Bioinformatics: Recent Trends in Programs, Placements and Job Opportunities

Report to the Alfred P. Sloan Foundation

Grant # 2002-5-58 BCMB

June 2004

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We would like to thank Eleanor Babco and Fred Fox for their help and encouragement and Donald Hemenway of AAAS for providing electronic copies of ads from *Science*. Asmaa El-Ganainy provided research assistance on this project. Cynthia Blasdell and Ruxue Xia assisted with the design of the web survey.

EXECUTIVE SUMMARY

The current study collected information on conditions in the bioinformatics labor market during the period 2000-2004. A three-pronged approach was used. First, all 74 known academic programs offering degrees in bioinformatics were surveyed in the spring of 2003 with a response rate of 59.5 percent; second, position announcements were analyzed for all bioinformatics-related ads placed in *Science* during the three-year period ending in 2003; position announcements on two internet sites were examined as well. Finally, a pilot study of seven firms was also conducted, exploring the firms' perception of the state of the bioinformatics labor market. Results of the study are compared to those from a 1999 survey of academic programs and a 1998 study of position announcements.

We find:

(1) A dramatic increase in the number of academic training programs as well as the number of individuals enrolled in programs. To wit, during the period between 1999 and 2003 the number of known programs grew from 21 to 74 and the number of students enrolled in bioinformatics programs that responded to our survey grew from 169 to 881.

(2) Little change, except at the master's level, between the 1999 survey and the 2003 survey in the number of reported placements from academic programs.

(3) That the number of newly minted individuals trained in bioinformatics during the five-year period is fairly small relative to the number of position announcements.

(4) A decrease in the number of advertised positions regardless of the level of experience or level of training. By 2003 the number of positions advertised in

Science was below the 1997 number; the number of positions posted on www.bioplanet.com declined between 2002 and 2003. The seven company interviews provide qualitative support regarding the softening of the market.

(5) A change in the source of demand, with a shift to academe and away from industry, especially for those with a Ph.D.

(6) That salaries in the bioinformatics market have risen during the 1999 to 2004 period but that the substantial wage premium associated with bioinformatics jobs in the past has virtually disappeared and is unlikely to be offered under the current market conditions.

Our analysis leads us to conclude that the bioinformatics labor market has gone through considerable change in recent years. In the context of a relatively fixed supply of specialists, salaries for individuals with skills in bioinformatics soared in the 1990s. Strong demand and the concern that the "seed corn was being eaten" led to the creation of numerous new training programs in bioinformatics. These training programs are now beginning to generate graduates. Many of these graduates assumed they would go to work in industry, yet positions in industry appear to be on the decline, and many of the positions that are available are for individuals with considerable experience. The strongest area of demand in recent years has been from academe, seeking faculty to staff new programs and to broaden research expertise. Unless conditions in industry change dramatically in the next few years, it is likely that many trainees from these programs will have difficulty finding jobs in industry.

I. Introduction

The vast amount of biological data that has become available sine the early 1990s has made computational methodologies in the life sciences increasingly important in research. This in turn has created the need for scientists with interdisciplinary skills in computational science and biology and has led to the emergence of bioinformatics as a distinct field.

Little is known about the labor market in bioinformatics, including training opportunities, except for the previous work by Stephan and Black (1999a, 1999b, 2000). In 1998 they analyzed position announcements placed in *Science* as a measure of demand, and in 1999 they surveyed all known academic programs related to bioinformatics to collect information on characteristics of the training programs, starting salaries of recent graduates, and the identity of institutions hiring these graduates.

The information collected by Stephan and Black in their earlier studies is now at least five years old. In a field that is fairly stable, data of this age can often present a reasonably reliable indication of current conditions; in an emerging field like bioinformatics, such data give little indication of the market's current condition. For instance, approximately 50 more institutions have begun to offer training programs since the 1999 survey. In addition, the media has continued to report that the field still offers opportunities and that a shortage of qualified individuals persists (Chabrow 2004; Henry 2001, 2002; Park 2001). And programs and articles cite a National Science Foundation estimate that the United States will have 20,000 bioinformatics jobs to fill by the year 2005.[1] At the same time the biotechnology industry has faced a considerable economic downturn and restructuring. In effect, there has been little

[1] The NSF projection is quoted on a number of web sites. See, for example, the joint bioinformatics track through the departments of biological sciences and computer science at San Jose State University (http://www.cs.sjsu.edu/faculty/khuri/Bioinformatics/description.html), an article in Forbes, March 15, 2001, (http://www.forbes.com/2001/03/15/0315malone.html), and an article in *Time*, April 29, 2002, (http://www.time.com/time/business/printout/0,8816,233967,00.html).

accurate information on the changing state of the bioinformatics market, including its current condition, over the past five years.

To address this dearth of information regarding the bioinformatics labor market, this report presents findings from a recent survey of academic training programs and an extensive analysis of recent position announcements. All academic programs included in Stephan and Black's original survey as well as all programs identified since the 1999 survey were invited to participate in a new survey designed to collect information on the characteristics of current training programs and the experiences of their recent graduates. The analysis of position announcements includes all bioinformatics related ads placed in *Science* in 2000 through 2002, as well as recent electronic ads listed on select internet employment boards. A pilot study of seven firms was also conducted. The seven firm interviews had two goals: (1) to provide preliminary information concerning the perception of firms regarding the state of the bioinformatics labor market and (2) to provide information concerning the best way to approach firms if the study were to be expanded to a larger, more representative set of firms.

II. Academic Training Programs

In March 2003, the 74 academic institutions with known bioinformatics-related training programs at the undergraduate, graduate, and/or postdoctorate level were asked to participate in a web survey.[2] Appendix A lists the institutions targeted for this survey and identifies those that replied. The survey was designed to elicit standardized information across institutions while offering a convenient web-based format to encourage participation and enhance data collection and analysis. Appendix B includes a copy of the survey questionnaire. Forty-four institutions

[2] Programs were identified from (1) institutions targeted in the 1999 survey, (2) professional science master's programs in bioinformatics sponsored by the Alfred P. Sloan Foundation, (3) extensive internet searches, and (4) talking with individuals involved in established bioinformatics training programs.

(59.5 percent) responded to a part or all of the survey; 30 did not.[3] Targeted institutions were initially contacted via email to provide information and to request their participation in the survey. Approximately one week later, institutions were sent an email providing a hyperlink to the web survey and instructions. Three weeks later, a postcard was mailed to every targeted institution, thanking those that had participated and encouraging non-respondents to participate. Continued non-respondents were then contacted by telephone to increase the response rate.

Eighteen of the twenty-one known programs targeted in the 1999 survey replied to the 2003 survey (85.7 percent response rate); the response rate was considerably lower for the newer programs with 26 of the 53 replying (49.1 percent). One of the 27 non-respondents in the latter group specifically declined to participate due to the newness of the program; another non-respondent has a Ph.D. track in genomics and bioinformatics that was only implemented in 2001-2002. The three institutions that participated in the 1999 survey that did not reply in 2003 are Boston University, The University of Connecticut, and Northwestern University. At the time of the 1999 survey, only one of these institutions (Northwestern) had a formal program in bioinformatics. Boston University had plans to initiate a formal program at the M.S. and Ph.D. levels in the fall of 1999.

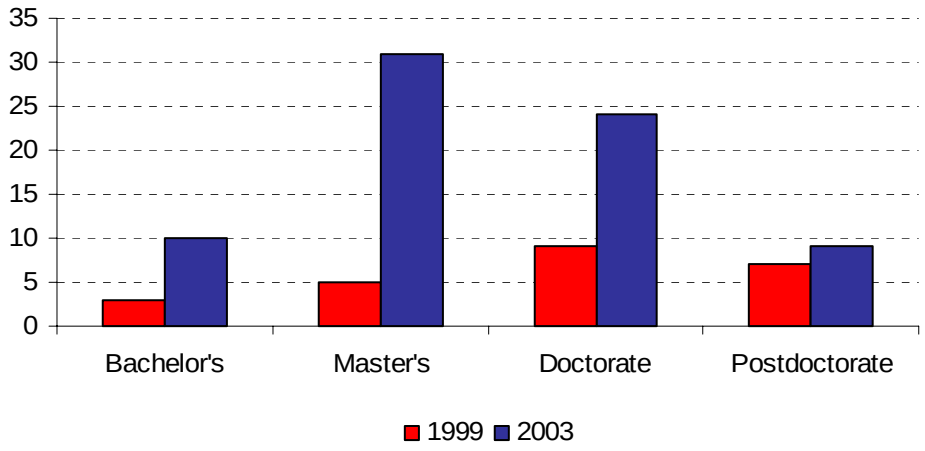
We conclude that the survey was reasonably successful at collecting information on established programs in bioinformatics. Data collected from the survey provide less accurate counts regarding newly established programs. This should not affect the accuracy of certain measures, such as graduation and placement counts, since many of the non-responding programs are too new to have graduated anyone; it does bias downward our counts of the numbers of individuals enrolled in these programs.

[3] The 59.5 percent response rate is comparable to that for the 1999 survey of 61.9 percent. The 1999 survey information was enhanced by web-based research on non-respondents. The large number of programs surveyed in 2003 limited our ability to do web-based research for the 30 non-respondents.

A. Characteristics of Programs

The number of academic training programs related to bioinformatics has grown substantially from the late 1990s to the early 2000s. Figure 1 shows the number of training programs by degree level, comparing the 1999 data with that for 2003. The highest growth was at the master's level, with over six times as many programs in 2003 as in 1999. This is in part due to the creation since the late 1990s of twelve professional science master's programs in bioinformatics, all initially funded by the Alfred P. Sloan Foundation.[4] The number of doctoral programs grew to 24 in 2003 from 9 in 1999. There are still relatively few programs at the bachelor's level though the number has more than tripled between 1999 and 2003. The small number of postdoctoral training programs undoubtedly reflects in part the informal nature of many postdoctorate training positions.

Figure 1
Number of Training Programs



[4] Nine of these twelve Sloan programs replied to the survey.

As seen in Figure 1, most of the academic programs are relatively new. Of the 10 bachelor's programs, 4 started since 2000 and another 2 began in 1999. Among the master's programs reporting start dates, 7 started in 1999, another 7 in 2000, 4 in 2001, 4 in 2002, and 1 in 2003. Seven Ph.D. programs were created in 1999 alone and seven more have been created since 2000. The reader is reminded that these counts are biased downward given that new programs were less likely to reply than were older programs. Unlike the other programs, little growth has occurred at the postdoctorate level since 1999.

