desired career paths of students in their third or later year of graduate school. According to our survey, the branched nature of this pipeline can be predicted as early as the third year in graduate school, with 40% of these later-stage students intending to become a principal investigator in academia, 26% intending to pursue other research-focused career paths, and 33% intending to pursue non–research career paths. Many of these students move on to postdoctoral training—including some students who prefer to pursue a non–research career path.

SUMMARY OF THE DATA

In conclusion, our data showed that UCSF PhD students were considering many different career paths, with most simultaneously considering both non–research and research career paths. Career path choices shifted during the first 3 yr of graduate school. This was primarily driven by decreased interest in becoming a PI at a research-intensive university. By the later years of graduate school, fully one-third of students stated they would choose a non–research career path (Figure 3and Table 2).

ARE THESE LOCAL EFFECTS OR A NATIONAL TREND?

Are these data unique to UCSF? Some characteristics of the university itself may have influenced the data. First, UCSF's location in the San Francisco Bay Area, a geographic region rich in biotech companies, may attract prospective students who are already interested in diverse career paths. A second influencing factor might be the variety of resources historically available to assist UCSF students as they explore careers beyond academic research. These resources include seminars and individual consultations provided by the Office of Career and Professional Development, the Center for Bioentrepeneurship's "Idea to IPO" (a course created through a collaboration of UCSF faculty and leaders in nearby industry), and numerous alumni events hosted by student organizations. It is possible UCSF students experience a broader awareness of their career path options because these resources exist. However, the data suggest these influences play a minor role: only 24% of respondents described "positive" reasons for moving away from research-intensive faculty careers (for example, increased knowledge about a career path), compared with 91% of respondents who described negative aspects of the research-intensive academic career path.

The question remains, then: does the UCSF environment in some way cause students to move away from research-intensive academic careers? UCSF, an academic medical center, is itself a research-intensive graduate-level institution. Faculty members focus on research and have minimal teaching responsibilities. It is common for faculty salaries to be supported entirely by grant money, with limited "hard money" support. UCSF therefore naturally attracts and promotes faculty driven by a singular passion: research. Students observe their advisors and wonder, "Would I also enjoy this career path?"

In addition to the environment of UCSF, the students themselves are also potentially different from students at other institutions. Entering students are high achievers, as evidenced by high Graduate Record Examination (GRE) scores and prevalence of external funding (PhDs.org, 2011; based on NRC, 2010). As high achievers, these students were probably coached to pursue academic careers by their undergraduate advisors. They may have entered graduate school with especially high expectations of pursuing and succeeding along an academic career path. As a result, our data may exhibit a sharper drop in interest for academic careers among UCSF students compared with students at other institutions. An in-depth, cross-institutional study should be pursued to test how (or if) undergraduate academic success impacts students' career preferences and their confidence in career choice, and how their career preferences change with time.

While UCSF may be among the nation's most research-focused institutions, it is hardly unique. Many basic biomedical sciences doctoral programs are similarly housed in research-intensive academic medical centers. Many of these programs also attract highly talented students. We predict a national survey of similar institutions would reveal that graduate students' career decisions follow a similar trend, with a drop in interest for research-intensive academic positions following a year or less of full-time experience at the bench. Preliminary discussions of the data with colleagues at other institutions support this prediction, but a formal cross-institutional study should be done.

DATA HIGHLIGHT DISCIPLINE-SPECIFIC INFLUENCES ON CAREER CHOICE

Most studies of doctoral student career preferences report data averaged across all disciplines (Rice *et al.*, 2000; Golde and Dore, 2001; Goulden *et al.*, 2009; Mason *et al.*, 2009; among others). However, disciplinary culture—and institutional culture—can affect how and why students choose certain career paths. Here we compare our qualitative data with the data of others to highlight some important differences.

As described above (see "Why Do Students Move away from the Academic PI Track?"), our respondents cited several reasons for no longer considering the traditional academic track. Two of the major themes—anticipated competition/stress and insufficient work–life balance—were also two of the greatest concerns cited by doctoral students in cross-disciplinary studies (including the humanities and social sciences; Rice *et al.*, 2000; Mason *et al.*, 2009). Stress and lack of work–life balance are legitimate concerns: cross-disciplinary studies have shown that new faculty frequently use terms such as "stress, pressure, and uncertainty" to describe their role (Rice *et al.*, 2000; Austin, 2002). What is more, longitudinal studies show that faculty stress intensifies over the first 5 yr (Olsen and Sorcinelli, 1992).

