Careers and Rewards in Bio Sciences:
the disconnect between scientific progress and career progression

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Richard B Freeman
Eric Weinstein
Elizabeth Marincola
Janet Rosenbaum
Frank Solomon

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The rate of progress in the biological sciences and biotechnology is extraordinary. Every week there are findings that generate wide interest from scientists and the general public and that hold the promise of improving human life. A priori, one would expect that the rapid rate of scientific progress would create an intellectual gold rush that would attract the "best and brightest" young Americans to the biological sciences and reward them with good career prospects. Instead, the field faces a "crisis of expectations" among new entrants (NRC, 1998) because "it is increasingly difficult for new scientists to establish independent research careers"[1]. Salaries and career opportunities fall short of those in other high-level occupations and are lower than those in the biological sciences in the recent past. As a result recent National Research Council (NRC) panels assessing biological sciences have called for PhD production to stabilize.[2] What economic forces underlie the disconnect between the scientific progress of the field and job market prospects?

What reforms could make the job market more attractive to new entrants?

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[1] National Research Council (2000, p 1)

[2] Biology has been more forthcoming about job problems facing new entrants than many other disciplines. The American Association of Cell Biology surveyed members to assess the increased difficulty that PhDs had in moving into full-time work. The National Research Council's 1998 Trends in the Early Careers of Life Scientists brought the "crisis of career expectations" into the mainstream. The 2000 NRC report to NIH Addressing the Nation's Changing Needs for Biomedical and Behavioral Sciences concluded that the flow of new Phds to the field was "well above that needed to keep pace with growth in the US economy and to replace those leaving the workforce as a result of death and retirement".

To examine these questions, we use data from the National Science Foundation's (NSF) SESTAT files[3]; interviews with 31 principal investigators at several research centers, interviews with PhD students and post-doctoral fellows in some of their laboratories; and a survey of undergraduate biology concentrators at Harvard university. In addition, we compare the career information that biology departments provide prospective graduate students with the information that professional schools provide their prospective students. From this evidence, we develop a model of how the job market for biological scientists works. We use the model to interpret the disconnect problem and to assess ways to improve career prospects for younger PhDs.

Section I of the report describes the work force and research activity in the biosciences. Since NRC and NSF publications document employment, earnings, and career patterns, the description is brief. Section II examines some important features of the market for young bioscientists: the mixing of education and employment, the years spent moving from the PhD to a job, the long hours worked; low salaries; and the low lifetime earnings that make the field a relatively poor economic investment. Section III reports on the responses of students to the job market. Section IV probes the reasons for the disconnect between the intellectual success of the field and career opportunities. The final section considers ways to structure the market to make careers more attractive and less precarious for new entrants.

The main theme of our analysis is that the disconnect results from the way careers for biologists are organized, rather than from any short term supply-demand imbalance. We argue that the incentives to principal investigators and other participants in academic bioscience create a self-perpetuating "tournament style market" where small laboratories compete for research grants through extensive hours of work and inexpensive graduate student and post-doctorate labor. This situation is unlikely to change unless the main stakeholders in biological research seek ways to reform the tournament, and NIH provides the extra research support that any reform will require. Stabilizing PhD production will reduce supply pressures in the market but not reform the career structure.

I. The Biology Research Enterprise and Work Force

[3]SESTAT is a comprehensive and integrated file that combines information from several surveys on the employment, educational, and demographic characteristics of scientists and engineers (S&E) in the United States. It was created by the National Science Foundation (NSF) to provide data for policy analysis and general research, and is the best source of data on the scientific work force in the United States.

In 1999 there were an estimated 128,050 PhDs in the biological sciences and 21,390 PhDs in the related health sciences, constituting a bioscience PhD work force of nearly 150,000 persons (Table 1). Most of these PhDs worked in what the NSF identifies as the life science field,[4] where they made up the vast majority of PhD life scientists. Fifty-eight percent were employed in colleges and universities, 5 percent in other non-profit private employment, 10% were employed by government, and 28% were employed in the business sector. Of those employed in colleges and universities, three quarters said that they were active in research and over half said that their primary work responsibility was research. Within academe, the proportion whose primary work responsibility is research has risen since 1973.[5] This trend reflects the expansion of R&D activity in the 1990s in many traditionally non-research universities. At the same time, the business share of bioscience research activity has increased, as bio-technology has been one of the economy's fastest growing sectors.

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[4] The NSF publishes some data following one set of definitions of fields and other data for different definitions of fields. Fields can also be defined either by the highest degree obtained or by occupation. For a discussion of NSF some of the problems in counting the science and engineering work force, see Melissa Pollak, "Counting the S&E Workforce -- it's not that easy" NSF Issue Briefs, May 3, 1999.

[5] See NSF, Science and Engineering Indicators 2000, appendix table 6-28 for the proportion of academic doctoral scientists with work responsibility for R&D and appendix table 6-30 for trends in primary work responsibility.

Table 1 presents data that describe the PhD work force in the biological and health sciences and the PhD work force in science and engineering more broadly (including bioscientists). The biosciences and health sciences have relatively more women than other science and engineering fields. Over half of the work force in health sciences are women. Expansion of the bio-tech sector notwithstanding, most biological scientists continue to work largely in colleges and universities. The table shows, however, that a sizable proportion of those in academe are not employed in tenure or tenure track jobs. They are in the "not applicable" category, which consists largely of post-doctoral positions for which there is no tenure. As a result a much smaller proportion of PhD biologists have tenure or tenure track positions than other PhD scientists and engineers. In addition, a relatively large proportion of PhD scientists with life science degrees work in non-S&E jobs. In 1997, when NSF estimated that 162,500 persons held PhDs in life/related sciences, only 109,096 PhDs listed bioscience as their occupation. Biosciences gained 22,000 PhDs from other fields, sent 21,000 PhDs to other science and engineering fields, and lost about 54,000 PhDs to non-science work, based on the degrees and occupations reported by scientists in the 1997 SESTAT data files.[6]

From the 1970s through the 1990s, employment in the basic biomedical sciences increased rapidly. It increased by 43% from 1975 to 1985 and by 47% from 1985 to 1997 (Table 2). In both periods, moreover, R&D expenditures for research in the area grew more rapidly in real terms than the number of bioscientists, so that the ratio of R&D to researchers -- a key determinant of salaries in the field -- increased. The paucity of data on researchers and spending by sector[7] show that from 1973 to 1985 and from 1985 to 1997, expenditures on life science research in academic institutions grew more rapidly than the number of life science academic researchers over approximately the same periods. From 1985 to 1997 company funded bioscience research spending increased more than the number of bioscientists working in industry. Although the data cover different groupings of biological scientists, they all show that total research spending increased more rapidly than the number of researchers, ruling out any demand-side explanation of the job market problems facing bioscientists.

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[6]This was the highest outflow of people from any PhD science field where they received their degree save for political science. See NSF Science and Engineering Indicators 2000, appendix table 3-2. Note the table does not record the period of time over which the flow occurred.

[7] This is the only source of data available on expenditures by field of research. Because the employment and R & D spending data come from different surveys with differing field definitions, only crude comparisons can be made.

The federal government, particularly the National Institute of Health (NIH), plays a major role in shaping the bioscience job market. The major single source of bioscience research funds is the federal government, and NIH is the single largest source of federal funds.[8] The government influences both the supply and demand of research activity. It affects supply through policies on post-doctorate fellows and research assistantships and through its fellowship grant policies. NIH is the single largest funder of graduate students and post-doctorate fellows and the market leader in determining the level of stipends[9]. In addition, government policies toward the entry of foreign students and scientists affect the supply of biological science researchers. On the demand side, the federal government determines demand for bioscientists via federally funded research grants and through policies toward universities and private firms doing research.[10]

The most rapidly growing area of employment of bio science PhDs is industry. Bio- technology firms have developed close ties with principal investigators in universities and hire a rising proportion of new PhDs. While the growth of doctoral bioscience employment in business may decelerate, an increasing proportion of new PhDs are still likely to find jobs in that sector. The traditional doctoral education and the lengthy postdoctoral training designed to produce university researchers may not be fully appropriate for them.

II. Characteristics of Bioscience Research and Job Market

Biological science in universities is "little science". A typical research laboratory is run by a principal investigator (PI) whose name is attached to the laboratory. The PI directs post-docs, graduate students, and a technician or so, all of whom work with the labs' equipment in its own space. The students and post docs perform most of the basic work in laboratories. They are paid stipends rather than wages. They depend on the laboratory and university for their education, career development, and income. Large labs have a few more post-docs and grad students, and a visiting researcher or two, but with the exception of a few large research centers associated with universities, university biology research remains dominated by individual investigators pursuing their own work with a small team of students and post-graduates. Universities pay PI salaries, though some PIs, particularly in medical schools rely on "soft money" in the form of grants to cover their pay.

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[8] To a greater extent than almost any other field outcomes in the bioscience market depend on federal policies. Meteorology is the most striking exception.

[9] According to NIH, Office of Extramural Research, NIH statement in response to <u>Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists</u>, "NIH supports about 30% of all biomedical graduates students". NSF, <u>Graduate Students and Postdoctorates in Science and Engineering</u>, Fall 1999 Supplemental Tables, table A-21 shows that 20% of all full-time biological science students listed NIH as their primary source of support.

[10] The federal government can be thought of as a monopsonist, given its important role as funder of basic researcher, but its power is greater than that of a standard monopsonist because the government also can affect the supply side of the market.

The little science structure of bio-science research gives the job market for bioscientists a distinct set of features, some of which contribute to the disconnect between the field's intellectual success and the career difficulties that face potential new entrants.