Institutions participating in the survey were asked if additional levels of training were currently being considered. Sixteen institutions (36.4 percent of the responding institutions) indicated that they had no intention of expanding their current programs and another fourteen offered no indication of their plans. Over one third of the responding institutions, however, were considering additional training at different degree levels than currently offered. Five indicated interest in creating Ph.D. programs in bioinformatics or computational biology.[5] Four were considering graduate certificate programs to provide graduate level training without a full master's program. Possible master's training was being considered by four institutions, and three institutions were considering bachelor's training. Three institutions were considering additional training but did not specify at what level.

Institutions were asked the degree to which they thought their programs met student demand for bioinformatics/computational biology training at their institution. Twenty-five institutions indicated their programs mostly or completely met demand for training at their institution. Five institutions reported that they somewhat met demand, while only one institution indicated their program did not at all meet demand. Several institutions did not reply to the

[5] Institutions may have indicated more than one level of training being considered so the counts by degree level sum to more than sixteen, the number of institutions reporting that they were considering the addition of new levels of training in their programs.

question. When asked about the strength of demand for bioinformatics programs at their institution, 30 of the responding institutions perceived demand to be moderate or great, with 22 of those describing demand as great.

Comments from respondents describing demand for training at their institution and their consideration of adding additional levels of training to their current programs included:

- "An externally funded pre-doctoral training program is pressingly needed."
- "There is clear demand for a curriculum in bioinformatics at the undergraduate level that we have yet to address but are now working on."
- "Demand is strongest at the undergraduate level."
- "There is no way that we could accept all 170 grad applicants who applied this year – 16 was all we had room for. We expect the pool to be even bigger next year…."
- "We are not addressing one great area of demand – training master's level students or training at a pre-master's certificate level…. We have decided to concentrate on Ph.D.-level training, and do not satisfy this great need."
- "We are not really meeting demand of those who are not in our MS degree program. We are actually working hard to keep the classes from over-enrollment with those in other programs."
- "Students in other programs would like to have more training in this area."
- "Since [our current program] is only a summer program and since we are required to attract at least half of our students from outside the state, [our program] cannot meet the growing demand for an undergraduate training program in bioinformatics and computational biology."

The establishment of these training programs has not come without challenges. Thirty of the forty-four institutions described a problem or challenge when asked to describe the most difficult challenge faced in establishing their program. The most common challenge was a spectrum of issues broadly related to administration and university support of a program. For example, several programs had difficulty receiving approval from university administrators.

Others faced limited administrative resources and difficulties structuring programs across academic units. The next most frequently reported challenges revolved around program funding, securing faculty involvement, and curriculum development.

Across these challenges runs the underlying thread of interdisciplinarity. The interdisciplinary nature of bioinformatics programs makes for practical hurdles in their creation within the traditional university environment. It can be challenging to recruit faculty, allocate course credits and students, obtain resources, assign administrative responsibilities, and develop curriculum across departments and colleges at a given university. The difficulties surrounding the development of interdisciplinary programs are not symptomatic only of newer programs but also of early training programs, arguably contributing to the sluggish response of universities to industry's growing demand for graduates with bioinformatics training in the 1990s (Stephan and Black 1999).

B. Financial Support

No dominant pattern of financial support is evident from the surveyed bioinformatics programs. Seven institutions reported that their bachelor's bioinformatics program is fully funded internally. Fourteen of the master's programs were reported to be at least 95 percent internally funded. Six institutions fully funded their doctoral programs internally. Only one postdoctoral program reported to be fully funded internally. More commonly, many institutions have relied, to some extent, on external sources of funding to support their bioinformatics programs. Table 1 lists the reported sources of external funding for responding bioinformatics programs. External funding is less prevalent for bachelor's and master's programs. The breadth of external support is also less broad for these programs. For institutions reporting sources of

support, bachelor's programs received support from only three sources. Eight institutions reported funding for master's programs from the Alfred P. Sloan Foundation. The wide range of sources for doctoral and postdoctoral programs is largely due to financial grants awarded for research. The National Institutes of Health has provided funds across all levels of training. The Keck Foundation, the National Library of Medicine, and the National Science Foundation each have provided funds for programs at three of the four levels of training.

Table 1
Sources of External Funding for Bioinformatics Programs by Level of Training

Funding Source	Bachelor's Programs	Master's Programs	Doctoral Programs	Postdoctoral Programs
Alfred P. Sloan Foundation	X	X		
Burroughs Wellcome Fund			X	X
Department of Defense			X	
Howard Hughes Medical Institute		X	X	
Inter-university consortium			X	X
Keck Foundation		X	X	X
MDL		X		
Merck Foundation			X	
National Institute of General Medical Studies			X	X
National Institutes of Health	X	X	X	X
National Library of Medicine		X	X	X
National Science Foundation	X		X	X
Pennsylvania Tobacco Settlement Fund			X	
United States Department of Agriculture			X	
Unspecified agencies and foundations			X	
Unspecified private companies		X	X	
Whitaker Foundation				X

The sources of funding are considerably broader than those reported in 1999, when only seven sources of financial support for programs were reported. Moreover, the only overlap

across the four-year period between 1999 and 2003 is the National Institutes of Health, the National Library of Medicine, the National Science Foundation, and the Keck Foundation.

Support for students varies widely across programs and levels of training. No program-related support was reported for students in bachelor's programs. This suggests that undergraduate students in bioinformatics programs are using personal finances or other means, such as scholarships and loans, to finance their education. Financial support is more prevalent in graduate bioinformatics programs. Among master's programs, assistantships are the most common form of support reported. Master's students at twelve institutions receive research assistantships, while eleven institutions offer teaching assistantships. Eight institutions with master's programs indicated that students' employers also provide some level of funding for educational expenses. Personal support is common for master's students: 16 institutions reported that at least some students rely on personal finances to help fund their bioinformatics training, and 10 indicated that at least 50 percent of their master's students rely to some extent on personal finances.

Support at doctoral programs is more extensive. Fourteen institutions reported that students receive financial support through research assistantships; teaching assistantships were cited by five institutions as a means of student support. In addition, 14 institutions indicated that doctoral students receive support from fellowships, with 6 institutions reporting that at least 50 percent of their doctoral students receive fellowships. Other sources of support included tuition waivers, endowment funds, and industrial internships. Only two institutions with doctoral programs reported that students used personal finances as a means of support.

Due to the nature of postdoctoral appointments, sources of funding for postdoctorates come almost exclusively from fellowships and research grants. Postdoctorates at four

institutions with postdoctoral bioinformatics training programs receive fellowships; at two of these institutions, every postdoctorate was on a fellowship. Two of the institutions with postdoctoral programs reported that postdoctorates are partially or fully funded through external research grants.

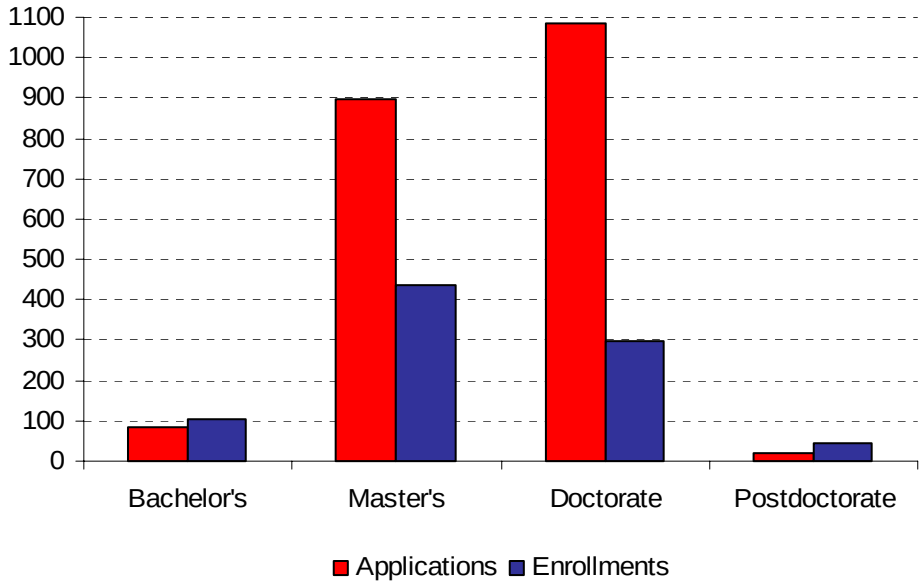
C. Enrollment

Figure 2 characterizes the aggregated size of bioinformatics training programs as of the 2002-2003 academic year. Master's programs had the highest total enrollments (435) followed by doctoral programs (296). Total enrollments were far lower for bachelor's (103) and postdoctoral (47) programs. Applications for fall 2002 enrollment were dramatically higher for master's and doctoral programs, with almost 1100 reported applications to doctoral programs and approximately 900 applications to master's programs. Yield rates varied considerably by level of training. Thirty-eight new bachelor's students enrolled, comprising forty-five percent of the applicant pool. At the other end of the spectrum, 100 students were newly enrolled in doctoral programs, comprising only 9 percent of the applicants. Master's programs saw the largest number of newly enrolled students (244), comprising 27 percent of the applicant pool, and postdoctoral programs the lowest by far (5).

Enrollments in 2002-2003 were much higher than in 1998-1999 due in large part to the rapid growth in the number of programs in the four-year period. Moreover, given that new programs had a lower response rate than older programs, the number of enrollees and the growth rates are biased downward. Undergraduate enrollments in bioinformatics programs increased from approximately 23 students in 1999 to 103 in 2003. The number of master's students skyrocketed over this period, increasing by 400. Doctoral enrollments rose substantially as well,

increasing by over 200 from 1999 to 2003. The number of postdoctorates in bioinformatics programs also increased, rising 88 percent from approximately 25 postdoctorates in 1999 to 47 in 2003.

Figure 2
Applications and Total Enrollments in Bioinformatics Programs, 2002-2003



While total enrollments across levels of training vary considerably, the average size of a bioinformatics program is similar across the levels. Average enrollment for the 2002-2003 academic year was approximately 17 for bachelor's programs, 19 for master's programs, 16 for doctoral programs, and 9 for postdoctoral programs. Three institutions had bachelor's programs with above-average enrollments. For master's programs, 7 institutions reported above-average enrollments; 6 for doctoral programs and 2 for postdoctoral programs.