Although stress and lack of work–life balance seem to be themes independent of discipline, our study highlights distinct disciplinary differences in the underlying causes for these concerns. While doctoral students in broader studies noted that faculty lack time for research because of significant teaching responsibilities (Rice *et al.*, 2000), this was not a theme echoed by our respondents. Instead, UCSF students' concerns about future stress and work–life balance were often described in the context of the scientific research itself. In particular, difficulty in getting research funding was specifically described by 24% of respondents in our study ($n = 19$). A lack of concern about teaching is not surprising: UCSF faculty have few teaching responsibilities. Instead, faculty promotions—and even salary—are often contingent on research productivity and funding.

Another example of how cultural differences impact career perceptions stems from the level of collaboration within department, institution, and research field. The cross-disciplinary study "Heeding New Voices" identified "isolation"—an insufficient sense of community and collaboration—as a primary concern for aspiring and junior faculty (Rice *et al.*, 2000). As expected, this was not a concern expressed by students in our study. Basic biomedical research is increasingly interdisciplinary and collaborative, a culture of sharing ideas and projects within and across lab groups, and even across institutions. Others have noted this cultural difference as well (Gardner [2007] and Golde [1998], as referenced in Gardner [2010]).

These analyses emphasize that there are distinct differences in the cultures and nature of work—and therefore in career decision making—that depend on discipline and institutional context. To best understand the needs of basic biomedical science trainees, many of whom are trained in institutions similar to UCSF, we need to pursue cross-institutional studies specific to students within this field and within the research-intensive context of health science campuses.

HOW SHOULD WE REACT TO THESE DATA?

Some in our scientific community argue that the purpose of graduate education is to train future academic research faculty. If this is indeed the purpose of graduate education, then the data presented in this report are troubling. The question ultimately arises: should we be more selective in graduate school admissions in the first place, admitting only students who are both highly likely to succeed in these careers and also likely to pursue them? Our study suggests such an approach would be fruitless. Despite an already highly rigorous selection process and prevalent initial interest in academic careers, 60% of UCSF students in their third year or later would choose a career path beyond the traditional academic path. As discussed above, this trend is likely echoed at other research-intensive graduate institutions.

Instead of turning talented students away from doctoral education based on their career preferences, we believe that we, as educators, should embrace the branching career pipeline and shift the current paradigm for graduate education toward a more inclusive curriculum capable of preparing doctoral students for a variety of scientific careers. Indeed, to maintain our science pipeline, we must ensure graduate-level training and career prospects after training are perceived as valuable and rewarding. To quote Bruce Alberts, former President of the National Academy of Sciences and current editor-in-chief of *Science*, "The entire enterprise will be jeopardized if students generally feel dissatisfied with their training" (personal communication). In combination, our data and data from prior studies (Golde and Dore, 2001; Aanerud *et al.*, 2006; Mason *et al.*, 2009) support three recommendations for how we as scientists, educators, and policy makers can strengthen graduate training, improve student wellness and satisfaction, and produce a more highly skilled national scientific workforce.

1. SHIFT ACADEMIC CULTURE TO EMBRACE THE "BRANCHING" SCIENCE CAREER PIPELINE

We believe the academic community should be supportive of individual PhD-level trainees interested in pursuing careers beyond the traditional academic path. Our data show that trainees do not make major career decisions lightly; respondents shared thoughtful reasons for shifting their career choices away from the traditional research-intensive PI track. The PI track, and the lifestyle, stressors, and lack of security currently associated with it, is not a fit for everyone. Moreover, there are not enough jobs in the academic sector for all PhD-trained life scientists, and this "supply–demand" gap is growing each year (Teitelbaum, 2008; Cyranoski *et al.*, 2011; NRC, 2011).[4] With only 14% of PhDs in the biological sciences entering tenure-track positions within 5–6 yr of earning their PhD (2006 data; Stephan, 2012), how can we continue to devalue other career paths? Finally, it is important for us to have PhD-trained scientists in roles that will benefit the scientific enterprise as a whole. They provide services critical to the advancement of science in today's world, by developing and running research facilities, working with researchers to patent discoveries, bringing those discoveries to market, funding research, setting policies, and teaching future generations of scientists. As a scientific community and as individual mentors, we should be applauding PhD graduates who move on to become leaders in any science-related career path. When PhD-level scientists are distributed broadly throughout the workforce, we all benefit, because we are "creating the bridges needed for science to affect a wider society" (Alberts, 2008).

[4]As demonstrated in the Bridges to Independence report (NRC, 2005), the number of PhD-trained life scientists ages 35 and younger increased by 59% between 1993 and 2001 in the United States, but the number of these scientists in tenure-track positions increased by only 7%. The job market is perhaps tightest at research-focused universities: the number of tenure-track life scientists at Research I institutions decreased over this time by 12%. Clearly, there are not nearly enough tenure-track positions available for the number of life scientists being trained.