1. The education/work link

Academic bioscience depends on inexpensive graduate student and post-doctorate labor to perform research. Because the PI is both employer and teacher and the student/worker is both employee and student, laboratory work arrangements are analogous to apprenticeships, which invariably creates a natural tension over the time when studying ends and work begins. The student/worker is often most valuable to the laboratory when he/she is ready to leave to undertake independent work. If the educational needs of a student meshed with the work needs of PI, or if all PIs managed conflicts perfectly, this would create no problem. But the pressures on the PI to obtain results to gain research funding and the need of the graduate students and post-docs to develop an independent scientific and personal life almost guarantees some conflict of interests. The power in the relationship lies with the PI – a situation which many students feel deeply.[11]

The need for graduate student and post-doctorate fellows to perform research is a critical factor in how university departments operate and how the job market works for new bioscientists. Bio- science departments admit graduate students in part to obtain researchers for the labs of senior professors. Principal investigators recruit post-docs to undertake research on their grants. Some of the principal investigators we interviewed were explicit about this:[12]

> "Research labs are driven on cheap labor in the form of graduate students"
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> "They (graduate students) are necessary for the research program of faculty"
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> "Many institutions view graduate students not as individuals training for careers but as a labor force"

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[11] The blurred line between education and work is not unique to the biological sciences. Graduate students do much teaching in colleges and universities. In humanities, senior professors benefit from graduate students taking research seminars or advanced courses and teaching the basic courses, freeing the senior professors to pursue their scholarly agenda. Breneman (The Ph.D. Production Process: A Study of Departmental Behavior, University of California, Berkeley, Ph.D. Economics Dissertation, 1970) has shown that these incentives are an important determinant of the longer period it takes students to complete their PhDs in some fields than in others.

[12] Throughout this report, we give representative quotations from PIs. Our interviews were all done on a confidential basis, so that we do not provide the specific attribution.

"The practical considerations of having the manpower to make labs runs drives how many graduate students to accept."

"It (the biology research enterprise) developed historically on the backs of cheap labor in the form of graduate students."

Many university departments in addition to biological sciences rely on graduate student labor. This has led students to form trade unions and negotiate collective bargaining arrangements to cover their wages and working conditions. Many state labor relations boards, which govern labor relations in state and local government, have decided that graduate student teaching and research assistants at state universities are employees protected by state labor laws. In April 2000 the National Labor Relations Board has decided that graduate students in private universities do sufficient work to be classified as employees, with the rights to organize that such a position holds[13]

Bioscience is unique in that the day-to-day student work in research is funded from the PI's research grants, rather than from the University. In the humanities, faculty often support the demands of their teaching assistants for higher pay, unionization, or other benefits since the money comes from the University and has no direct effect on their careers. In biosciences, increased pay would raise the cost of research from grants and reduce the amount of research in a PIs lab. The extended post-doctoral period also maintains the student/employee relationship long after students have matriculated.

Many of the students we interviewed felt that much of what they do in the laboratory is more work than training.

"I consider myself out of the training phase. In grad school you're not really getting training; after two years, you're basically just working."

"I've always been a pair of hands for PIs"

"It (the biology post-doctorate career structure) serves the people at the top and not the people at the bottom."

"Personally, I think the PD is a waste of time ... a way to keep people without pay for a longer period."

[13] http://www.aflcio.org/news/2000/1120_nyu.htm. For a more detailed discussion of the NYU decision, see the GESO Voice, "Graduate Students are Employees -- it's official" May 2000, http://www.yaleunions.org/geso/voice/NYU-May2000.htm

For their part, PIs view graduate students and post-docs as critical inputs in their work. Most said that both graduate students and post-docs became fully productive in the laboratory relatively quickly. Graduate students who joined the lab after completing their course work often made a full contribution within 6 months. Post-doctorates were viewed as fully productive in a shorter span of time. Many post-docs and graduate students quickly became partners in the research. The pressure to produce research in the most economical way dictates that labs use post-docs, who receive stipends rather than salaries, rather than regular employees. As one PI told Science, "You get the biggest bang for your buck by using postdocs."[14]

[14] Donald Brown, quoted in Science, vol 285, 3 September 1999, p 1518

In the market as a whole, mixing education and research work links the supply of biology graduates to the demand for research.[15] The demand for student labor helps determine the scale of the training system. This is clearest for post-docs. If principal investigators cannot obtain post-doctorate fellows from the US they will widen the locus of search outside the US. For their part, graduate departments can adjust admission standards to have enough graduate students to supply PI labs with RAs. In the biological sciences, the proportion of full-time graduate students with a research assistantships as their primary mode of financial support increased from 26% in 1980 to 40% in the 1990s.[16] The NRC report, Trends in Federal Support of Research and Graduate Education, has documented the close link between federal research spending in an area and graduate enrollments. For instance, the 21% drop in constant dollar federal funding for university research in physics from 1993 to 1997 was accompanied with a 22% drop in graduate enrollments from 1993-1999. By contrast, the biosciences had an 18% increase in funding and 2% increase in student enrollments over the same periods. Looking across all fields, there is a clear positive relation between federal research spending, students supported, and graduate enrollments in the data, although the NRC data does not pin down the appropriate lags well.[17]

2. Delay to job

In the 1990s the typical PhD in biological sciences entered the job market in his or her mid thirties. The median length of time between entry into a PhD program and graduation with a degree in the basic bio-medical sciences in 1997 was 7.83 years. The median age for getting the degree was 30.92 years.[18] For PhDs in non bio-medical fields, the median age was 34.1. The median time holding a post-doctorate job after obtaining the PhD was 3.8 years.[19] Thus, it takes close to 12 years of doctorate and post-doctorate work before the bio PhD who follows the standard post-doctorate path to enter the job market.[20] Someone who obtains their baccalaureate at age 22 will enter the job market at about age 34-35.

The delay to the job in the 1990s is considerably longer than in the recent past. Median years to the PhD has gone up by 1.8 years since 1970.[21] Median years as a post-doc has gone up by approximately

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15 Goldman and Massey make the link between the need for graduate students as employees and training a key component in their analysis of the job market of PhDs.

16 NSF, Science and Engineering Indicators 2000, appendix table 6-41

17 NAS Board in Science, Technology, and Economic Policy, Trends in Federal Support of Research and Graduate Education (2001), p 13. The key data are in table D-1.

18 National Research Council, Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists, table G-1.

19 NAS, Enhancing the Postdoctoral Experience for Scientists and Engineers, table B-9, where the figures refer to biological scientists.

20 We recognize that one adding the two medians does not give the median delay, but given that the published data are medians, we use these figures in this manner to get an approximate picture.

21 NRC, Trends in the Early Careers of Life Scientists, table E.7 shows that 31% post-docs in

the same amount, 1.8 As a result, the median age for a biological science PhD obtaining their first job has gone up by 3.6 years..[22]

With many years working in laboratories, bio science PhDs bring to their first job a wealth of research experience. To have a reasonable chance of obtaining an assistant professorship at a university, a post-doctorate must complete significant research, with publications preferably in major journals as well as in more specialized journals. Comparing the situation today with that in the past, one principal investigator said that "We look at our own job candidates and think that if we were competing against them with our CVs when we were looking for jobs we would not be competitive." Another PI said that the market for new faculty had changed from one where job offers were based on promise to one where they were based on accomplishment.

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the PhD graduating class of 1989-90 had greater than 4 years of post-doctorate training compared to 19% in the graduating class of 1969-70.

[22] National Research Council, Trends in the Early Careers of Life Scientists table E-7 shows a median years of post-doctorate training of 2 in 1969-70. NAS Enhancing the

From one perspective, biology has effectively adopted the medical training path, where it takes 10 or more years of training to become a specialist (4 year education; 3 years of internship; 3 years of further specialization). But biology PhDs earn significantly less than MDs[23]. And the long training period and reduced chance of getting an academic job has shifted the risk of whether a new PhD will be succeed from the university to the job candidate.

3. Extensive hours worked

> "If you work 9 to 5 and take off weekends, you'll never make it"

> "My mother is always telling me she worked hard to get us out of the sweatshop and here we are back in it."

> "My supervisor ... would work until 2 AM. (It made me realize I wanted to have a family.)"

> "You have to work your butt off ... you have to deal with uncertainty at every level. It's not for everybody."

Even in a nation of workaholics,[24] bioscientists stand out as putting in long hours. The PIs, post-docs, and graduate students we interviewed said that they worked about 60 hours per week. Most said that late-nights at the lab were frequent. And, as the preceding quotes indicate, there was widespread agreement that success in bioscience requires long work hours.

Postdoctoral Experience for Scientists and Engineers, table B-9, gives median months for biological scientists of 46 or 3.8 years.

[23] The American Medical Association reported that the median income, after expenses, for all physicians was about $164,000 in 1997, which compares to the $56,000 for biological science PhDs shown in table 4. See http//stats.bls.gov/oco/ocos074.htm#earnings

[24] The US currently leads the industrial world in hours worked over the year, in large part because Americans have not followed the historic pattern of increasing vacation hours as incomes rise. See International Labor Organization, "Key Indicators of the Labour Market 1999,"International Labour Office, Geneva, Switzerland

Data from the NSF confirms this picture of long hours even compared to other PhD scientists (see table 3). In 1995 PhD biological scientists averaged 48.4 hours per week – 2.4 hours more work per week than other PhD scientists or engineers. Nearly one third of PhD biological scientists put in 60 or more hours per week[25] compared to 24% of other PhD scientists. Bioscience PhDs aged 35-44 worked about 50 hours per week.[26]

Long working hours make it difficult for people to balance raising a family and a career. This is a particularly great problem for women, who typically do most child-rearing. Among all PhD biologists, men work more hours than women, but among those without children, the pattern reverses and female bioscientists work more hours than male bioscientists.[27] The overall difference in hours worked by gender is due to the presence of children. Having children aged less than 2 reduces female work time to 42.2 hours. Having children aged 6-11 and even children aged 12-17 also reduces working hours for mothers compared to women with no children. By contrast, hours worked among men rises with the presence of children. Men with children work more hours than men without children.[28]

The drop in hours worked among women with children is likely to have a more deleterious consequence on their career progression in bio sciences than in other scientific specialties. This is because the biosciences are making such rapid progress. One indicator of this is the median number of years of citations in journals (citation half life). Preston has shown that bio sciences had the shortest citation half lives of all science fields in 1992 and also the most rapidly decreasing half-lives from the 1980s until 1992. She finds that this rapid pace of progress makes it difficult for women to take time off because of child-bearing and then try to return to the normal career progression.

4. Low salaries

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[25] Our interviewees thus fit into the upper third of PhD bioscientists in terms of hours worked..

[26] There is also a difference between hours worked of biologists and other scientists among the small sample that was past retirement age but still working.

[27] But female bio scientists work more hours than do men in other sciences.