D. Graduates and Placements

Programs were asked to supply information about the number of graduates as well as the number of job placements. Job placement numbers are usually considerably lower than the number who graduated. This is due in part to the fact that students often begin a new degree program after graduating or that students had yet to find a position at the time the survey was administered.

Table 2 shows the number of graduates from bioinformatics training programs for the period January 2002-March 2003. All told 152 graduates were reported. As indicated in the table, not all programs reported the number of graduates. This was usually due to the newness of the program, although in certain cases it was due to lack of information.

The largest number of graduates was from master's programs. Combined, the 23 institutions providing information awarded 102 master's degrees in bioinformatics.[6] Only 26 doctoral degrees were awarded from eight institutions. This is a reasonable count of the population of new Ph.D.s during this period given that of the 24 Ph.D. programs that replied to the survey 14 were too new to have awarded a degree by 2003. Non-responding institutions could, of course, also have awarded Ph.D.s but most of these programs were also too young to have produced graduates. Only 17 degrees were awarded at the bachelor's degree level as reported by the five programs that provided graduation data; four of the ten bachelor's programs that replied to the general survey were in all likelihood too new to have awarded a degree. Only seven individuals were reported to have completed their postdoctoral appointment during this period.

[6] Seven of the twenty-three reported zero graduates; eight other master's programs that replied to the survey did not indicate the number who had graduated with a master's degree.

The number of graduates is considerably lower than would be expected from the enrollment data presented in Figure 2. Once again, this is an indication of the newness of many of these programs. It is also a powerful reminder that in the next few years the number of graduates is expected to increase by two or three times.

Table 2
Number of Graduates from Bioinformatics Academic Training Programs
January 2002-March 2003

Level of Training	Number of Graduates (Number of institutions providing number of graduates/number of institutions replying)
Bachelor's	17 (5/10)
Master's	102 (23/31)
Doctorate	26 (8/24)
Postdoctorate	7 (2/8)
All Combined	152

Table 3 shows the number of students from bioinformatics programs by level of training who were placed in positions during the period January 2002 to March 2003. Once again, not all responding institutions supplied an answer. Except for master's students, student placements in 2002-2003 changed little from the number of placements in 1998-1999. Undergraduate placements doubled but the number remained quite low, likely due to the lack of graduates from newly created bachelor's programs. Doctoral and postdoctoral placements dropped slightly, likely a result of the drop in demand in the early 2000s. On the other hand, master's placements more than doubled, rising from 23 in 1998-1999 to 58 in 2002-2003.

Table 3
Number of Students Hired From Bioinformatics Programs, January 2002 to March 2003

	Bachelor's Programs	Master's Programs	Doctoral Programs	Postdoctoral Programs
January 2002 – March 2003	6[a]	58[a]	11[a]	9[b]
January 1998 – March 1999	3	23	13[b]	14[b]

[a]At least one institution indicated that students were hired during this period but could not or did not report a specific number. Therefore, the counts shown are lower bounds for the number of students hired during this period from the reporting institutions.
[b]Count includes student hires prior to designated start date due to survey response.

Table 4 explores the placement of students from bioinformatics programs by level of training for institutions that reported job placement information. Private industry was the most frequent employer across levels of training, though the academic sector was a close second—particularly for students from graduate bioinformatics programs. Employment at non-profit organizations was almost nonexistent, and government employment was limited. There was virtually no overlap in hiring institutions across levels of training, with the exception of Stanford University which hired both masters and doctoral students.

Five institutions were reported to have hired bachelor's students, with two from private industry, two from the public sector, and one from a university. Nineteen distinct institutions were reported to have hired master's students: 10 (52.6 percent) were private companies (including those unidentified), 7 (36.8 percent) were academic institutions (including those unidentified), 1 (5.3 percent) was a government laboratory, and 1 (5.3 percent) was a non-profit organization. The distribution of institution type for doctoral hires was similar to that for master's students. Seven (53.8 percent) of the thirteen hiring institutions were private companies, and five (38.5 percent) were universities; one (7.7 percent) was a government

agency. The distribution of hiring institutions was comparable for postdoctorates as well. Half of the ten hiring institutions were private firms, three were universities, and two were in the public sector.

Table 4
Job Placements of Students from Bioinformatics Programs, January 2002 to March 2003

Bachelor's Programs	Master's Programs	Doctoral Programs	Postdoctoral Programs
Economic Board of Singapore	Affymetrix	Amgen	Brown University
Georgia Institute of Technology	Atto Bioscience	Duke University	Children's Hospital Medical Center (Cleveland, Ohio)
Intel	Eli Lilly	GeneLogic	Cytogenix
Unspecified companies	Human Genome Sciences	Harvard University	Institute for Genomic Research
Unspecified government agencies	Memorial Sloan Kettering Hospital	ISIS Pharmaceuticals	Johns Hopkins University
	Merck	National Institutes of Health	National Computational Biology Institute
	New Jersey Institute of Technology	Pfizer	Sandia National Laboratory
	Novartis	Quallion	Tripos
	Oak Ridge National Laboratory	Rosetta	University of Cincinnati
	Ohio State University	Stanford University	Unspecified companies
	Perkin-Elmer	University of Washington	
	Purdue	Unspecified companies	
	Riken Biological Research Center	Unspecified universities	
	Stanford University		
	University of Alabama-Birmingham Medical Center		
	University of Medicine and Dentistry of New Jersey		
	Unspecified companies		
	Unspecified universities		
	Zuyder Pharmaceuticals		

Salary information was provided by only 13 institutions for 20 of the 84 reported placements; in 1999 salary information was provided for 35 of the 53 reported placements. At the time of the 1999 survey the small amount of salary information collected was thought to reflect the fact that many faculty simply did not know the salary offer that their students received. Moreover, at least one faculty member indicated at that time that he considered it inappropriate to make inquiries concerning starting salary. The even smaller amount of salary information collected in 2003 may reflect a continuation of that trend as well as the fact that 2003 respondents were more likely to be staff administrators with less student contact than were 1999 respondents.

Table 5 summarizes the frequency of reported salary ranges by level of training for the period January 2002 to March 2003. The greatest lack of salary information is at the undergraduate and doctoral levels. Only one institution provided salary data concerning placements of bachelors; only three doctoral programs reported salary data for placements; twelve master's programs supplied salary information and three postdoctoral programs supplied information.

The range of starting salaries tends to increase with the level of training as would be expected. Students with bachelor degrees from the one institution reporting salary data received a salary of $50,001-$60,000. Starting salaries for master's students from nine of the 12 reporting institutions were over $60,000, and six of these indicated starting salaries over $125,000 for their recently hired master's students. However, starting salaries for master's students exhibit the greatest variance, ranging from a low of $30,001-$40,000 to over $125,000. The majority of institutions providing salary information for doctoral placements reported starting salaries in the range of $80,001-$90,000, with no salaries below $60,000. Recently hired postdoctorates

Table 5
Starting Salary Ranges for Recently Hired Bioinformatics Students by Level of Training
January 2002 to March 2003

Level of Training	Salary Range (Number of Institutions Reporting Range)
Bachelor's Program	$50,001-$60,000 (1) Unknown (3)
Master's Program	$30,001-$40,000 (1) $40,001-$50,000 (1) $50,001-$60,000 (1) $60,001-$70,000 (2) 80,001-$90,000 (1) Over $125,000 (6)
Doctoral Program	$60,001-$70,000 (1) $80,001-$90,000 (3) Unknown (3)
Postdoctoral Program	$80,001-$90,000 (1) Over $125,000 (2)

received starting salaries over $80,000, with two institutions reporting salaries of over $125,000 for their postdoctorates. Compared to the data collected in 1999, salaries have increased the most dramatically at the master's level where the median salary went from $50,000-$60,000 to

over $100,000. Care, of course, must be taken in making these comparisons given the small amount of salary data that was made available.

E. Job Search Experiences

The most useful job search strategies reported by institutions (e.g., Question 6.23 of the survey) were advertisements (position announcements) and telephone contacts with faculty by professional recruiters and headhunters. Among the top three search strategies, the most useful strategy cited by institutions was personal contacts. Online sources and internships also were important search methods. Some differences exist in search methods by level of training. For graduates of bachelor's programs, institutions most frequently indicated that calls to faculty by recruiters and headhunters was among the top three search strategies, followed by the use of placement services. Other search methods were highest on the list for graduates of master's programs, with internships and position announcements the most frequently cited, followed closely by online sources and personal contacts. Faculty contact with professional recruiters and headhunters was the number one search method cited among doctoral and postdoctoral programs. The use of job ads was ranked second for doctoral programs and was tied with faculty contacts as the most frequently cited search method for postdoctoral programs.

Campus placement services targeting students in the bioinformatics training programs seem to play little role in the search strategy of bioinformatics students at the graduate level. This may be due to the declining availability of placement services at increasingly higher levels of training. For institutions reporting whether program-related placement services were available, two thirds of those with bachelor's programs offered such services. Approximately 57 percent of the institutions with master's programs had placement services, compared to 44

percent for institutions with doctoral programs. Only one of the four responding institutions with a postdoctoral program offered job placement services targeted to the bioinformatics trainees.

III. Demand in the Bioinformatics Market

To estimate demand for individuals with bioinformatics related skills in the early 2000s, bioinformatics-related position announcements were analyzed. Earlier work by Stephan and Black (1999b) examined bioinformatics advertisements listed in *Science* in 1996 and 1997. The current study of recent position announcements allows one to examine how demand has changed during the past five years. This time period offers insight not only into what has happened to demand as the science and technology markets of the late 1990s continued to boom but also what happened to demand during the economic downturn of 2001 and 2002. The analysis of position announcements also provides information on the size of the bioinformatics market and the characteristics of demand, including the institutions placing announcements.

The validity of using position announcements as a measure of demand was underscored in Black and Stephan's 1999 survey of academic programs when, in response to how job positions were located for students, directors replied that the most common means was reliance on position announcements. The 2003 survey, as noted above, indicates that position announcements continue to play a strong role in the placement of students.