2. INTEGRATE CAREER DEVELOPMENT INTO THE GRADUATE CURRICULUM

Our national investment in graduate-level training will be optimized when trainees have a positive graduate experience, and then move on equipped to succeed in their future career paths.

Some institutions already offer career and professional development services tailored to graduate students and/or postdoctoral scholars in the basic biomedical sciences; examples are given in Table 3. However, such offerings are not the norm. Even institutions that do offer such services frequently emphasize preparation for academic careers,[5] offering little support to students planning to pursue other types of career paths. We need to supplement graduate education with career development initiatives—including career planning and professional skills development—that will prepare our doctoral trainees for careers both within academia and beyond.

The branching nature of today's biomedical sciences career pipeline—and trainees' low confidence in their career choices within the pipeline—underscores the need for structured career planning at the doctoral level, yet few science trainees are provided with career-planning assistance. A lack of career planning is likely one factor contributing to the high proportion of students who move on to postdoctoral training (80% of all biological sciences PhDs nationally [NRC, 2011]), even though this additional training is unnecessary for most students following a non–research career path.

Currently, career discussions between students and mentors often occur near the end of training, if at all. Our data emphasize that this is too late. Career education, guidance, and mentoring—tailored to the needs of students in the basic biomedical sciences and provided early in students' graduate education—would help students make career decisions from a well-informed position. Students considering non–research career paths (or research career paths outside of academia) may greatly benefit from an opportunity to try out this new role through a short-term internship. This would help ensure career decisions are made based on realistic expectations.

Skills in areas such as interpersonal communication, presentation, leadership, management (Smith *et al.*, 2002; Melin and Janson, 2006; Rudd *et al.*, 2008), and networking are imperative for success in all careers. Teaching skills are also needed in many of the career choices. Yet, with our traditional emphasis on developing scientific knowledge and research skills in graduate education, few if any resources are dedicated to the broader professional development of graduate students and postdoctoral fellows. Graduate education should be supplemented with structured training and mentoring in these broader professional skills areas to prepare students for success in the broad range of traditional or nontraditional science-related careers.[6] Students could each

[5]Many academic career development initiatives are based on the successful Preparing Future Faculty model (www.preparing-faculty.org; DeNeef, 2002).

[6]Table 3 provides examples of centralized initiatives in this arena.

Table 3. Career development initiatives tailored to the needs of doctoral students and/or postdocs in the basic biomedical sciences[a]

Fred Hutchinson Cancer Center, Office of Scientific Career Development	www.fhcrc.org/science/education/grad_postdoc/oscd
Medical College of Wisconsin, Office of Postdoctoral Education (for graduate students also)	www.mcw.edu/VirtualCareerCenter.htm
National Institutes of Health, Office of Intramural Training and Education	www.training.nih.gov/career_services
The Scripps Research Institute, Career and Postdoctoral Services Office	www.scripps.edu/services/postdocs
Stanford University School of Medicine, Career Center	http://med.stanford.edu/careercenter
UCSF, Office of Career and Professional Development	http://career.ucsf.edu
UCSF, Graduate Student Internships for Career Exploration Program	http://gsice.ucsf.edu
University of Pittsburgh School of Medicine, Office of Academic Career Development	www.oacd.health.pitt.edu
Vanderbilt University School of Medicine–Biomedical Research Education and Training, Office of Career Development and Outcomes Analysis	http://bret.mc.vanderbilt.edu/career_development

[a]This list highlights offices and programs within research institutions whose primary purpose is to target the career development needs of graduate students and/or postdocs in the basic biomedical sciences. The list is intended to provide examples of the breadth of services that can be tailored to this population, and how they are implemented. This list is in no way exhaustive, or intended to be an endorsement of any particular program.

create an Individual Development Plan (IDP) and then discuss their own professional skills training with mentors to ensure such training is pursued in a time-efficient and productive manner (Lindstaedt, 2009; National Institute of General Medical Sciences [NIGMS], 2011).

Some will argue that encouraging students to explore career options and prepare for these careers will take time away from the lab, and detract from research training. Graduate students and postdocs make up as much as 50% of the basic biomedical research workforce (NRC, 2011), and their tuition and stipends are increasingly funded by PIs' research grants (NIGMS, 2011). This creates an apparent conflict of interest for the PI: optimizing productivity of the lab as a whole, while being supportive of individual trainees within that lab as they pursue career-preparation activities (Benderly, 2010). One way to alleviate this conflict of interest is to give thesis committees, rather than individual PIs, the responsibility for overseeing student career development. It would be appropriate for thesis committees to participate in career-related mentoring, discuss with the student his/her IDP, and help the student and PI negotiate an appropriate level of time spent toward career-related activities.