[28] That the presence of children reduces work hours of women and increases work hours of men is found throughout the work force.

Annual earnings in the biological sciences are below those in other sciences. This is shown in table 4, which records the median PhD salaries for biology and other scientific occupations overall and separately for those working in the university sector.[29] The gap between bioscience and the other occupations ranges from 14% (physical sciences) to 25% (economics and computer science), and 40% versus PhD scientists and engineers working as managers. The gap in median income with doctors is even more dramatic. In part this is because interns are not included in the sample of physicians while post-docs are included in the sample of engineering and science PhDs. Still, removing the post-docs by focusing on PhD scientists and engineers in their 40s would still leave a massive difference.[30] More detailed comparisons using multi-variate statistical analysis that compare researchers with similar demographic characteristics (age, gender, race) place the bioscience deficit at around 5 percent in annual earnings relative to other science and engineering PhDs, Since bioscientists work exceptionally long hours, hourly pay of bioscientists falls even further below that of other scientists and professionals. We estimate that, all else the same, PhD bioscientists are paid about 10 percent less on an hourly basis than other PhD scientists[31].

The largest percentage earnings gap between bioscientists and other scientists occurs at age 30-34, when many biologists still work as post-docs or have just left their post-doctorate position for a first job (figure 1). PhD biologists aged 30-34 make 2/3rds the salary of other PhD scientists and engineers. There is, moreover, no overtaking in salaries in later years to compensate for this. Compared with other professionals, such as business school graduates or lawyers, who are generally paid more than PhDs, the salary disadvantage of getting a bioscience PhD is even greater. In the 1990s median lawyer salaries were on the order of $85,000 and median MBA salaries were on the order of $102,000, which compares with the $56,000 shown for biology PhDs in table 4.

There is a wide distribution of earnings around the average in the biological sciences as in other occupations. Some PhDs make much more than average while others make much less. This adds an element of risk to investing in training . Figure 2 displays one widely used measure of dispersion of earnings for PhD bioscientists -- the standard deviation of the ln of earnings. The dispersion is quite high, indicative both of differences in individual characteristics and in salary policies of different employers. An additional risk in pursuing a bioscience career is that the chance of gaining an independent academic position has decreased in recent years. Because it takes such a long time to reach the job market, moreover, the risk of getting a career return on years of investment in schooling

[29] These data relate to the occupation in which people work rather than to the degree they hold, though data by area of study show a similar pattern.

[30] Biological and agricultural scientists 40-44 have median annual salaries of $60,000 while those aged 45-49 reported median annual salaries of $65,900. NSF, Characteristics of Doctoral Scientists and Engineers in the US: 1997, table 52.

[31] This is based on ln regressions. The coefficient on bioscience in the regression for annual earnings was .049, which translates into 5.0%. The coefficient on bioscience in the regression for hourly earnings was .096, which translates into 10.1%.

are more important than they would be in fields where a person graduates into full time employment after 2-3 years of training.

5. The lifetime income disadvantage

It is difficult to measure economic rewards in careers which have a long education or training period because one needs information on earnings over the lifetime or of prospective earnings in succeeding years Since earnings early in a career are more valuable than earnings received later (they can be invested and earn the going rate of return), moreover, analyses that compare career earnings usually measure rewards in dollars discounted to present value at some going rate of interest or as an internal rate of return. Since it is easier to think about the lifetime income disadvantage in terms of annual salaries, we transform differences in discounted lifetime earnings into their equivalent in annual salaries.

Life-time earnings in biology are lower than in other high-level careers for two reasons: bioscientists are paid less than other highly educated workers at any given level of job experience, and bioscientists take longer to obtain full-time jobs. The two factors cumulate to a huge life-time economic disadvantage -- on the order of $400,000 in earnings discounted at 3% compared to high-paying PhD fields such as engineering, which also require many years of preparation, but where graduates do not in general delay entry into the job market to take post-docs. This is equivalent to a salary disadvantage of approximately $25,000 per year for every year of working life.[32] Medicine, which has a similar career as the biosciences due to residency in hospitals after completion of training has approximately twice a discounted lifetime income as in the biosciences.

The economic disadvantage is greater when we compare bioscience to professions that require less preparatory training. Consider for example a person who has just graduated from a 2 year MBA program. To make matters specific, the Boston University School of Management reports that in 2000 first year MBAs earned $77,000 in base salary and $12,560 in signing bonus (without stock options)[33]. A bioscience PhD from the same university who completed their post-doctorate training might earn $50,000 as a starting assistant professor. But the MBA graduate would have spent 2 years in school compared to the 10-12 years that bioscientists spend as graduate student and post-doctorate fellows. The longer time period to obtain a job and the salary differential cumulate to a lifetime difference in earnings, exclusive of stock options, conservatively estimated at 1.0 million dollars discounted at 3% -- which is comparable to $62,000 per year of working life.[34] Add in the

[32] These are all approximations based on cross section earnings data. Using the 1997 NSF median earnings, PhD bioscientists have a net present value lifetime income discounted at 3% of $1,116,000 while PhD engineers have a value of $1,529,000. With a return of 3% a present value of $413,000 is roughly equivalent to $25,000 a year for someone who starts working at age 30.

[33] http://management.bu.edu/smg/news/index.asp#Rankings

[34] For these calculations, we took a starting MBA salary of $80,000 and assumed a lifetime income profile with the same shape as weekly earnings for managers with master‘s degrees as given in

options and bonuses that managers get and this differential could easily double.

the Current Population Reports Consumer Income Data File for 2000. The discounted value for the MBA was $2,176,000

Since PhD training has always taken longer than professional school training and PhDs have always had lower lifetime earnings than MBAs, lawyers or doctors, it is more useful in understanding the current job market to consider the economic cost of the 4 or so additional years it takes the biology PhD to reach the job market than in the 1970s. Because the delay occurs at the outset of the career, it has a large impact on lifetime earnings discounted into current dollars. A 4 year delay is comparable to a $6,700 per year reduction in earnings per year for every year over the working life.[35] For women who pursue a career in bioscience, the biological clock on family formation and child-bearing adds another critical cost to the delay.

III. Supply Side Responses

How does the career structure of the biosciences affect the supply of students to the field? To what extent do prospective entrants recognize the pluses and minuses of a career in biological sciences? Is bioscience losing top students to other disciplines because it offers insufficient economic attractions?

1. Selectivity and adaptation

The characteristics of bioscience careers discussed above create an environment that will select young researchers with attributes suitable or who can adapt readily to the characteristics. What kind of people are these likely to be? To delay obtaining a first job until one is in the early thirties when classmates with professional school degrees are progressing in their careers requires students who have a long time horizon (low discount rate), considerable fortitude, and a willingness to postpone family responsibilities. To work extensive hours requires workaholic attitudes and willingness to sacrifice social life. To accept low earnings and risky prospects requires a low valuation on income and economic security. While many of these characteristics may be positively associated with scientific productivity, they are not the same thing. Selection into biological science research requires a distinct set of preferences beyond scientific talent. Most of the PIs we interviewed recognized this:

> "(The issue) is whether all of their skills are commensurate with being able to compete for what are in the end very high pressure jobs ... with lower remuneration and greater uncertainty (than business)."

> "The ones who have left ... were bright enough ... but found the lifestyle too demanding."

> "You don't do science for money."

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[35] Again, this is based on a simplified spread sheet simulation. The discounted value of a stream where a person takes two less years to get their PhD and two less years to move from post-doc to a job raises their present value by some $122,000 or about $6,700 in annual salary.

> "(It's) the career path as a lifestyle decision ... not having a paying job for 4 to 5 years after graduate school, and then not knowing where it was, and ... another 5 years before tenure."
>
> "The people who want to do it, do it. Period"

2. Information about career prospects

If students are aware of the risks of investing in a bioscience research career when they choose graduate training, dissatisfaction later has less cogency than if they are unaware of those risks. For this reason, and to improve student choice, the NRC Committee on Trends in the Early Career Patterns of Life Scientists recommended in 1998 "that accurate and up-to-date information on career prospects ... and career outcome information ... be made widely available to students and faculty. Every life science department receiving federal funding for research training should be required to provide to its prospective graduate students specific information regarding all predoctoral students enrolled in the graduate program during the preceding 10 years." [36]

To find out whether bioscience departments followed up on this or the recommendations of other groups to improve the provision of information to prospective students, in spring 2000 we surveyed ten leading biological science departments in the US[37] about the information available to students considering a career in the biosciences. For purposes of comparison, we also surveyed professional schools to see what career information they provided prospective students. The results show a striking difference in the availability of information about job outcomes between biological science and professional schools.

Bio departments had information available about time to degree and percentage of matriculating students who obtained the PhD, but not about job placement. Most departments were uncertain about which office kept track of the appropriate statistics, and when we tracked down offices with information, they often had fewer statistics than the departments thought. Department representatives emphasized the difficulty of tabulating outcome data gathered for the purposes of training grants and said they didn't

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[36] NRC, Trends in the Early Careers of Life Scientists, Recommendation 2, p 6.

[37] The departments were Harvard, including both the faculty of arts and sciences and medical school, Wisconsin, Pennsylvania, Stanford, University of Washington, University of Texas Southwest Medical Center, University of California San Francisco, University of Chicago, Berkeley, Rockefeller Institute.

have the time to try to do so. No department had a job placement advisor, though in some universities career counseling offices tried to help students leaving academic science find non-academic jobs. Three departments said that they kept track of long-term outcome data for training grant reports but that the data existed only in confidential list formats.

The lack of information about job outcomes reflects the "little science" structure of bioscience. An official at the Harvard Medical School told us that it was up to individual labs to gather data, and that the PIs relied on informal channels – seeing former students at conferences and the like – to keep tabs on their progress. Indeed, all of the PIs in our interviews were able to place virtually of their graduate students and post-docs. Some PIs with larger labs produced lists of graduates and post-docs with their current positions, and none complained about the time or difficulty involved in determining where members of their "research family" were. But because the information is located at labs rather than centrally, it is effectively inaccessible to prospective students to graduate programs.