Two indexes of position announcements are analyzed: ads listed in *Science* for the years 2000, 2001 and 2002 and announcements listed on selected internet websites during the period 2002-2003. Position announcements in *Science* were chosen because the journal consistently publishes employment announcements related to bioinformatics and provides for a comparison to Stephan and Black's 1999 analysis of bioinformatics positions. Job announcements in every

issue of *Science* were examined for the years 2000, 2001, and 2002.[7] Announcements placed on internet websites were also examined to broaden the estimate of demand and explore whether trends in demand varied by method of advertisement. Two representative internet sites were chosen to monitor employment listings related to bioinformatics.[8] One, www.monster.com, is a large employment board that covers all types of jobs. The other, www.bioplanet.com, is an employment information board focused solely on bioinformatics. Employment listings on www.monster.com were analyzed for the period June 2003 to January 2004 (excluding October 2003). The limited time period reflected the availability of historical ads online. Listings on www.bioplanet.com were examined for the 24-month period of 2002 to 2003.

For all analyses of position announcements, a position was counted if the announcement specifically referred to bioinformatics or a closely related computational science, such as computational biology. For example, an ad requesting a bioinformatist or computational biologist would be counted. An ad for a programmer to develop a software platform for computational gene expression analysis with experience in Java, Perl, MySQL, and Linux with an interest in the biological sciences would also be included. Counts are lower bounds of actual position openings because some advertisements do not state the specific number of position openings but instead indicate more than some specified number. In such instances, the lower bound was recorded. Within each calendar year, every effort was made not to count repeated announcements for the same position.

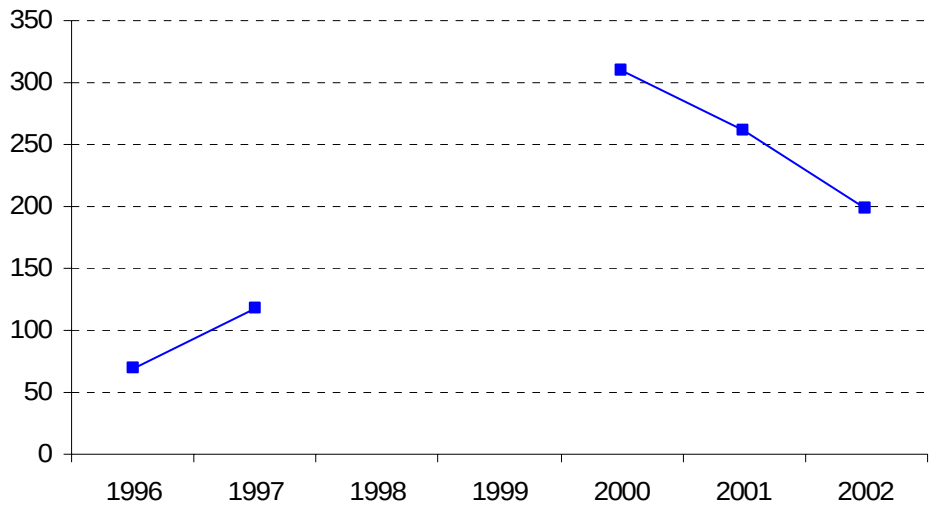
[7] In the 1999 study the position announcements were counted from hard copies of the journal. For the current study, position announcements were computed from electronic files supplied by the journal. This creates a possible downward bias in counts for the earlier period compared to those for the latter period since key word searches are likely to yield a more accurate count than does a careful "eyeballing" of the announcements.

[8] These web sites were chosen after discussions with Steve Dahms, Steve Wickert, and participants at the symposium on Career Development for Graduate Trainees in Bioinformatics, Lake Tahoe, February 23-26, 2003.

A. Position Announcements in *Science*

The number of bioinformatics-related employment ads listed in *Science* fell substantially in the early 2000s. Figure 3 shows the trend in the number of employment ads listed in *Science* from 1996 to 2002. In 2000, 309 employment announcements were listed; this number fell to 261 in 2001 and 199 in 2002—a drop of 35.6 percent over this three-year period. The number of bioinformatics employment ads in each of the three years, however, considerably exceeded the number of bioinformatics ads listed in 1996 and 1997. In 1996, 70 ads were placed in *Science*; 118 were placed in 1997.

Figure 3
Number of Bioinformatics Employment Ads in *Science*, 1996-2002*



*Data not collected for 1998 and 1999.

Table 6 shows the number of bioinformatics-related positions announced in the advertisements in *Science* from 1996 to 2002.[9] Following the same pattern seen in the number of employment ads, the number of positions announced in these ads increased from 1996 to 2000 but fell rapidly in 2001 and 2002. By 2000 almost 450 bioinformatics positions were advertised in *Science*; by 2002 this number had dropped to 254. The number of positions in 2001 closely resembled the level of positions advertised in *Science* in 1997, and by 2002, the number of advertised positions was fairly close to the 1996 level.

Table 6
Number of Bioinformatics Positions Advertised in *Science*

Year	Number of Positions	Percentage Change From last period
1996	209	-
1997	354	69.4%
2000	443	25.1%
2001	372	-16.0%
2002	254	-31.7%

In addition to a change in number of ads and number of positions advertised during the six-year period, the mix of institutions advertising in *Science* changed as well during the period. Employment ads were dominated by industry in 1996 and 1997, with little demand coming from the academic, public, and non-profit sectors (Stephan and Black 1999b). The predominant source of demand shifted during the 2000-2002 period to the academic sector, with industrial demand considerably lower. Appendix C documents this shift in the sectoral source of demand,

[9] There is not a one-to-one correspondence between the number of positions and the number of employment ads because an ad may announce more than one position opening. For example, one ad may list three position openings.

listing the institutions that placed employment ads in *Science* in 1996, 1997, 2000, 2001 and 2002.

Table 7 shows the distribution of advertised positions in *Science,* during 2000-2002, by sector of hiring institution and educational degree requested in the ad. For all degree levels combined, academic institutions grew from placing 66.8 percent to 79.9 percent of all advertised positions during the three year period, while positions in industry fell from 21 percent to 16.6 percent. Demand from the non-profit and public sectors was minimal, well below 10 percent, respectively, in every year except for the non-profit sector in 2001.

Table 7
Distribution of Advertised Positions in *Science*
by Sector of Hiring Institution and Requested Degree, 2000-2002

Requested Degree	Total Number	Industry (% of Total)	Academe (% of Total)	Non-Profit (% of Total)	Government (% of Total)	Unknown (% of Total)
Bachelor's						
2000	0	0%	0%	0%	0%	0%
2001	0	0%	0%	0%	0%	0%
2002	0	0%	0%	0%	0%	0%
Master's						
2000	46	39.1%	45.7%	10.9%	4.3%	0%
2001	21	28.6%	52.4%	0%	4.8%	14.3%
2002	6	33.3%	66.7%	0%	0%	0%
Doctorate						
2000	431	16.5%	71.9%	5.6%	5.6%	0.5%
2001	314	9.6%	82.2%	3.2%	4.8%	0.3%
2002	241	4.1%	85.9%	4.6%	5.4%	0%
Combined						
2000	443	21.0%	66.8%	5.6%	6.3%	0.2%
2001	372	14.0%	67.7%	12.4%	4.6%	1.3%
2002	254	16.6%	79.9%	3.9%	5.5%	0%

Note: Counts by degree level do not sum to the total counts for all degrees combined because some advertisements may specify multiple degree levels for a given position.

No position announcements in *Science* sought individuals with bachelor's training and few sought individuals with master's training. Instead, and consistent with the audience for this top-tier research journal, the position announcements were overwhelmingly directed at the doctoral population. Demand from the academic sector accounted for the vast majority of openings requesting a doctoral degree. Approximately 72 percent of the positions requesting a doctorate were in academe in 2000; by 2002, this proportion had risen to 86 percent. Industrial demand for those with a doctorate simultaneously fell during this period, accounting for 16.5 percent of these positions in 2000 but only 4 percent by 2002. Demand from the academic sector was lower for the master's level during this period, though it still outweighed demand for master's students from each of the other sectors.

The analysis of position announcements in *Science* suggests that demand for individuals trained in bioinformatics peaked in the year 2000 and has been on the decline since that time.[10] This result holds within major sector as well as across all sectors. For example, in both academe and industry the actual number of positions advertised declined during the period at both the master's and Ph.D. level of training. The especially large decline in industrial demand, as well as demand for individuals with master's training, does, however, raise the possibility that part of the decline was a result of a change in the advertising behavior of firms seeking new employees in bioinformatics. For this reason, and also because the *Science* series stopped during the recession, we also analyze two sources of web-based position announcements, covering 2002 to the beginning of 2004 when the economy was well on its way to recovery.

[10] It is possible, of course, that the market peaked in either 1998 or 1999, the two years for which we do not have data.

B. Position Announcements on the Internet

The analysis of online employment announcements is enlightening, in that there is virtually no overlap between online ads and those listed in *Science*.[11] Unlike the distribution of demand for positions advertised in *Science*, recent online position announcements were largely placed by the industrial sector with relatively few ads from other sectors including academe. However, ads from www.bioplanet.com show that industry's share of advertised openings in bioinformatics fell considerably from 2002 to 2003, with the academic sector's share rising substantially (see Table 7). This suggests that the decline observed in positions in *Science* as well as the change in the mix of position announcements is not an artifact but characterizes the market.

Appendix D lists the institutions placing employment announcements on www.monster.com from June 2003 to February 2004 (excluding October 2003). Appendix E lists the institutions placing announcements on www.bioplanet.com in 2002 and 2003. Similar to employment ads in *Science*, the majority of internet announcements requested a doctoral degree followed by a master's degree. Unlike ads in *Science*, many online employment announcements were placed by professional recruitment firms, typically on behalf of private companies.

Table 8 shows the number of positions advertised on www.monster.com by sector of hiring institution for the period June 2003 to February 2004. In this eight-month period, 256 openings related to bioinformatics were posted on www.monster.com. More than nine out of ten of these advertised openings were in industry. Bioinformatics positions listed by recruiters for which the sector of the actual hiring institution could not be identified accounted for approximately six percent of openings. Virtually no academic positions were posted on

[11] The lack of overlap suggests that this analysis does not provide an overall count of the number of vacancies in bioinformatics.

www.monster.com. The same was true for positions in government and non-profit organizations.