Recent studies suggest career development activities do not negatively impact research training or productivity; in fact, the opposite may be true. Nationally, a recent report from NIGMS noted many investigators believe "training and laboratory productivity are synergistic" (NIGMS, 2011). Indeed, graduate students participating in the National Science Foundation's GK–12 program (spending 15 h/wk developing teaching skills through training and in-classroom experience) reported that the experience improved their time-management skills and motivated them to complete their graduate degree. In fact, GK–12 fellows spent, on average, the same number of weekly hours on their doctoral research projects and ultimately completed their doctoral degree in the same amount of time as their non-GK–12 peers (Gamse *et al.*, 2010). Other data take this a step further and suggest that career development activities can improve research productivity. Paglis *et al.* (2006) showed that doctoral students in the physical sciences who had received research mentoring submitted more abstracts, papers, and grants during their training. A national study funded by Sigma Xi found that postdocs who participated in career development-related activities reported better advisor relations, fewer conflicts, higher satisfaction, and, in some cases, more first-author papers and grants submitted (Davis, 2006). While further study is needed to determine how best to prepare students for a branching career pipeline—and how this training may or may not affect their productivity in the lab—the benefits and (lack of) risks already demonstrated by local and national initiatives strongly suggest career development should become a standard aspect of graduate training.

3. TRANSFORM GRADUATE EDUCATION POLICY AT THE NATIONAL LEVEL

Change in graduate education is often motivated by policies set at the national level. As such, it is important to consider how actions by national agencies might impact our view of the branching scientific pipeline and our ability to assist trainees in their career development.

Although the concept of the branching pipeline is becoming more broadly accepted at the institutional level and by individual faculty mentors, national funding agencies continue to use the traditional academic pathway as the formal definition of success. For example, in a ranking of graduate schools released in 2010 by the NRC, student career outcome was defined as the percent of PhDs "with definite plans for an academic position" (NRC, 2010). In addition, currently most, if not all, biomedical funding sources evaluate U.S. doctoral training programs based in part on the success of alumni, with many measures of success pointing to PI-level positions in academia.[7] Funding agencies and review

[7]NIH T32 training grant review criteria include "Training Record" as one of the five core criteria used to score training grants (National Institutes of Health, 2011). This, in part, is described as "How successful are the trainees in achieving productive scientific careers, as evidenced by successful competition for research grants, receipt of honors and/or awards, high-impact publications, receipt of patents, promotion to scientific leadership positions, and/or other such measures of success."

committees should explicitly redefine the description of a "successful" PhD graduate as one whose contributions promote the scientific enterprise, including a variety of research and non–research career paths in both academic and nonacademic sectors. This would allow graduate schools to more freely support and encourage graduate students considering such career paths.

In addition to redefining a successful career outcome, funding agencies could urge institutions to incorporate career development components into all graduate programs. As discussed in recommendation #2 above, preparation of our future scientific leaders should include training beyond scientific knowledge and research skills. To promote this broader curriculum, funding agencies should define national expectations for mentoring, professional skills training, and career development for graduate and postdoctoral trainees, and provide funding to develop and implement these types of initiatives.

CONCLUDING REMARKS

Part of our responsibility as educators is to adequately prepare doctoral students for success in their upcoming careers. To achieve this, we will need to realign our goals in graduate education with the realities of today's branching science career pipeline. Pursued simultaneously, the cultural, academic, and policy changes recommended in this and other reports will help us continue to develop talented, confident, and well-trained scientific professionals who will contribute directly to our research enterprise as trainees, then move on to diverse careers that will elevate the pace and quality of scientific discovery, improving the health of our nation and our world.

ACKNOWLEDGMENTS

We thank foremost the many UCSF students and postdoctoral scholars who participated in this study. Thank you to Bruce Alberts, whose advocacy around these issues served as inspiration for this study. C.N.F. thanks Bill Balke, Laurie Littlepage, Françoise Chanut, and Brian Kelch for discussions that clarified the story and Quincey Justman, Kristin Krukenberg, Mark McCormick, Theresa O'Brien, Alexandra Schnoes, and Teresa Scherzer for their participation in testing the survey for clarity. Thank you to UCSF's graduate program administrators, who helped to distribute the survey to all students, and to Tracy Kress and Quinn Mitrovich for overseeing distribution of the postdoctoral survey as part of a larger survey project for the Office of Career and Professional Development. Thank you to the UCSF Graduate Division for providing enrollment figures for the time period of this study. We are deeply appreciative of research analyst Jason Wang for assisting with statistical analyses of data in the paper. Finally, thank you to the many faculty, students, postdoctoral scholars, and staff who have engaged in discussions on this topic, and who have advocated for and supported efforts of professional development and career mentoring at UCSF and beyond.

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