By contrast, all of the professional schools – law, business, medical – tracked the salary and position of their graduates through Student Affairs or Career Services Offices or told us the information was available through alumni and development offices. We surveyed nine major business schools. All provided detailed data on starting salaries and jobs, often on the school web site.[38] Berkeley's business school has a placement list that included career trends, top employers, top 5 industries/functions, summer internships, as well as information on jobs and salaries. Harvard's business school contained median and percentile salary statistics, times of job offers, and potential employers (http://www.hbs.edu/career_services/step5/page5-1.html). The Boston University Graduate School of Business highlighted on its home page that starting salaries for graduates were $89,560 in 2000 (exclusive of options) and that MBA salaries rose by 30% over the previous year.[39]

The difference between the information at biology departments and at business, medical, and law schools reflects the difference between arts and sciences and professional schools. Professional schools attract students by placing graduates in good professional jobs, and the school takes responsibility for recruitment. In biological sciences, recruitment takes place at the laboratory level Still, one might expect that a bio-department that has a good job placement record could attract better students more easily than one with a poor placement record, and would advertise as much. Perhaps the quality of placements is so well correlated with the ranking of schools that students already know that the chances of a good job are better from university X than university Y.

3. An undergraduate perspective

"... the future of science needs these kids opting to do science. And they're not opting to." (S.

[38]Harvard, Wharton at University of Pennsylvania, Berkeley, Wisconsin, UT Austin, University of Illinois, Columbia, UCLA, and Boston University.

[39] The data were moved to http://management.bu.edu/smg/news/index.asp#Rankings

Tilghman, quoted in The Scientist, 14 (19): 32, Oct 2, 2000).

To learn how undergraduates from top universities view PhD level careers in biology compared to other fields, we surveyed Harvard students enrolled in the main bioscience concentrators' course. We asked them about their knowledge of careers in biological sciences and their career intentions.[40] While Harvard students are not representative of American students in general, they are reasonably representative of students at top US universities.

Most students said that they had a diverse set of skills and interests that give them a wide choice of alternative major fields of study and careers. Ninety percent of the students surveyed classified themselves as having versatile skills and interests rather than as specialized exclusively on science (table 5). The implication is that the biosciences compete for the best and brightest with many other disciplines. Students "on the margin" between biological research and other fields are not exclusively looking at medicine as the alternative, though the majority intended to go to medical school after graduation.

Overall, students had a mixed picture of the job market for biological scientists. A quarter thought that there were many good jobs which offered a chance for independent work; eighteen percent thought the job market was so poor that there was little chance of obtaining an independent scientific career; while the majority fell somewhere in between these extremes. The students recognized that it would take a long period of post-doctorate work after completing a PhD to get a job in the field. And they recognized the difficulty of obtaining a tenure track university position: only 10% of those who responded thought that they had an excellence chance of obtaining a tenure track job if they were to pursue biological research. Asked about the salary that biologists made, students gave realistic numbers: $28,000 for a starting post-doc, $52,000 for an assistant professor, $77,600 for a full professor. Asked about the salaries for the comparison group of MBAs, they also gave realistic numbers: $68,500 for a starting MBA and $178,000 for an MBA with comparable experience to a professor.

We asked the concentrators an open-ended question "What would make a bio sciences career more appealing to you?". The responses showed that a significant number of students were deterred by the potential economic difficulties in the field. Over fifty percent volunteered that economic career issues in the form of salaries or a more secure career path would make the field more appealing. Here are some representative comments about the changes that would most appeal to these students :
"some way of lowering chances of being stuck in lab doing someone else's project for long, long time".

"If I knew my career would progress with time – in terms of salary, (and) independence"

[40] We gave students a book certificate for participating in the survey and obtained nearly 100 respondents for an extremely high response rate.

"More money!"

"Higher salaries"

"Mo' Money"

"More secure job prospects"

" If there's not 20 separate labs working on the same problem repeating the same stuff with only one person getting credit (whoever's first to publish)"

"Make postdoc/grad student positions less like indentured servitude"

"Reasonable pay, easier entrance into independent work"

We also asked students about the impressions they obtained about the job market from various sources. Table 6 groups the responses into four categories: positive impressions; negative impressions; mixed impressions; and none, where the student said they got no information from the source.[41]

The majority of students said that they received no information about the job market from the Biology Department. The few that did receive impressions from the Department were more likely to report positive than negative impressions about job prospects. Students who learned about the job market from professors also obtained a more positive than negative reading of the job market, though not as positive a one as the departments. But most students said that they got impressions about the job market from graduate students and post-doctorate fellows and they reported predominantly negative impressions. In addition the 70% of students who said they obtained impressions of the job market from their family also reported that negative impressions far outweighed the positive impressions. The following comments shows the way students reported these negative impressions.

"There is no job market. I need to go professional"

"Jobs are hard to come by."

"No money to be made in bio"

[41] This table covers the 60 or so students who volunteered answers, so that the none category is a response rather than failure to answer the question. We classified the responses into positive, negative, and mixed.

> "Research? Does that mean you're going to be poor the rest of your life (to which the student added ... not good impression of job market)"

> "The salary and personal value ... is hardly worth the time devoted and the loss of family time and personal social life".

Because Harvard students come largely from academic and professional family backgrounds, they may have more information from their families than do other students. That the potentially highly knowledgeable families of the "best and brightest" group see the long arduous path to a bio science career as something for other folks' kids is striking. Concern over career problems among students at top US universities is not limited to Harvard. Surveying its June 2000 graduates, Princeton University's molecular biology department reported that only three out of 72 were going into PhD or PhD-MD research programs – a yield far below that in earlier periods.[42]

[42] This was reported by Douglas Steinberg, „Another Study Raps PhD Overproduction" in The Scientist http://www.the-scientist.com/yr2000/oct/prof_001002.html. At Harvard the number of undergraduate students who concentrated in biology fell in the late 1990s. In 1994 biology had 448 concentrators; in 1998, it had 303 concentrators. In biochemical sciences the drop was from 353 to 226. But since most majors go on to medical school, this could reflect a drop in interest in medicine.

There is scattered evidence that suggests the bioscience has problems holding the best and brightest of US students more broadly. The 1995 National Survey of Recent College Graduates, which covers students who graduated with bachelor's or master's degrees in science and engineering in 1992-93 or 1993-94 asked respondents to give their undergraduate grade point averages -- one indicator of their ability. Of graduates with grade point averages of 3.75 to 4.0, proportionately fewer (21%) bioscience bachelor's recipients remained in their same science field as of 1995 than of bachelor's recipients in all science and engineering fields (32%).[43] Among graduates who obtained a Masters degree, the pattern is similar: 45% of top biology students remained in the field compared to 59% of Masters degrees in other science and engineering fields. In all disciplines, what dominated the decision to leave science and engineering were: lack of jobs; pay and promotion opportunities; and change in interest. Among bachelor's graduates with GPAs in the 3.75 to 4.00 range, 21% cited lack of jobs, 23% cited pay/promotion opportunities, and 18% change in interest. Among master's graduates, 42% cited lack of jobs, 12% pay or promotion, and 18% change in interest. While some may question the validity of self-reported reasons for leaving science, the dominance of job market factors over change in interest makes it clear that career prospects are prominent in the thinking of these top students.

In addition, PIs at two leading research universities observed a decline in the proportion of their graduate students from the top US universities. One stressed that almost no students were applying from Ivy League schools to graduate biology at his university. The other PI was "happy there are small liberal arts colleges, where students do not appreciate fully the career situation faced by young biologists, so our department gets some very bright young applicants." We have not examined whether this pattern generalizes to other leading PhD programs.

4. Degrees and enrollments

While the biological sciences may not be attracting as many students from the top universities as in the recent past, the field has still maintained its production of degrees and increased its share of graduate enrollments compared to other PhD areas. Table 7 shows that from 1989 to 1998 the number of PhDs in biosciences increased by 42%. This increase exceeds the increase in all PhDs and the increase in the number of people in the age group that typically receive their PhDs. Much of the increase in bioscience PhDs came from women and from non-US citizens. The share of degrees granted to women rose from 37.5% in 1989 to 43.3% in 1998; while the share of degrees granted to non-US citizens rose from 19.8% to 26.2%. The number of PhDs granted to native born men increased only slightly

Over the same period, the number of PhDs granted in specific areas of bioscience changed substantially (table 8). Nine sub fields had rising shares of bioscience PhDs. These areas raise their share of bioscience degrees from 29% to 41%. Eleven sub fields had declines in their share of bio degrees

[43] Tabulated from NSF Retention of the Best Science and Engineering Graduates in Science and Engineering, www.nsf.gov/sbe/sr/nsf99321/text.htm, Table 3.

granted. The share of bio science degrees in these fields fell from 57% to 44%. This reflects the responsiveness of students to the swings in opportunity among fields due to changes in scientific productivity, funding, and fads in interest.

In the late 1990s, enrollments in graduate sciences in the US fell modestly, leading the National Science Board to warn the country that the drop in graduate science enrollments could be economically damaging (Chronicle of Higher Education, 23 June 2000). The number of graduate students enrolled in the biosciences dropped less than in other fields, so that the bioscience share of graduate students increased from 12.3% in 1990 to 14.1% in 1998. Given that the number of Americans with bachelor's degrees stabilized in the later half of the 1990s
as the number of 20-24 year olds fell by nearly 20 percent from the 1980s[44], stagnant graduate enrollments in biosciences and in other sciences should not be a cause for "shortage" alarms. In fact, 1999 graduate enrollment in science and engineering was up slightly.[45] In any case, the question for the biosciences is the opposite one: why in the face of worsened career prospects has the field increased its supply of students relative to other PhD fields?

There are two possible factors at work. The first is that the intellectual excitement generated by the rapid pace of scientific advance dominates economic rewards for many students. The supply curve of students to the field may be far more response to the potential for contributing to knowledge than to economic incentives. The supply curve may also be highly inelastic, so that students will be barely deterred by declining economic prospects. The entrepreneurial nature of PI careers, the shifting of PhDs from one sub discipline to others in response to changing prospects, the shift in the demographic mix of entrants to the field from men to women and from American citizens to the foreign born, and the responses of Harvard concentrators to our survey are not consistent with an "inelastic" supply story, though undoubtedly the intellectual excitement must have shifted supplies in recent years.