Table 8
Number of Positions Advertised on www.monster.com by Sector of Hiring Institution
June 2003-February 2004*

Sector of Hiring Institution	Number of Positions (% of Total)
Industry	234 (91.4%)
Academe	4 (1.6%)
Government	0 (0%)
Non-Profit	2 (0.8%)
Recruiter	15 (5.9%)
Unknown	1 (0.4%)
All Sectors Combined	256

*Excluding October 2003

Table 9 shows the distribution of positions listed on www.monster.com by requested degree for June 2003-February 2004. A doctoral degree was the most commonly requested level of training, with approximately 49 percent of the openings having ads that mentioned having a doctoral degree. Master's degrees followed closely behind at 36 percent, and a bachelor's degree was sufficient for well over one quarter of the positions listed on www.monster.com. An ad for one position specifically mentioned a certificate in bioinformatics. A desired educational background was not indicated in the ads for a significant proportion of bioinformatics positions listed on www.monster.com.

Table 9
Distribution of Positions Listed on www.monster.com by Requested Degree
June 2003-February 2004*

Requested Degree	Number of Positions (% of Total Positions)
Bachelor's	73 (28.5%)
Master's	93 (36.3%)
Doctorate	125 (48.8%)
Certificate	1 (0.4%)
Unknown	57 (22.3%)
All Combined	256

Note: Counts by degree level do not sum to the total count for all degrees combined because some advertisements may specify multiple degree levels for a given position.
*Excluding October 2003

The characteristics of positions listed on www.bioplanet.com follow a rather similar pattern as those listed on www.monster.com, although there are some differences. Despite the website's specialization in bioinformatics jobs, fewer numbers of bioinformatics positions were advertised on www.bioplanet.com, with 168 openings listed in 2002 and 111 in 2003, compared to the 256 listed on www.monster.com in an eight-month period. The number of positions listed on www.bioplanet.com show a decline over time in demand, which, as noted above, corresponds to the drop in demand suggested by declining numbers of positions in *Science*.

Table 10 presents the distribution of positions advertised on www.bioplanet.com by sector of hiring institution for 2002-2003. As with positions listed on www.monster.com, the majority of openings were in industry. However, the concentration of openings in industry fell dramatically from 2002 to 2003. In 2002 over eight in ten advertised positions were in industry,

but in 2003 that ratio dropped to only one in two positions. Academic positions listed on www.bioplanet.com grew substantially between 2002 and 2003. Openings in academe listed on www.bioplanet.com accounted for less than one in ten of all listed positions in 2002 but approximately one third of all positions in 2003.

Table 10
Distribution of Positions Advertised on www.bioplanet.com
by Sector of Hiring Institution, 2002-2003

	Number of Positions (% of Total)	
Sector of Hiring Institution	2002	2003
Industry	138 (82.1%)	56 (50.5%)
Academe	16 (9.5%)	37 (33.3%)
Government	3 (1.8%)	2 (1.8%)
Non-Profit	3 (1.8%)	8 (7.2%)
Recruiter	2 (1.2%)	2 (1.8%)
Unknown	6 (3.6%)	6 (5.4%)
All Sectors Combined	168	111

Table 11 shows the distribution of bioinformatics positions listed on www.bioplanet.com in 2002-2003 by requested degree. The distribution of positions by requested degree did not change substantially from 2002 to 2003. Moreover, this distribution was more heavily skewed towards graduate degrees than the distribution for positions listed on www.monster.com. Approximately two-thirds of positions listed on www.bioplanet.com mentioned a doctoral degree in their ad. Over a fifth of the positions in both years mentioned a master's degree. A bachelor's

degree was associated with approximately 14 percent of the positions listed on www.bioplanet.com in 2002-2003, compared to approximately 29 percent for positions listed on www.monster.com.

Table 11
Distribution of Positions Advertised on www.bioplanet.com by Requested Degree, 2003-2004

	Number of Positions (% of Total Positions)	
Requested Degree	2002	2003
Bachelor's	24 (14.3%)	15 (13.5%)
Master's	35 (20.8%)	25 (22.5%)
Doctorate	108 (64.3%)	74 (66.7%)
Unknown	35 (20.8%)	118 (16.2%)
All Combined	168	111

Note: Counts by degree level do not sum to the total counts for all degrees combined because some advertisements may specify multiple degree levels for a given position.

Our analysis of position announcements leads us to conclude that demand for individuals trained in bioinformatics declined during the 2000-2003 period, especially in industry. This may be due in part to the recession. However, as discussed below, part of the decline is arguably related to the fact that the role that bioinformatics plays in drug discovery changed during the period. The mix of position announcements also changed dramatically during the period. The relatively stronger demand in academe, compared to industry, in all likelihood relates to the establishment of more than 50 new degree programs in bioinformatics during the period.

IV. Pilot Study of Firms

Previous work in the 1990s (Stephan and Black 1999b, 2000) suggested that a large number of bioinformatics-related positions went unfilled, or at least were not filled by individuals trained in bioinformatics. Evidence from the current study suggests that this remains the case—at least in the short run—despite growth in the number of training programs and weaker demand in the earlier 2000s for individuals with bioinformatics skills. What has not been clearly understood are the experiences of companies hiring in bioinformatics. To address this issue, the current project included a pilot study of a small sample of firms with a history of hiring in bioinformatics. The goal of the pilot study was to examine the experiences of six to eight firms in the bioinformatics labor market since the bioinformatics boom in the mid-1990s and their perceptions of the future direction of the bioinformatics labor market. For instance, the pilot study allows one to examine how firms coped with the apparent shortage of bioinformatics-trained individuals and whether this shortage has continued. The study also provides information on the bioinformatics-related hiring experiences and practices of these firms, including numbers of hires, salaries and compensation, search methods, retention, and employees' educational backgrounds.

The pilot study was conducted by collecting information from a nonrandom small sample of biotechnology companies. Twenty-one firms were targeted for potential participation. The targeted firms were selected based on a nonexclusive list of criteria:

> (1) firms that placed employment announcements in *Science* during the 2000-2002 period for more than five open positions;
> (2) firms that placed employment announcements in *Science* in 1996-1997 for more than four open positions;
> (3) firms identified in Stephan and Black's 1999 survey of academic training programs that hired more than one graduate from responding programs;

(4) firms that participated in a February 2003 conference on Career Development for Graduate Trainees in Bioinformatics that focused on the Alfred P. Sloan Foundation's professional science master's programs in bioinformatics;
(5) firms recommended by academic program administrators and industry representatives.

These criteria provided a sample of target firms that varied in age, size, location, and primary business activities—as well as firms that had a noticeable interest in the bioinformatics market during the period 1996 to 2003. Representatives for each targeted company were identified via online corporate information and recommendations from academic program administrators or other industry representatives. Firm representatives were initially contacted by email to provide information on this study and to solicit their participation. Follow-up contact by email and phone were used to increase non-response. Information for each firm was collected by personal interviews with a corporate representative.

The success of the pilot study (and any future larger-scale analysis) hinged on the willingness of firms to participate in the study. With minimal follow-up, representatives from one third of the twenty-one targeted firms volunteered to participate in the pilot study. Several of the seven firms participated and shared information with the understanding that the firm's identity would be kept confidential and that corporate information would only be reported in an aggregated or non-identifiable form. Therefore, while the corporate representatives were extremely candid in their responses, these conditions suggest that publicly available case studies of experiences at individual companies could be difficult to obtain in the future for a significant sample of firms. At the same time, the corporate representatives were extremely accommodating, freely discussed at length their experiences in the bioinformatics market, and they seemed personally interested in participating in this study.

The seven companies participating in this analysis are a representative sample of companies engaged in activities related to the biological sciences. Six of the companies are in pharmaceuticals, and the other is in agribusiness. Five are large, long established firms with global operations and thousands of employees. The remaining two are newer and smaller. One is a medium-sized firm just over ten years old with approximately 1500 employees. The other is only seven years old and has less than 80 employees. Two of the companies are located in the Midwest, one on the west coast, and four in the Northeast.

A. State of Bioinformatics in Industry

The current size of the bioinformatics groups at the seven companies is small. Among the interviewed companies, the number of employees reported to be working in bioinformatics at each firm (based on U.S. operations) ranges from less than 10 to approximately 30. Three of the seven firms have less than twenty employees in bioinformatics. The largest company interviewed, with over 120,000 employees worldwide, employs approximately 20 individuals—10 scientists and 10 IT researchers—in its informatics group in the northeast. The group started in 1999 and has experienced modest growth in computational biology since 2000. A pharmaceutical firm with almost 60,000 employees has approximately 30 employees working in bioinformatics, most concentrated in one research center in the northeast. Another pharmaceutical company with over 40,000 employees currently has approximately a dozen bioinformatics scientists and another dozen IT workers involved in bioinformatics. This group started in 1999, growing over the next two years, but began to stagnate by 2001. The bioinformatics group at another of the interviewed companies started in 1996 with 3 employees and now has 11; its desired size is estimated at approximately 20 employees. The company

employs over 31,000 workers. A fifth company, whose largest bioinformatics group was disbanded in 2003, began its main bioinformatics group in 1998 with a handful of employees. By 1999 the group had already expanded to 35 and continued to grow until disbanded in 2003. This company maintains a smaller bioinformatics group in another location of the United States with 25 workers and an Indian operation with another 25 employees. These units have remained somewhat stable over time with slight declines over the past few years. Another pharmaceutical company, with approximately 1500 employees, was the sixth firm interviewed. It started a bioinformatics group in 1994 with four individuals; by 2002 the group had expanded to 80 employees. In 2002 half of the bioinformatics employees were laid off and in summer 2003 the group was effectively dismantled. A computational sciences group currently exists, and of the 10 employees in this group, only a few are focused on bioinformatics and computational biology. The smallest company interviewed, with less than 80 employees, has an informatics group with eight individuals. In summary, of the seven firms, six have intact bioinformatics groups. The size of these units is generally small relative to the overall number of employees. Bioinformatics groups at two of the seven companies were disbanded in the early 2000s.

B. Past Hiring Experiences and Practices

Few hires were made in bioinformatics by the seven firms during the last two years in the U.S. market. Four of the seven companies reported no new hires.[12] Of the three firms that hired during the past two years, one hired one junior-level employee, another hired four (three developers), and the other hired "no more than a handful." Only one of the companies was searching for a new hire when interviewed and that search had been open for six months.

[12] Two of these firms collectively hired approximately three replacements for employees that were leaving.