The second explanation is that the supply is largely set by the researchers' demand for graduate student employees in laboratories. Increases in research funding generates increases in student enrollments, as departments widen their search to new geographic areas or reduce standards for admission. If biosciences cannot find students or post-docs in the US, the field will recruit and accept them from outside the country, where there is a very elastic supply of potential researchers, drawn in part by the chance to come to the US.

In either case, the economic problems in the field will not cure themselves by the reduction in supply that normally occurs in an occupation when job prospects worsen for new entrants.[46]

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[44]NSF, Science and Engineering Indicators 2000, appendix table 4-7

[45]National Science Foundation Data Brief NSF 01-312, January 11, 2001

[46] When earnings fall below expectations, the normal market adjustment is for the supply of new entrants to decline until an equilibrium is reestablished. Given the time delay between graduate training and entry into the job market, the period of self-correcting adjustment can be quite long and can

generate cyclical “cobweb” swings in which supply and demand oscillate out of balance for some period. This occurred in the 1980s in physics due to cutbacks in research funding (Freeman, 1975) in the 1990s in mathematicians (Davis); and underlies the perpetual shift between shortages and surpluses of BS engineers (Freeman, 1976)

IV. The Structure of the Bioscience Job Market

In university-based bioscience, the PI is a scientist/entrepreneur responsible for choosing the research topics and publishing output; for raising and juggling budgets and managing employees who have diverse interests and skills. The lab operates much like a small family-owned business [47] The PI work closely with their graduate and post-doctorate students, relying on personal relationships and the dedication of students to science rather than money to motivate them. The students form research families, with close personal as well as professional ties to their peers and the PI.. And just as small family-run businesses operate in a highly competitive market, where the slightest edge can be the difference between success and failure, so too do the labs of many PIs. Virtually all the PIs we interviewed regularly received NIH support, and many won other grants as well. Still, they worried about raising funds since failure meant a stoppage of activity. They offered conservative high probability of success proposals to NIH, usually extensions of previous work, and often assigned their post docs to these projects, since post doctorate careers depended on successful completion. The PIs did more innovative and risky research "on the side" or with other money, and assigned or encouraged graduate students to undertake such projects (since they had time to recover from failure).

Worried about being "scooped" by competing labs, PIs and their students work long hours. Many PIs seek as many post-docs in their lab as their funds permit on the notion that the more post-docs, the higher will be the lab's output. One PI described the situation vividly, "If I have 3 post-docs and we work all the time, I have a bigger chance of getting my results out first than if I have 2 post-docs and I take off weekends". The small businessperson might have said "if I keep the store open weekends or late at night, I have a bigger chance of getting additional customers than an otherwise identical business which is open fewer hours."

1. The tournament model

[47]The analogy between a research lab and a family business resonated with some of the PIs that we interviewed:

"My lab is like a store that rents space in the University mall. Indeed, I moved from the West Coast to Boston because the University here gave me more floor space"

"My farm background – seeing my father run the family farm – helps me run my lab."

"Face it, a lot of (science) is driven by recognition and interest from the field. A lot of it is very individual and entrepreneurial."

Economists have developed a tournament model of market work that seems to fit the biology research job market.[48] A tournament market operates by making the chance of winning a prize – tenure, named chairs, scientific renown, genuine prizes – a major part of career rewards. Well-structured tournaments stimulate effort among those who have the skills to compete for the prize. They generate greater inequality in rewards than in output, since the winner may gain the prize by being just a trifle better or quicker than other competitors – completing the key experiment a week earlier than the next lab, for example. The analogy is with golf tournaments, where many professionals have a chance of winning and where slight differences in performance can produce large differences in career success and financial rewards.

Under some conditions, tournament job markets are socially efficient, producing high effort and output from all participants, though they distribute rewards unequally. Tell three bright students that the one who does best will get a good job and all three may work longer and harder than if the rewards were more equally divided.. Rewarding the winner with the extra value created by the effort of all three may be a greater motivator than paying each for their individual contribution. Under other conditions, however, tournaments can produce outcomes where everyone would be better off if the market were organized differently. Let three bright students know that the last one to leave the laboratory at night gets the job, and all three may work into the night even if the extra hours worked does little to advance knowledge and makes them miserable. This is what is popularly called a rat race. Alternatively, perhaps two of the students, realizing that they cannot compete with the third in hours worked, may decide to reduce their hours and effort, lowering total output.

Tournaments are most likely to generate productive effort when potential participants have reasonable chances of winning. In biology, many researchers, be they PIs, postdoctorates, or graduate students, have sufficient scientific talent and the appropriate equipment to make a big discovery. Scientists working in Scotland with only modest scientific reputations can undertake a risky experiment and produce Dolly the cloned sheep. When a new technology or idea opens up virgin research territory, many PhDs with research experiences and training can rush in and with luck grab the "low hanging fruit". To the extent that the chance of finding something extraordinary rises with increased effort, researchers have strong incentives to work many hours and to hire as many post-docs or graduate students as possible.

The link between hours worked and scientific success that underlies the tournament model can be seen in NSF data on hours worked, publications, and pay. To succeed in science, one needs publishable research findings – the more publications, the greater the chance of getting ahead. Bioscientists typically publish more papers (short reports of experimental findings) than scientists in other fields. The 1995 Survey of Doctorate Recipients shows that bio scientists averaged 6.7 publications from 1990 to 1995

[48] Edward P. and Rosen, Sherwin. "Rank-Order Tournaments as Optimum Labor Contracts." Journal of Political Economy, Vol. 89, No. 5, (October 1981), pp. 841-864.

compared to 4.7 publications over the same period for other science and engineering PhDs. Over 20% of bioscientists published more than 10 articles in this period.

Figure 3A shows that the PhD bioscientists who reported more hours worked also had more publications. Using a regression model to summarize the data, an extra 5 hours of work per week was associated with approximately one additional publication. Figure 3B shows that the number of publications is associated with higher pay (up to 50 publications and then drops slightly). Persons with substantial publications earn 60% to 90% more than those without publications. Using a regression model, each publication earns a bio scientist approximately 0.9% higher salary. In short, scientist who work more hours publish more and earn more. To be sure, these data are cross sectional, and thus do not provide an ideal estimate of the impact of hours worked on papers published or earnings. If more able researchers work more hours than less able persons the cross section data overstates the extent to which an extra hour worked by the same person would increase publications and pay. If less able researchers work more hours, the converse is true. But the fact remains: bioscientists who work more hours have better career outcomes.

2. Incentives

The goal in a tournament model is to be a prize-winner. To win, a PI must obtain research findings and publish results before competing laboratories. Trying to get the most output from a given budget gives PIs an incentive to keep productive graduate students and post-docs in the lab as long as possible and to orient students toward academic research that builds on the laboratories' work. Outside the tournament setting, senior scientists might prefer to pay their post-docs more, give them more time for family life, and so on, but they adapt to the incentives facing them. If graduate students provide cheap labor, labs will use them as their primary labor input. If NIH sets post-doc stipends at low levels, senior scientists will pay those levels even though they recognize that this creates economic hardship. If producing graduate students and post-docs with intensely focused and narrow specializations helps PIs win the research tournament, they will do so even if alternative forms of training, or leaving the lab earlier rather than later might better serve the students. If, as one PI told us, "it is more prestigious for the faculty member if a student graduates from your lab and pursues an academic path" they will favor students with academic career plans over those with other plans. Much the same incentives operate among students. A PhD student will often hide interest in possibly working in industry or going into teaching from their advisor, for fear that the advisor will lose interest in them and their work.[49]

Departments are also driven by the tournament style rewards. They compete for professors with outstanding scientific reputations. That the bioscience department gave Harvard concentrators a favorable impression of the job market for biology reflects the benefits to the faculty of having students

[49] This is not unique to biology. Economics students do the same, surprising advisors in the final stages of their PhD dissertations by suddenly announcing a job at McKinsey or Goldman-Sachs or some other firm.

enroll in the field. Even if a department believes that the job market is not working well, so that incoming students should be warned about prospects, to do so by itself would be irrational, since the department that gave such rewards would lose relative to competing departments.[50]

[50] Still, this is what the Berkeley English Department did in the 1970s to make sure that its graduate students understood the prospects facing them.

The incentives facing government research funding agencies, such as NIH, are more complex. A tournament structure that generates good research by employing idealistic young graduate students and post-doctorates, many from other countries, at low cost is a good expenditure of taxpayers dollars. But complaints by US graduate students, post-docs and others about their career prospects generates adverse publicity. Ultimately, the potential loss of the best and brightest from the pool of American students to the field can generate long term problems. This makes some agencies sensitive to potential shortages of PhDs but not to potential surpluses. It helps explain why the National Science Board proclaimed a possible shortage of PhD students at the same time that two NRC committees reported that young PhDs in the biosciences were having economic troubles (NRC 1998, 2000). In its deliberations the Committee on National Needs for Biomedical and Behavioral Sciences explicitly sought to balance the dependence of research on student labor with the desire to stabilize the supply-demand situation in the field.[51]

Professional societies, such as ASCB, AAAS, ASM, AACR, FASEB and others must also worry about the long term prospect of maintaining a system where many participants are unhappy. As representatives of the scientific community, such organizations reflect the interests of members, largely principal investigators and leading scientists, but in a wider context of what is best for the field in the long run.

3. Will career prospects for new PhDs improve naturally?

Our analysis of the bioscience job market suggests that the market for young entrants is unlikely to improve by itself.

On the supply side, the ratio of tenured faculty to doctorates in 1997 was the lowest among all science and engineering fields (see table 9). This guarantees a continued supply pressure on the market for academic jobs. The other field with a markedly low ratio of tenured faculty to doctorates, chemistry, has proportionately half as many Phds working in the university sector as the biological sciences.[52] The possibility of continued increases in the supply of graduate students and post-docs from abroad in response to research assistantships, moreover, implies continued supply of Phds into the future. Barring a sudden reduction in the supply of students from overseas, say because US-Chinese relations

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[51] NRC, Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists, chapter 2.

[52] NSF, Characteristics of Doctoral Scientists and Engineers: 1999 Early Release Tables, table7 shows that universities and 4 year colleges employed 54.9% of biological scientists compared to 27.9% of chemists.

worsened, or some other breakdown in foreign relations, the supply of new Phds will continue to raise the number of PhD bioscientists, absolutely and relatively to employment in general in the US.

On the demand side of the market, the Bureau of Labor Statistics currently anticipates an increase of 35% in bioscience jobs at all degree levels from 1998 to 2008 and an increase of 26% in jobs in the medical sciences. These changes, while larger than the expected 14% growth of employment economy wide are much smaller than the 51% projected for science and engineering overall[53], and imply a deceleration in the growth of demand for the biological sciences. At best, they could stabilize the current situation. The NAS Committee on National Needs for Biomedical and Behavioral Scientists projected increased demand for between 1500 and 3000 new biomedical PhDs compared to an annual supply of nearly 5400, which implies a marked worsening in the job market prospects for new PhDs.

There is, however, a wide band of uncertainty around all demand projections. Predicting the market for PhDs is difficult given that demand depends critically on federal funding, which can shift with the state of the government budget or with new initiatives. During the preparation of this report, the US moved from a budget surplus, which made it easier to fund science, to a potential recession-induced deficit to a war against terrorists, whose consequences for research funding are uncertain. In addition, if demand for bioscientists grew rapidly in the business sector, the higher salary scales compared to stipends for graduate and post-doctoral students would surely alleviate some of the job market problems of new PhDs.

That unanticipated demand or supply shocks can greatly change the market balance does not, however, gainsay our claim that normal market adjustment processes are unlikely to improve the career prospects and earnings of new PhDs in the biosciences. Absent structural reforms in the market, the tournament market incentives will perpetuate the pyramid career structure, benefitting senior investigators at the expense of new entrants in almost any plausible future. No single principal investigator or department, however well-meaning, can change the current steep pyramid career structure nor raise the stipends of post-docs without suffering a competitive disadvantage in fund-raising. Any substantive change in the structure of the bioscience job market has to be global, supported by NIH and other outside funders of bioscience research and guided by the principal participants in the market through their professional organizations.

V. Reforming the Market

> "There is a pressing need to make sure that PhDs are received before social security ... a combination of lab selfishness and ... economic incentives ... prolongs this process." -- PI

> **"I don't find a whole lot wrong with it ... It's not broken" -- PI**

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[53]NSF, Science and Engineering Indicators, 2000, Appendix table 3-28

"Any time you make a major change you're lucky if things are a little worse than they were before you started." -- PI

As the preceding quotations indicate, some of the PIs we interviewed believe that the biological sciences job market should be changed to improve the job situation for new entrants. Some who favored change were disdainful toward second or third tier institutions that filled slots with foreign students because they could not attract Americans and recommended solving the job market problem by simply shutting down „inferior programs". Others were leery of change and fear that the risks of changing the system exceed potential benefits. Most of the PIs we interviewed, however, had not considered deeply the merits of any particular set of reforms

Such a divergence of views appears to be representative of the profession more broadly. In 1997 the ASCB conducted a survey of its members, which showed a range of opinions. Ninety per cent of PI's responding agreed that it was increasingly difficult to find an independent position and acquire funding. A slightly smaller proportion also believed that too many PhD's were being trained, and that the field had grown too competitive. But those same PI's were divided on what remedies to apply. None of several possibilities listed on the survey gathered majority support. The one favored by the largest number of PI's (37%) was to cap the funding to any one laboratory, which would be difficult to execute and would have at best an indirect effect on the supply of jobs and trainees. It would also risk lowering research output.

There is no comparable divergence among the postdocs or graduate students we interviewed about the seriousness of the problem and need for immediate reforms. This also is consistent with the results of other recent assessments. In its special report The World of Postdocs, Science told about the job insecurity and problems of postdocs and summarized what postdocs want in the form of institutional changes: written contract, uniform title and benefits, representation on committees, university post-doc associations.[54] In 1999 the Johns Hopkins Postdoctoral Association laid out an 8-point plan for reforming the post-doctoral employment relation.[55] The Nature report on the March 2001 Washington meeting organized by the National Academies' Committee on Science, Engineering, and Public Policy to discuss follow-up to the COSEPUP report, Enhancing the Post-Doctoral Experience for Scientists and Engineers stressed the different urgency for change in modes of mentoring and pay between postdocs and representatives of NIH and NSF.[56]

When we began this study, reforms in the bioscience job market to improve the economic prospects of young scientists seemed unlikely. Given that the tournament style market has accompanied (and

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[54] Science,vol 285, 3 September 1999, 1515

[55] http://www.med.jhu.edu/jhpda/news/news_items/PDAproposal.html

[56] Corie Lok, "Postdocs Call for Better Pay and Conditions," Nature 410,137 (March 8, 2001).

possibly produced) rapid scientific progress in the field, reforms are likely to come slowly, so as not to endanger a successful research enterprise. Now, however, changes are on the horizon, for a number of reasons.

The first reason is that top NIH officials recognize that young bioscientists have legitimate complaints about the job market, and have committed the Agency to act on this. The NIH responded positively to the call by the NRC Committee on National Needs for Biomedical Scientists in 2000 for substantive reforms in the structure of the bio science job market. It committed itself to giving 10-12 percent increases per year in post-doctorate stipends until they reach a target of $45,000 for entry-level postdoctoral students and $25,000 for graduate students and looked favorably at "the concept that postdoctoral trainees should be converted to non-training staff or faculty positions at the earliest practical opportunity ...with appropriate levels of income and benefits ... that such costs be built into future competing applications." (http://grants.nih.gov/training/nas_report/NIHResponse.htm)

The second reason for expecting reform is the growing unionization of students and the advent of collective bargaining for graduate students. Students in bioscience labs are less likely to join unions than students elsewhere in universities because they work personally with PIs (much as the employees of small firms are less likely to join unions than those of larger firms). Still, at several locales, postdocs have formed postdoc associations, to express their concerns to the relevant institution.[57] In any case, unionization of graduate students occurs campus-wide, not department by department, and campus wide collective agreements could cover bioscience RAs and potentially postdocs. At the minimum, graduate student unions will add a vocal force for improving work conditions and pay for research assistants and post-docs in the biosciences.

The third reason for expecting reform is that too many NAS committee reports and other reports have directed attention at what we call the disconnect problem for it to be brushed under the rug. There is growing recognition that the biosciences cannot expect to attract the number of "the best and brightest" US undergraduates that it deserves on the basis of the potential for scientific progress if career opportunities are poor relative to those in competing fields.

The key question, then, is what possible reforms or package of reforms could make the job market work better for new entrants while minimizing the risk that the changes will bring more harm than good to the overall research enterprise?

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[57] The National Academy lists 19 associations on its web site, but not all of these may be currently active (www4.nas.edu/pd/postdoc.nsf/web/postdoc_associations?OpenDocument). See also Dan Ferber, "Getting to the Front of the Bus" Science, September 3,99, vol 285, p 1514.

Almost any reform that raises the earnings or changes the career structure in the field in ways that increase lifetime incomes for young entrants will require additional funding to maintain the amount of research. A policy that raised post-doc stipends or created staff scientist jobs paid regular wages in place of some post-docs without increasing research budgets would reduce research output. PIs would look for ways to economize in the face of increased costs, but would have to cut some projects to pay the additional labor charges.

In addition, it is important to recognize that any policy that improves the economic position of young scientists will generate offsetting supply responses that will reduce its impact on the earnings and career prospects. For instance, a policy that improves the earnings of post-docs will make it more attractive for students to pursue a career in biology. This will increase the number of students who enroll in biology PhD programs, which in turn will increase the competition for post-docs and ultimately reduce the earnings of researchers later on. Offsetting changes in supply cannot, however, totally undo the effects of a reform, for they are contingent on some improvement in lifetime career prospects.

With these considerations in mind, we consider four interrelated reforms designed to change the mode of funding graduate education, postdoctoral training and level of pay for laboratory work; and the career structure in academic laboratories. The purpose of these reforms is threefold: to give students a greater role in managing their own careers and to shift the balance of power in the PI-student relationship toward students without setting up intervening organizations, ombudspersons and the like; to improve the economic rewards to bioscientists, so that the most able students will go on in the field; and to reduce the linkage between research grants and the supply of new entrants.

Reform 1: Shifting the balance between fellowships/traineeships and research assistantships by creating more fellowships controlled by graduate student recipients

The first reform would be to increase the number of graduate students supported by fellowships relative to the number of graduate students supported by research assistantships. The main argument for this change is that it would empower graduate students to be better able to "bargain" with departments and PIs about the nature of their education and training. Limited evidence from NIH shows that students funded by traineeships or fellowships have shorter times to degrees and are more likely to receive research grants,[58]but this would be an added bonus, not the main goal of the change.[59] We would

[58] Pion, Georgine, "The Early Career Progress of NRSA Predoctoral Trainees and Fellows" NIH 00-4900 March 2001, Appendix, p D-7, D-42 and D-43. But not every outcome variable shows traineeship/fellowship students doing better than others, and NIH has properly worried over selectivity since NRSA awards have never been awarded randomly to PhDs to see what affect they have on career outcomes.

[59] This change was recommended by both recent NAS committees reviewing the bioscience job market (NAS, 1998; 2000) but has received little support from NIH. http://grants.nih.gov/training/nas_report/NIHResponse.htm discussion of recommendation 2-2, objected

expect efficiency gains to come as students press departments to offer programs that are more relevant to the non-university based careers that an increasing proportion will follow in the future. By giving students the funds, it would encourage universities to innovate in graduate education to meet potential student demands.

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on the notion that it is an attempt to stabilize the number of graduate students, which goes beyond the purpose of research assistantships and training grants. A program of this type has also been proposed by Paul Romer, "Should the Government Subsidize Supply or Demand in the Market for Scientists and Engineers?" (NBER Working Paper 7723, June 2000).