All but one of the corporate representatives interviewed reported experiencing a skills mismatch while searching for new employees during the bioinformatics boom of the mid-to-late 1990s.[13] One company reported that it could not find "anyone" with the desired skills in 1996-1997. One corporate representative estimated that approximately 60 percent of his time as a bioinformatics group leader was spent searching for individuals with the right mix of skills in the mid-1990s. The common reason for observing skills mismatch was difficulty in finding candidates with an adequate understanding of biology and computational skills who also had prior industry experience. The newness of the field of bioinformatics, lack of formal training to integrate these skills, and the rapid rise in demand for individuals with bioinformatics skills all contributed to the widespread hiring difficulties experienced by many firms. The shortage of desired job candidates resulted in longer search periods at some firms, especially for more specialized positions. One representative recalled hiring two individuals on the spot due to his desperation in finding much needed personnel in bioinformatics.

Time needed to fill open positions since the bioinformatics boom has varied across the seven companies. Furthermore, the length of time reported by the corporate representatives does not appear to have changed significantly over time as would be expected given the recent fall in demand from industry. This may be an artifact of the small sample of companies and the types of positions most recently open at these firms.[14] For a typical lower level position, time ranged from a matter of days up to nine months; three of the companies reported an average time of at least three months. At the time of the interview, one company had been searching for someone

[13] The company not experiencing hiring difficulties did not perceive a limited supply of or inadequately skilled pool of labor for its bioinformatics positions during this period. This is attributed to the prevalence of high-skilled labor in the northeast where new hires would be employed. Moreover, the company's reputation and strong market connections may have more easily attracted job candidates in bioinformatics than newer, smaller, or less stable companies.

[14] Several of the corporate representatives responded based on their most recent hiring experiences. Since no new positions were filled during the past two years at four of the companies, estimates of hiring time may not accurately reflect the typical market experience.

with a biostatistics background for over six months. The company that filled positions quickest attributed its success to the hiring manager contacting candidates with whom they had had a prior connection when a position became open. Time to fill positions has also varied by type of position. For example, developers were hired more quickly than junior scientists. The greatest differences have been between lower level and senior or highly specialized positions. Time to fill more senior positions typically has taken at least one year. One company had openings for two senior-level group leaders within the past two years. Each position was open for over one year, and no one with the desired credentials was found. One position was filled by transferring an existing employee within the company to the position and training that individual. The lengthy search times for senior or more specialized individuals and the changing skills desired by industry (discussed later) suggest that a skills mismatch persists at least under some circumstances.

Strategies used to fill openings were similar across the interviewed companies, with minor differences in the predominant method used. All but one of the companies used networking by company employees. Networking methods ranged from personal contacts to participation at professional meetings to flyers distributed to selected academic departments. Position announcements were posted by most of the companies. Print announcements in leading journals such as *Science* and *Nature* were more common for higher level positions, while local newspapers were used for lower level positions. Electronic announcements were listed on corporate websites, various internet employment listings, and websites for professional associations. The use of professional recruitment services was not widespread and typically reserved for searches for individuals with unique qualifications. Moreover, at least two of the

industry representatives indicated that in the current bioinformatics labor market the need to resort to such services to find job candidates would be unlikely.

Every corporate representative interviewed stated that wage premiums were attached to bioinformatics jobs in the past, particularly for entry- or lower-level positions. Three of the companies previously offered salaries for bioinformatics hires above those for comparably skilled individuals in other areas. One representative estimated that the wage premium offered to bioinformatics hires at his company was 10 to 15 percent above the salary for a comparable individual in another area during the bioinformatics boom in the 1990s. Two other companies indicated that they attempted to avoid offering wage premiums to attract bioinformatics candidates for most openings. Instead, they offered incentives in the form of cash, stock options, or other perks to keep new hires for a specified period. Signing, retention, and referral bonuses were also common. One of the seven interviewed companies offered retention bonuses during 1998-2001 as a means to reduce quick turnover among new bioinformatics hires who had numerous employment opportunities during the period of rapid growth in bioinformatics. One of the companies offered a referral bonus in the form of cash or stock options to employees who provided leads on potential job candidates. One corporate representative reported using signing bonuses to attract new hires in addition to offering a premium wage. Another representative stressed the importance of other benefits, including flexible scheduling and work environment, to the recruitment process

All the corporate representatives believe that the current market conditions for bioinformatics workers no longer support the use of wage premiums to attract job candidates and have no intention of offering them in future recruitment. The lack of a need to use wage premiums, according to the corporate representatives, stems from a greater supply of adequate

bioinformatics talent than in the past, increased competition for jobs from laid-off bioinformatics workers, lowered expectations of the job market, and less demand for bioinformatics workers in industry. As one representative put it, "Many people in the industry just want a job," having fewer opportunities and lower expectations of the market compared to several years ago, and are unwilling to demand a premium salary.

In terms of current salaries, one firm reported that starting salaries for individuals below the Ph.D. level were $35,000-$70,000 in 2000, while another firm reported salaries around $70,000 for similar individuals in 2004. In the 1990s two companies offered starting salaries of $60,000-$65,000 for new Ph.D.s. Two companies were offering approximately $80,000 for a new Ph.D. in 2000. More recent salaries for new Ph.D.s were estimated around $100,000 at two other companies. Starting salaries for senior level personnel were higher, ranging from $90,000 to $130,000 across firms. While salaries appear to have grown in absolute terms, the relative difference between bioinformatics salaries and those for comparable individuals in other fields has declined according to the corporate representatives.[15]

C. Demand for Bioinformatics Workers

None of the industry representatives believe a shortage of labor currently exists, at least to any serious extent, in the bioinformatics market. According to one representative, "I used to hear colleagues at a lot of firms talk about this issue [of a shortage], the need to hire, and the difficulty finding good people. I don't really hear this anymore." There is strong agreement among the seven industry representatives interviewed that four key factors have altered the bioinformatics market in the early 2000s. First, the economic downturn in 2000-2001 particularly affected technology related markets, including pharmaceuticals and biotechnology.

[15] One company indicated that it continued to offer retention bonuses.

Firms postponed new hiring and some laid off workers as companies tightened budgets. Magnifying this effect was the fact that some pharmaceutical companies faced patent expirations on drugs during this period, which reduced revenue streams that could have funded new hires.

Second, and perhaps related, the biotechnology and pharmaceutical industries experienced significant restructuring during this period. Mergers and acquisitions took place at several large prominent firms in these industries, including GlaxoSmithKline, Millennium Pharmaceuticals, Monsanto, and Pfizer. Firms involved in mergers and acquisitions typically seek to reduce costs, in part through temporary reductions in hiring. Four of the firms interviewed have been involved in mergers or acquisitions since 1999 and faced hiring restrictions of some kind; one firm implemented hiring freezes in 2000 and 2002 and three faced widespread layoffs.

Layoffs in the pharmaceutical and biotechnology industries were not uncommon in the early 2000s, occurring at companies including Bristol-Myers Squibb, Human Genome Sciences, Schering-Plough, and most recently Incyte Pharmaceuticals. Four of the interviewed companies experienced layoffs during this period, with two of these dismantling bioinformatics groups. Two representatives reported that laid-off bioinformatics workers took three to six months to find new jobs. According to one representative, those who were able to find jobs the most quickly were experienced software engineers and computer scientists. At the companies that dismantled bioinformatics groups, some workers were able to transfer to different positions within the companies, though these positions were almost always in areas other than bioinformatics. One representative reported that most laid-off employees took salary decreases at new jobs.

The factor which is expected to have the longest impact on the bioinformatics market is the reevaluation of industry's expectations concerning the contribution of bioinformatics to drug discovery. The genomic boom in the 1990s was in part stimulated by industry's expectation that the generation of massive amounts of genomics data would translate into outcomes with commercial potential in a short time. Many pharmaceutical companies invested heavily in genomics related areas, including bioinformatics. For instance, many pharmaceutical companies began to build sizeable bioinformatics units, and several large companies developed multi-million-dollar joint research programs with other institutions. Moreover, many startups focused on bioinformatics services were formed. Several of the interviewed corporate representatives likened the phenomena to the over-exuberance in the dot.com industry. According to the corporate representatives interviewed, the expected results from the heavy investment in bioinformatics have not paid off to date with substantial contributions to the drug discovery process.[16] Outcomes predicted to emerge in a few years have yet to come about.

Finally, the push to continue generating vast amounts of genomics data has declined since the early 2000s when the sequencing of significant genomes was largely accomplished. The slowing down of data collection in this "post-genomic era" has reduced demand for bioinformatics personnel and raised the need to redirect the applications of bioinformatics activity. The effect of the reduction in the generation of genomics data, though distinct, coincides with the third factor discussed above.

[16] To illustrate the difference in perceptions over time, an article in 1999 stated, "Companies, from small biotechnology startups to giant established drug-makers, are hoping the computer-science techniques of bioinformatics can help them accelerate development of new products and save hundreds of millions of dollars in the process." (Griffith 1999) In the same article, the executive director of the Massachusetts Biotechnology Council was quoted as saying, "Will every company eventually have a bioinformatics department? Probably." These high expectations changed drastically. In 2004 a venture capitalist stated, "We got pretty jazzed about bioinformatics four years ago, but the truth is, we haven't been able to find a single thing to invest in." (Diedrich 2004) Dietrich (2004) suggests that bioinformatics may never "live up to its expectations" arguing that it suffers from poor business planning among startups, increasingly public data, and slow adoption of some bioinformatics products.

Given these four factors, many companies (including most of those interviewed) have undergone extensive reevaluations of their bioinformatics programs. One of the interviewed companies totally disbanded its main bioinformatics unit. The unit at another firm, for all practical purposes, no longer exists; this unit experienced a 50 percent reduction of employees in 2002, followed by another significant layoff in 2003 that virtually eliminated the group. Another firm downsized its bioinformatics labor force over the past two years. None of the seven firms foresee extensive hiring in the near future. Of those anticipating hires within the next two years, one company expects few hires at the Ph.D. level at their U.S. operations. Another anticipates that one to two new employees may be added every couple of years starting in the not-too-distant future. The smallest firm interviewed is likely to hire one to two new employees within approximately a year. Another firm expects to hire no earlier than 2005 or early 2006 and largely at the master's degree level.

The refocusing and streamlining of bioinformatics activity at dominant companies has also impacted young bioinformatics services startups. One corporate representative knew of 40 to 50 bioinformatics related startups that had closed in the early 2000s due to a lack of profitability. This reevaluation and redirection of the role of bioinformatics in industry has reduced recent demand for bioinformatics workers and may have long-term implications for demand in the future. To offer a sense of the bioinformatics needs at one large pharmaceutical company, the representative stated that only six out of 1000 researchers work in bioinformatics at one of the company's large research facilities.