Giving more fellowship and traineeships to graduate students would restore the balance between fellowship/traineeships and research assistantships that existed when the current set of PIs obtained their education in the field. In 1975 57.6% of graduate students in the basic biomedical sciences receiving federal support were supported by training grants and fellowships. In 1997, by contrast, only 26% of federally supported students received fellowships or grants. There was a mass transformation in the mode of graduate student support to research assistantships. Between 1975 and 1997, the number of NIH and other DHHS traineeships and fellowships fell by 22% while the number of NIH and other DHHS research assistantships increased by 306%!.[60] In the biological sciences in total, 18,499 full-time graduate students supported themselves through research assistantships compared to 5,803 who received fellowships and 5,285 who received traineeships.[61]

To implement such a change, NIH would have to increase the number of NRSA recipients. In addition, because universities receive approximately $7,500 less in indirect costs for NRSA recipients than for graduate student research assistants,[62] NIH would have to give more in indirect costs with NRSA awards. But to the extent that graduate students with NRSA type awards continued to do research on projects funded by NIH, there would be a partial offset in those costs. This reform is a structural one, not a financially expensive one.

Reform 2: Creating New Post-Doctorate Fellowships.

In 1999 there were 15,910 postdoctoral appointees in the biological sciences, 73% of whom were supported by the federal government. Just 1,437 of these postdocs had fellowships and 1,074 had traineeships.[63] The rest were covered by research grants. While we know of no study that compares

[60] NAS, Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists p 24 and Table G-7, p 117

[61] NSF , Graduate Students and Postdoctorates in Science and Engineering: Fall 1999, table A-23.

[62] NAS, Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists, table 2-1.

[63] NSF, Graduate Students and Postdocs in Science and Engineering, Fall 1999 Supplemental Tables, Table A-17

the career outcomes of the postdocs with fellowships or traineeships and postdocs funded on research grants, those with fellowships should be better able to control their research careers than those depending on RA moneys controlled by PIs. Given the complaints that postdocs have made about mentoring and the unwillingness of NIH and NSF to include mentoring outcomes as part of the grant proposal review,[64] giving moneys to the postdocs that they could take from one lab to another would allow them to choose labs where postdocs are treated better. Labs could, moreover, compete with extra moneys for the services of post-doctorates, which would raise the total income of the postdocs.

At present, Howard Hughes Medical Institute (HHMI) gives predoctoral fellowships to students in their first and second year of training to last for 4 years but does not provide fellowship support toward the end of their graduate careers. NIH and HHMI could give highly successful students in the 4th years or 5th years of their PhD studies 4 year fellowships that would provide funding for their completing their PhD work and that would cover a substantial fraction of their ensuing postdoctoral training. This would help identify and strengthen the position of the 'best' students and give them greater freedom in pursuing their own research agenda. A similar piece of bridge funding could go to especially well qualified postdocs at the end of that part of their training to help them finish postdocs and set up their own labs. .

These changes would also be relatively inexpensive, since they would largely involve shifting the way post-docs are supported rather than increasing the cost of research. Laboratory A would have to bargain differently with postdoc X over his/her working in the lab because the moneys would be lodged with the post-doc rather than with the research grant of the lab. Some labs might find it preferable to hire full-time workers, along the lines of staff scientists laid out below. They would make it easier for younger scientists to pursue their own ideas as post-docs, which has the potential for improving research productivity.

Reform 3: Raise post-doctorate stipends to "living wages" levels for PhDs.

This is the route that NIH seems to be looking on most favorably with its commitment to raise post-doctorate stipends to $45,000. The quicker this is done, the better. A more radical change would be for NIH to set post-doctorate stipends at a level proportionate to the average salary of, say, assistant professors or other full-time bioscientists as determined by a national survey, and raise stipends as those salaries increased. Paying apprentices a proportion of the earnings of masters is one way other occupations have dealt with the problem of determining apprentice earnings. And indexing payments to changes in prices or wages is a common feature of some government programs, such as social security. The virtue of this approach would be that stipends would rise automatically as salaries increased in the field and thus would not lag behind salaries because administrative adjustments were slow. At the

[64] See Corie Lok, "Postdocs call for better pay and conditions," Nature 410,137, March 8, 2001.

minimum NIH would have to justify why stipends did not rise in a particular year commensurate to the increase in salaries.

Unlike reforms 1 and 2, raising post-doc stipends would require increased budgets for research grants, less it reduce the amount of research. In addition, increases in stipends and grants would best be made simultaneously, for older grantees and post-docs as well as new grantees and new post-docs.

Reform 4: Creating staff scientist jobs in university labs

This is the Marincola-Solomon proposal,[65] which is gaining support from diverse groups, ranging from NIH to postdocs. It directly addresses the structural problem of the tournament style job market by offering a non-tournament style career option. A number of PIs whom we interviewed favored this because it would create a place for full-time scientists who may have fine scientific skills but who are not entrepreneurial in the grant world ("I favor staff scientists who do not write grants");and because it has the potential for increasing the productivity of labs by reducing turnover ("Every lab could use senior associate/manager familiar with research and rhythm of lab work"; "There is need in labs for scientific continuity, which a permanent position could bring."). Since staff scientists would be paid wages rather than student level stipends, it would increase the costs of research and thus require additional grant moneys.

Such a proposal would affect the job market and market for research along two dimensions: reallocating the work done in labs, and raising the costs of the work. Consider first a representative lab where research assistants (post-docs or graduate students) paid out of a research grant currently do the day-to-day work, but which then creates a full-time staff scientist job to do some of the work instead. Assuming for simplicity that total labor input remains the same, there will be one less RA employed in each period. If the RAs and the staff scientist worked in the lab for the same number of years, the reform would be largely relabeling.

But the staff scientist job is meant to be a relatively permanent one. If the staff scientist stayed at the job for twice as long as an RA, the lab would be reallocating its labor input from RAs to the staff scientist. For concreteness and simplicity assume that before the change the lab had 5 post-docs working on 5 year contracts, with one person in each year of the contract. Thus, there is a steady state workforce of 5 persons. Over ten years the lab would have a total of 10 RAs. Addition of a staff scientist who will hold a job for 10 years, would mean employment of 1 staff scientist and 8 RAs over the period, so that there would be demand for one less RA. Work which had been allocated uniformly would now be concentrated on the staff scientist. Alternatively, the lab could reduce the length of RA appointments

[65]Elizabeth Marincola and Frank Solomon. "The career structure in biomedical research: Implications for training and trainees," The American Society for Cell Biology Survey on the State of the Profession. Molecular Biology of the Cell, 9:3003-3006, 1998.

and still employ 10 people over the period.[66] The key point is that as long as the staff scientist position is longer than the RA position, it causes a reallocation of work in the lab, reducing demand for RAs. On the cost side, the cost differential would depend on the pay given between the staff scientist and the average pay of an RA.

How might this reform change the supply-demand balance in the job market? On the one hand, it would make bioscience careers more attractive, just as would an increase in post-doctorate or graduate student stipends. But it would also change the selectivity into the field by attracting people with scientific skills who find tournament-style competition and grant-raising unattractive. At the same time, however, this reform would reduce the link between research funding and the training of new entrants that has made it difficult for the job market to adjust to worsened opportunities in the normal way. The net effect should be to shift the supply of new entrants from entrants generated by research support to entrants generated by long term career considerations.

While each of these reforms can stand alone, we note that they complement one another in many respects. The higher the post-doctorate stipend, the more attractive will be staff scientists to PIs because there will be a smaller cost advantage to post-docs. Reduced demand for research assistants by PIs who hire staff scientists fits with greater support of graduate students and post-docs through fellowships.

In one sense, all of these reforms seek to differentiate better the education received and work performed by students and post-docs, which the current mode of financing and research has intermingled to the detriment of young bioscientists.

Conclusion

We began this report with the observation that there is a disconnect between the remarkable scientific progress in biosciences over the last several years and job market prospects in the field. The obstacles facing young people trying to establish an independent position are documented by National Science Foundation data. These obstacles may be discouraging promising young people who otherwise would have chosen a career in biomedical research. The graduate students and post-docs we interviewed are clearly aware of these problems, and are interested in the various remedies we presented to them. The

[66] Let RA be the number of research assistants and DAR be the duration of an RA position, SS be the number of staff scientists, and DSS be the duration of that job. Total work time is RA x DAR + SS x DSS, which we assume fixed. When DSS>DAR, the creation of an SS slot necessarily reduces either RA or DAR.

PI's we interviewed had a more complex response. We interviewed leading scientists with a substantive record of publication and training working in top research departments. Most of them candidly discussed the rigors of their jobs: the long hours, uncertainty, competitiveness. Compared to other careers available to people with similar talents, bioscience offers "...very high pressure jobs...with lower remuneration and greater uncertainty." Several agreed with the graduate students and post-docs that much of the duration of their positions is devoted to work rather than to training. They agree that following this career track means "...not having a paying job for 4 to 5 years after graduate school." These leaders of the profession agree with the trainees and the available data on the costs of a pursuing a career in bioscience.

However, many of the PI's expressed reservations about remedies. Although postdocs are willing to consider any of several approaches that would relieve their own situations, many PI's are less willing to engage changes. The system is "not broken," and the risk of "washing dirty laundry" in public is too great. These PI's point to the tremendous success of the biomedical research enterprise. They hope it can continue without reform, and they are understandably cautions about changes which they fear may cause more harm than good. Obviously, any effort to reform the career structure and modify the job market without the support of leading PI's will be extremely difficult.

However, the costs of not changing may be mounting. Research in the biosciences is more dependent than any other field upon the young people it attracts; they are both the major laboratory work force today and the future principal investigator work force in the future. Should the quality or quantity of trainees decline in response to the job market, leading scientists would notice the difference. A decline in quality may be signaled by our interviews with undergraduate Harvard biology majors. The reasons they give for turning away from careers in research – a weak employment market, poor compensation, a demanding job that impinges on a family life – correlate well with the N.S.F. data that describe the experience of present

researchers. The attitudes of these competitive undergraduates may explain why one distinguished PI finds few applicants from Ivy League schools.

As significant as these attitudes are is the way they were formed. The undergraduates cited the graduate students and post-docs they knew as a major source of information, and overwhelmingly describe that information as negative. What the Harvard undergraduates learned from post-doc and graduate student colleagues is consistent with what we learned from them. Many of them reported that the training component of their employment was ended during the first year in their labs. They saw themselves as "...a pair of hands..." and as "...serv[ing] the people at the top." Even in graduate school they are '...basically just working..." and the post-doc is "...a waste of time." For undergraduates at the point of decision, the graduate and post-doc students they meet represent their near future. The dissatisfaction and pessimism spread by these contacts might well be strong enough to convince even a young person with an appetite for science to re-examine options.