D. Level of Training

A Ph.D. is the most common degree held by bioinformatics employees among the seven companies, though the distribution of degrees varies somewhat by firm. A majority of employees from four of the companies have doctorates and approximately half at two of the other companies.[17] The remaining employees hold a combination of bachelor's and master's degrees.

The training backgrounds of the bioinformatics workers at these firms span a range of fields. The most frequently cited fields of study include biology, chemistry, and computer science. Other areas cited by the corporate representatives are biophysics, chemical physics, mathematics, software engineering, and theoretical physics. Formal bioinformatics training has been rare among current or past employees but is becoming more common, likely due to the relatively new pipeline of graduates from the young training programs. Three of the interviewed companies indicated that at least one employee had a degree in bioinformatics or computational biology. A common thread among many of the bioinformatics workers is some level of understanding of biology. Two of the representatives stated that, although their employees came from various fields, almost all had some background in biology. One indicated that, especially among foreign hires, a common background was a Ph.D. in biology with a master's degree in computer science. Another stated that dual degrees in computer science and a hard science, such as biology, are particularly common among IT-focused workers in the bioinformatics group.

All the corporate representatives interviewed were aware of academic programs offering bioinformatics training, although their familiarity with these programs varied considerably. At least one representative knew little more than that training is being offered, while several others

[17] One corporate representative could not provide information on the educational backgrounds of bioinformatics employees.

have had direct interaction with programs. One of the representatives has taught in three of the Sloan sponsored bioinformatics programs. One of the companies has forged partnerships of some kind with six academic institutions in its area. None of the representatives indicated an unwillingness to consider students from these programs for future employment; several welcomed the opportunity to consider candidates with explicit bioinformatics training, which, as they noted, had been most uncommon during the bioinformatics boom.

There is consensus among the representatives that the existing academic programs providing bioinformatics related training can supply an adequate pool of graduates to meet demand by industry if it remains at or near its current levels (which seems to be the expectation for at least the next several years). Indeed, some concern was expressed that the recent rapid growth of academic programs may lead to an oversupply of labor in the bioinformatics market, at least if current conditions continue. As one representative stated, academic programs can supply "more than enough" individuals to meet industry's demand for bioinformatics workers. While these corporate representatives have a sense that a surplus may occur as upcoming graduates come out of the academic pipeline in the near future, no one could provide an estimate of the overall size of demand in industry in terms of number of workers needed by industry over time. The potential surplus was attributed by at least two representatives to the lagged response of academe in responding to the ever-changing nature of demand from industry. While this contributed to the sense of a shortage during the bioinformatics boom in the 1990s, it could also have the opposite effect during slow periods for industry, such as the recent downturn in the early 2000s. The cyclical nature of industry's demand, largely driven by overall economic conditions, and the more unpredictable component caused by factors such as technological developments, all contribute to shifting demand by industry. These shifts in industrial demand,

however, typically occur at a more rapid pace than academe is able to effectively react to by creating new programs, changing curricula, or implementing other responses.

Several of the interviewed representatives also attributed the rapid growth in training programs to the exaggerated hotness of the field in the 1990s. The high expectations for the rewards from the genomics push, targeted funding for bioinformatics related areas from the public sector, and increasing pubic initiatives to develop clusters of bioinformatics expertise were identified as factors helping stimulate academe's willingness to develop bioinformatics programs in the late 1990s and early 2000s. For example, the New Jersey High Technology Workforce Grant Act provided funding to academic institutions to develop new programs in "hot" areas, and New York created a statewide bioinformatics initiative that provides 50-percent cost sharing for crash courses in bioinformatics.

While the corporate representatives believe that the academic training programs can help reduce the skills mismatch observed during the bioinformatics boom in the 1990s, several representatives believe a skills mismatch may still exist to some degree, based in part on their experiences with current employees and job candidates. Several of the representatives expressed a strong desire for new hires to have prior experience working in industry, which they have found lacking in many candidates, particularly recent graduates. One representative noted the need for bioinformatics related workers with experience in clinical trials. In addition, several suggested that the desired skills set for bioinformatics workers is being altered by the changing role of bioinformatics in industry, especially in drug discovery. Greater understanding of certain biological areas, such as systems and structural biology, and stronger mathematical skills were emphasized—as well as the ability to adapt to changing technologies and computational techniques. Several corporate representatives, for example, indicated a deficiency in statistics

among employees and job candidates. One representative suggested that factors associated with at least some academic programs may contribute to a persistent skills mismatch. First, many universities are not able to provide students with access to the latest equipment and technologies which are used in industry. Second, faculty in some of the bioinformatics programs do not have strong bioinformatics backgrounds themselves or do not engage in extensive bioinformatics research, which affects the level of skills transferred to students. Third, due to the inherent nature of academic institutions, it can be difficult for the curriculum at bioinformatics programs to stay in tune with the bioinformatics needs of industry, which are likely to continue to change over time as the field evolves and companies' business strategies change.

Almost all the corporate representatives interviewed offered some advice to academic programs regarding curriculum. At the broadest level, they agreed on the usefulness of the interdisciplinary nature of bioinformatics programs that includes some mix of biology, mathematics, and computer science. There was some disagreement, however, on how much a given area should be emphasized in the curriculum, particularly areas related to computer sciences. Some argued that computational skills are becoming increasingly important in bioinformatics as the field evolves, so that offering strong computational training is vital. On the other hand, one representative, who did not dispute the need for computational skills, suggested that, of the topics that can be taught in a bioinformatics program, emphasis should be placed on providing a solid knowledge of the biological sciences. In his view, programming and other computational skills could be more easily picked up informally than could knowledge of biology. At the other extreme, another representative suggested that bioinformatics programs may not be able to sufficiently provide extensive enough computational training due to the interdisciplinary nature of these programs. One of the most frequently mentioned areas to include in the

curriculum was mathematics. Specific areas included statistics, linear algebra, differential equations, and machine learning. In terms of the biological sciences, systems, structural, and molecular biology were all recommended. Exposure to team-oriented exercises and the ability to communicate across disciplines was also viewed as important. Most of the seven companies operate under a project-oriented structure based on teams that are comprised of individuals from different units within the company. For example, at the smallest company interviewed, a typical team includes a Ph.D. chemist, a software developer, and a mathematician or statistician.

According to the seven corporate representatives, the most effective level of training is likely to remain the Ph.D.[18] One reason cited for the importance of a Ph.D. is the extensive exposure to a specific subject, such as biology, which gives a job candidate a solid understanding of an area that can hopefully be effectively applied in a dynamic industrial environment.[19] Another reason was based on the human resource policy at some firms which allocated hires across units on the basis of slots rather than on the basis of costs. For example, a bioinformatics unit within a firm may be allocated ten fulltime positions based on determined need with little regard for the cost of these new positions. Managers operating in such a system are not constrained by relatively minor cost differences between job candidates having a master's or doctoral degree, and the incentive is to hire at the doctoral level. As one representative suggested, a job candidate with a Ph.D. versus other training provides "more bang for our buck." The representative at one large pharmaceutical company also suggested that the Ph.D. will

[18] It should be noted that six of the seven representatives interviewed hold a doctoral degree, which could potentially bias their view.

[19] A representative of an emerging pharmaceutical company stated in late 2003 that "… the postsequencing climate mandates a large proportion of Ph.D.-level scientists. In the past we could get by with one Ph.D. to about 12 Master's and Bachelor's level scientists…. Now, as we move toward a more specialized degree of knowledge about the systems, we need a ratio more like 1:3." (Gwynne 2003)

remain their primary desired background given that many of their more routinized bioinformatics tasks are outsourced, reducing their demand for workers with lower levels of training.

The corporate representatives interviewed, however, were supportive of other levels of training, particularly the master's, which can offer sufficient training for many bioinformatics positions. One representative suggested that an ideal background for a job candidate is dual master's degrees: one in biology and the other in computer science. Another argued that a master's degree could provide adequate exposure to the areas needed for many bioinformatics positions, particularly those at lower levels such as associates. All the interviewed representatives indicated that they would consider individuals with less than a Ph.D. for at least some positions. Indeed, as mentioned in the previous section, one of the firms anticipating hiring in the near future expects to focus on positions at the master's level. No mention was made of hiring individuals with postdoctoral training, except by one representative who believed it offers little except to those who need to make up for insufficient lab experience during doctoral training.

E. Summary of Pilot Study

While it is unclear how representative the firms in the pilot study are, we find several common threads among the seven firms interviewed. First, the interviews suggest that substantial wage premiums in bioinformatics relative to other fields are no longer being offered. While premiums were commonly used during the bioinformatics boom in the 1990s, downward pressure on wages from recent economic conditions, corporate restructuring, revised expectations of the role of bioinformatics in industry, and the transition into the post-genomic era have all contributed to an erosion of the premium previously associated with bioinformatics.

Second, the interviews suggest that a skills mismatch was a common experience during the bioinformatics boom and continues to some extent despite an increasing supply of individuals trained in bioinformatics. The persistence of a skills mismatch in the bioinformatics market is in part due to the changing skills desired by industry as well as a continued need for some workers with unique skill sets, including experience in the industry.

The seven individuals interviewed foresee minimal hiring in the U.S. bioinformatics market in the near future, although, as economic conditions improve, hiring is expected to increase from levels in the early 2000s. Post-recession hiring is restrained by a restructuring of firms, lowered expectations concerning the role that bioinformatics can play in drug discovery and passage into the post-genomics era. These trends affect large companies as well as many of the bioinformatics startup companies. As an example of the scale of this effect on the market, one representative interviewed knew of 40 to 50 bioinformatics startups that had failed, with one closing as recently as two weeks prior to the interview. Expansion of bioinformatics employment, at least in the near future, is expected to be strongest overseas. Foreign operations are becoming increasingly important for technology-oriented companies, and bioinformatics is not unaffected by this trend. Bioinformatics operations have been well established throughout Europe and are expanding into southeastern Asia, with particularly strong growth in India and Singapore.

The interviews also suggest that the Ph.D. remains the preferred level of training for bioinformatics workers in industry. The preference for a Ph.D. is driven in some cases by the labor allocation mechanism at firms, which focuses on position slots rather than labor costs. Moreover, a Ph.D. is desirable because it provides more extensive training in a given field of study, which can be important in the dynamic research environment at many companies.