There has been considerable speculation in the last several years that the rise of bio-tech companies will provide ample and well-compensated employment for our trainees. The future of this relatively new industry is uncertain; we do not know how many scientists it can absorb, and at what level of training. The initial indicators are not encouraging. During the last 15 years, as bio-tech emerged, the time to the doctorate degree and the time in post-doc positions lengthened. Longer periods in such positions are clear evidence of a supply-demand imbalance that expansion of bio-tech has failed to offset. If the capacity of bio-tech does increase, this will create problems for academic research that will add pressures to reforming the career structure. New PhD's may have the choice of a protracted post-doc at a post-doc's stipend, and a job that pays enough to have a family and offers the potential for career development doing much the same kind of work. Bio-tech may also offer jobs that do not require doctoral training, on a salary scale that is more attractive than that of the academic sector.

We think that these forces will be noticed – indeed, that they are already evident. They have the potential to pressure the system for changes that can conserve what is best about the culture of academic science. To arrive at that point, the leaders of the profession – the prominent investigators, the leading departments, and most importantly the funding agencies – must act to reform a system that is in danger of losing a crucial element of its success, the nation's and the world's most promising young people; and that is by all accounts failing to offer its young entrants the career opportunities and rewards commensurate to their contribution to scientific progress.

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Table 1: The Phd Biosciences and Life-Sciences Work Force, 1999

Field of Highest Degree	Biological Sciences	Health Science	All S&E
Numbers	128050	21390	626700
% Full-time Job	72.5	80.7	78
% Part-time Job	5	7.5	6.5
% Post-Doc	10.5	2.4	3.8
%OLF / not retired	2.8	1.9	2.1
Unemployment Rate	1.2	1.3	1.3
% Female	29.9	54.4	24
% Native born	82	84.1	78.5
% Working in Life Sciences	59.3	--	18.8
% Working in non SE	34.4	--	25.8
Industrial Distribution			
% Education	57.5	57.8	46.2
% Nonprofit	4.8	5.4	5
% Business	27.7	26.1	39.1
% Government	9.9	7.8	9.4
Within Higher Education (4 or more)			
Tenure	42.5	43.2	51.7
On tenure track	15.2	25.5	15.6
Not on track	14.1	13.3	10.8
Not applicable	28.1	18	21.9

SOURCE:
NSF 1999 Characteristics of Doctoral Scientists and Engineers 1999 (Early Release Tables), table 1 for first 4 lines; table 2, for unemployment rate; table 3 for gender; table 5 for citizenship; table 7, for sector of employment; table 9 for tenure track. NSF Science and Engineering Indicators, 2000, % working in life sciences; in non SE, based on 1997 Survey of Doctorate Recipients, Appendix table 3.2. -- for the health sciences because these tabulations do not distinguish health sciences.

Table 2: Percentage Changes in Number of Persons and Research Spending in the Basic Biomedical Sciences, 1973-1997

Changes in Number of Bioscientists	**1975-1985**	**1985-1997**
Total	43	47.1
Academics	44.4	43.9
Tenure/tenure track	20.4	15.8
Industry	124.7	85.5
Changes in Expenditures on Life Sciences Research (in constant 1992 $)	**1973-1985**	**1985-1997**
Total	-	60.0*
Academic	51.5	80.6
Company funded drugs / medicines	-	134.3

SOURCE:
Numbers, NRC, Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists, table G-4.
Total and company funded R&D, NSF Science & Engineering Indicators 2000, Appendix table 2-50.
Academic R&D, NSF Science & Engineering Indicators 2000, Appendix table 6-7

NOTES: * 1985-1997

Table 3: Hours Worked Per Week by PhD Biologists vs other Science-Engineering , 1995

	Bioscience	All other Science Engineering
Mean Hours Worked Per Week	48.4	46
Percentage Working Over 50 Hours	62.5	51.8
Percentage Working Over 60 Hours	31.9	24.4
Mean Hours by Age		
35-44	49.6	46.8
45-54	48.9	46.7
55-64	48	46
65+	40.7	37.2
Mean, Hours by Gender and Children		
Female	47.1	43.3
no kids	49.3	45.4
kids <2	42.2	37.8
kids 2-5	43.1	39.4
kids 6-11	43.8	40.4
kids 12-17	45	42.2
Male	49.2	46.9
no kids	48.8	46.3
Kids <2	50	47.8
kids 2-5	49.4	47.8
kids 6-11	49.7	47.5
kids 12-17	49.7	47.4

SOURCE: Tabulated from SESTAT public files, 1997. These are unweighted counts.

Table 4: Median PhD Salaries of Engineering and Science Graduates, by Occupation and Field of Doctorate in 1997

	Occupation	
	All Sectors	**University**
Economics	$75,000	55000
Computer Science	75000	56000
Engineering	73000	65000
Physical Science	65000	52000
Biological Sciences	56000	40000
S&E PhDs in Management, Median Net Income. MDs	92000	85000
	Field	
	All Sectors	**University**
Economics	$69,000	62000
Computer Science	72000	57000
Engineering	75000	68000
Physical Science	70000	54300
Biological Sciences	60000	53000

SOURCE: NSF, Characteristics of Doctoral Scientists and Engineers in the United States: 1997, table 38, 40, 41.

Table 5: Attitudes of Harvard Concentrators in Biosciences to Career Options

The alternative concentrations they had considered		Views of Biology Job Market	
Social science	30%	Many good jobs with chance for independent work	24%
liberal arts	26%	Some good/some bad jobs	57%
other science	21%	Little chance for independent Science Career	18%
neuroscience	14%	Personal chances of getting tenure track job in bio research	10%
mathematics	9%		

Plans for Graduation		Mean Expected Salaries	
Medical School	57%	Bio Post-Doc	$28,000
Bioscience grad school	17%	Post-Doc, 5 years	$38,000
Work	16%	Assistant Professor	$52,000
Other	19%	Full Professor	$77,600

Certainty about career choice		Comparison MBA Salaries	
Very certain	56%	Starting	$68,500
Somewhat certain	30%	Experienced	$178,000
Not at all certain	14%		

Differences between chosen career or alternative to biology research	
Other is more interesting	78%
Other has better employment prospects	77%
Other has higher earnings	73%
Other more prestigious	52%
Other socially more valuable	57%

SOURCE: Sample of 94 students taking the principal concentrators' course at Harvard University

Table 6: Impressions of the Bioscience Job Market from Harvard Bioscience Concentrators

What impression do you get about the job market for biology researchers from...	Positive	Negative	Mixed	None	Ratio of Positive to Negative
The Department	24%	10%	6%	60%	2.4
Professors	31%	23%	10%	36%	1.4
Grad Students / Post-Docs	24%	59%	13%	13%	0.4
Family	16%	45%	8%	30%	0.4

SOURCE: Sample of 94 students taking the principal concentrators' course at Harvard University

Table 7: PhDs Granted and Enrollments in the Bio Sciences, 1989-1998

Year	PhD Degrees Granted		Persons Aged 28-32	Graduate Enrollments		Bachelor's Degrees Granted	Persons Aged 20-24
	Bio Sciences	All PhDs		Bio Sciences	All PhDs		
1989	4116	34327	21.5 million				
1990	4328	36067	21.4	48989	397135	1062151	18.8 million
1991	4650	37534	21.4	51778	412697	1107997	18.8
1992	4799	38890	21.3	54177	412697	1150072	18.8
1993	5092	39801	21.2	56452	435886	1179278	18.8
1994	5203	41034	20.7	58143	431251	1183141	17.9
1995	5376	41723	20.2	58736	422555	1174436	17.6
1996	5723	42414	19.7	58128	415363	1179815	17.5
1997	5786	42555	19.3	57135	415689	1186589	17.4
1998	5854	42683	18.8	57060	405280	1199579	17.3

SOURCE: National Science Foundation, Science and Engineering Indicators 2000, for persons aged 28-32 obtained by taking persons aged 20-24 as reported, eight years later. Degree data from NSF Science and Engineering Degrees, 1966-98; Enrollment data from NSF, 00-307, December 15, 1999 Graduate Enrollment in Science and Engineering Continued to Decline in 1998

TABLE 8: Changing Distribution of Biosciences PhDs, 1989-98*

	Subfields with Rising Shares of PhDs	
	1989	1998
Neurosciences	4.4	7
Molecular sciences	10	12.7
Development / Embryology	0.2	2.2
Immunology	2.9	4.2
Ecology	3.9	5
Biometrics	1.1	1.3
Biophysics	1.7	2.8
Genetics: Human/animal	2.7	3.4
Toxicology	2.1	2.7
	Subfields with "Stable" Shares of PhDs	
Botany	3.9	3.9
Endocrinology	0.4	0.5
	Subfields with "Falling" Shares of PhDs	
Biochemistry	12.9	11.6
Entomology	3.4	2.4
Anatomy	1.9	0.6
Nutrition	3.1	2.3
Microbiology	8.3	6.6
Parasitology	0.5	0.3
Pathology	2.6	1.6
Zoology	3.2	1.9
Pharmacology: Human/animal	5.9	4.4
Physiology: Human/animal	6.6	4.4
Other/General	8.4	7.6

*Biomedical sciences and Biotechnology research are new categories with PhDs in 1998.

Table 9: Ratio of the Number of Tenured Faculty to the Number of Doctorates, 1987-1997 and Doctorates Likely to Enter the Academic Job Market, 1997

	Ratio		Ratio
	Tenured Faculty / Doctorate		Tenured Faculty / Doctorate x% PhDs in Universities / 4 yr colleges
	1987	1997	1997
Biological Sciences	11.9	7.4	14.9
Chemistry	11.5	9.3	76.2
Physics and Astronomy	11.5	11.3	36.2
Earth Sciences	21.2	11.3	36.2
Psychology	32.9	19.1	127.9
Medical Sciences	43.9	19.8	–
Social Sciences	46.5	25.6	33.4

SOURCE: Ratio, tenured faculty/doctorate, NAS Enhancing the Postdoctoral Experience for Scientists and Engineers, 2000, table B-14; % PhDs in universities and 4 year colleges from NSF, Characteristics of Doctoral Scientists and Engineers in the United States: 1997
NOTE: table 18. -- no breakdown for medical scientists.