V. Conclusion

The 2003 survey of academic training programs, the analysis of print and online position announcements, and the pilot study of companies that have hired in bioinformatics lead to six main conclusions concerning changing conditions in the bioinformatics market during the period 1999 to 2003:

- There has been a dramatic increase in the number of academic training programs as well as the number of individuals enrolled in programs. To wit, during the period between 1999 and 2003 the number of known programs grew from 21 to 74, and the number of students enrolled in bioinformatics programs at all degree levels grew from 169 to 881; the latter is a lower bound given the relatively low response rate from newer programs.

- There was little change, except at the master's level, in the number of reported placements between the 1999 and 2003 surveys. Doctoral and postdoctoral placements dropped slightly but master's placements more than doubled. Based on the limited placement data from the survey, private industry remained the most frequent employer across levels of training with the academic sector a close second, particularly for students from graduate programs.

- The number of newly-minted individuals trained in bioinformatics during the five-year period is fairly small. For example, extrapolating from the two surveys, a ballpark estimate is that at most 78 new Ph.D.s in bioinformatics were minted

during the four-year period and 250 new master's degrees awarded in bioinformatics.[20] Given the number of position announcements examined in this study, which underestimates the full level of demand, it is clear that demand exceeded the supply of newly trained individuals, especially at the Ph.D. level. However, the seven company interviews suggest that in many instances the company placing the announcement is looking for individuals with considerable experience in industry, and thus there is a mismatch between the supply of newly trained, inexperienced individuals and demand.

- This analysis also suggests that the overall demand for individuals in bioinformatics, regardless of level of experience or level of training, declined over the period. The number of positions advertised in *Science* declined between 2000 and 2002, and the number advertised online at www.bioplanet.com declined between 2002 and 2003. The seven company interviews provide qualitative support regarding the softening of the market. Moreover, the interviews suggest that the market softened not only because of the recession of the early 2000s but also because of a restructuring in the industry, revised expectations of the role that bioinformatics plays in drug discovery and the transition to the post-genomic era. These conditions are likely to persist in the post-recession period and lead to minimal growth in hiring in the near future.

[20] Calculated using 1999 and 2002 number of graduates and assuming that the 2000 and 2001 number of graduates is equal to the mean for the two years.

- Based on the extensive analysis of position announcements, the sector of demand has changed. In the mid-1990s, industry was almost exclusively the sole source of demand. By the early 2000s, demand from the academic sector had grown substantially, surpassing industry as the largest source of positions advertised in *Science*.

- Salaries in the bioinformatics market have risen during the 1999 to 2003 period but the substantial wage premium associated with bioinformatics jobs in the past has virtually disappeared and is unlikely to be offered under the current market conditions. On the demand side, the same economic conditions that affect hiring contribute to this loss in wage premium. Moreover, the growth of industrial bioinformatics operations outside the United States has begun to reduce domestic demand for bioinformatics workers, and foreign operations are expected to continue to expand. At the same time, the number of academic training programs has skyrocketed since the mid-1990s, increasing supply. Moreover, competition for positions has stiffened as experienced but laid-off or underemployed bioinformatics workers compete with newly-trained graduates for fewer jobs. These factors have placed downward pressure on wages. This trend is not expected to turn around in the near future, as demand is likely to remain low in the U.S. while supply will continue to grow as increasingly more graduates enter the market.

This analysis leads us to conclude that the bioinformatics labor market has gone through considerable change in recent years. In the context of a fixed supply of specialists, salaries for individuals with skills in bioinformatics soared in the 1990s. Strong demand and the concern that the "seed corn was being eaten" led to the creation of numerous new training programs in bioinformatics. These training programs are now beginning to generate graduates. Many of these graduates assumed they would go to work in industry; yet positions in industry appear to be on the decline, and the positions that are available are frequently for individuals with considerable experience. The strongest area of demand in recent years has been from academe, seeking faculty to staff new programs and to broaden research expertise. Unless conditions in industry change dramatically in the next few years, it is likely that many trainees from these programs will have difficulty finding jobs in industry.

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Appendix A

Institutions Targeted for 2003 Survey Bioinformatics and Computational Biology Programs

Arizona State University*
Baylor College of Medicine*†
Boston University†
Brandeis University*
Carnegie Mellon University*†
Columbia University
Duke University*
Florida State University
George Mason University*†
Georgetown University
Georgia Institute of Technology*†
Harvard University*
Indiana University*
Iowa State University
Johns Hopkins University*†
Keck Graduate Institute of Applied Life Sciences*
Marquette University
Massachusetts Institute of Technology
Medical College of Wisconsin*
Montana State University
New Jersey Institute of Technology*
North Carolina State University*
Northeastern University*
Northern Illinois University
Northwestern University†
Ohio State University*
Pennsylvania State University
Princeton University
Purdue University
Rensselaer Polytechnic Institute*
Rice University*†
Rochester Institute of Technology
Rutgers University*†
San Jose State University
San Diego State University*
Stanford University*†
State University of New York-Buffalo
Texas A&M University
University of Alabama-Birmingham*
University of California-Berkeley
University of California-Davis*†
University of California-Irvine
University of California-Los Angeles*
University of California-Riverside
University of California-San Diego
University of California-San Francisco
University of California-Santa Cruz*†
University of Colorado*†
University of Connecticut†
University of Delaware
University of Houston*†
University of Illinois at Chicago*
University of Illinois at Urbana-Champaign
University of Maryland*
University of Massachusetts-Lowell*
University of Medicine and Dentistry of New Jersey
University of Memphis*
University of Michigan*
University of Minnesota*
University of Missouri-Columbia*
University of Nebraska-Omaha*
University of North Carolina-Chapel Hill*
University of Pennsylvania*†
University of Pittsburgh*†
University of Southern California*†
University of Tennessee-Knoxville
University of Texas at Austin
University of Texas at El Paso*
University of the Sciences in Philadelphia
University of Washington-Seattle*†
University of Wisconsin*†
Vanderbilt University
Virginia Polytechnic Institute and State University
Washington University*†
Yale University*

*Participated in the 2003 survey
†Targeted for participation in the 1999 survey

Appendix B

2003 Survey Questionnaire of Academic Bioinformatics Programs

Welcome to the Survey of Bioinformatics & Computational Biology Programs

This survey examines academic training programs in bioinformatics and computational biology and is funded by the Alfred P. Sloan Foundation. It focuses on (1) the demand for and types of training offered and (2) the hiring patterns of participants in these training programs. It updates an earlier study done by the co-PIs at the request of the Sloan Foundation.

Your participation is important to facilitate a better understanding of the bioinformatics labor market and the role of academic training programs. Results of this study will be available online later this year.

At some institutions, more than one individual may need to be involved since this survey addresses training at all levels from undergraduate to postdoctorate. If this is the case at your institution or if someone else at your institution is better equipped to answer the questionnaire, please send their contact information to gblack@gsu.edu and a survey will be sent to them.

Thank you for taking the time to answer this questionnaire. Please complete this survey by April 18, 2003.

INSTRUCTIONS

This questionnaire is administered online for your convenience. If you have any questions regarding the survey, please contact us at gblack@gsu.edu for assistance.

- You may wish to preview the questions before answering to help prepare your responses. Click here to open a printable version of the questionnaire.
- To respond to each question, simply click or type in the appropriate box/s. Please note that the text boxes can expand to contain an unlimited amount of text for your written responses. If you do not know the answer to a question, type "DK" in the box.
- To progress through the questionnaire, click the Continue button on each page.
- The questionnaire is designed so that you may revise or add to your answers at any time after your first response to the questionnaire. The email address you provide will serve as a user ID to access the questionnaire with your saved responses at a later time. No one will be able to view or access your responses without this ID.
- If you remain idle without entering any information, your session may "time out" after 20 minutes for security reasons. If this occurs you will be prompted to return to the survey home page and reopen the survey. Any previous responses should be automatically saved and will be accessible when you log into the survey again.

If you have not started the survey, Click here to take the survey.
If you have already taken the survey, enter your email address and click the Login button.

Email Address:

Login

---

1. Survey respondent's name: *
2. Email address: *
3. Institution name: *
4. Program or department name:
5. Program URL:

Note: * Required response

6. Does your program offer bachelor's training? *

☐ Yes ☐ No

6.1 Is a bachelor's degree awarded through this training program?

☐ Yes

☐ No. If no, identify affiliated department/s awarding the degree:

6.2 What year was your undergraduate program established?

6.3 What were the primary reasons for establishing your undergraduate program?

6.4 Is your undergraduate program a joint effort with other institutions?

☐ Yes. If yes, please list the other institutions:

☐ No

6.5 What proportion of your undergraduate program is funded:

Internally: [ ] %

Externally: [ ] % By what institutions? [ ]

6.6 How many bachelor's students:

[ ] were enrolled in your undergraduate program as of January 1, 2003?

[ ] were enrolled in your undergraduate program in its first year?

6.7 How many bachelor's students:

[ ] applied to your undergraduate program for Fall 2002 admission?

[ ] were admitted to your undergraduate program for Fall 2002?

[ ] accepted admission and enrolled for Fall 2002?

6.8 What proportion of the students in your undergraduate program as of January 1, 2003, are enrolled part-time?

[ ] %

6.9 What proportion of the students in your bachelor's program as of January 1, 2003, are:

[ ] % non-U.S. citizens?

[ ] % women?

[ ] % underrepresented minorities (African American, Latino, and Native American)?

6.10 Approximately what proportion of all the students in your undergraduate program is financially supported by:

[ ] % Scholarships

[ ] % Fellowships

[ ] % Research assistantships

[ ] % Teaching assistantships

[ ] % Employer

[ ] % Personal resources

[ ] % Other Please specify the source: [ ]

6.11 How many students graduated from your undergraduate program during the period January 2002 until January 2003?

[ ]

6.12 How many students who graduated from your undergraduate program have subsequently enrolled in a graduate program at any institution during the period of January 2002 until January 2003?

6.13 Are placement services offered to students through your undergraduate program or affiliated departments?

☐ Yes

☐ No

6.14 How many students in your undergraduate program accepted a job in the bioinformatics/computational biology field during the period January 2002 until January 2003?

6.15 What proportion of these newly hired bachelor's students completed their degree before leaving to take this job?

%

6.16 What proportion of these newly hired bachelor's students is employed in:

% Private industry

% Not-for-profit organizations

% Educational institutions

% Government

% Other Please specify:

6.17 What proportion of these newly hired bachelor's students is employed:

% Locally (within 50 miles)

% Regionally (within 500 miles)

% Nationally

% Internationally

6.18 A specific goal of this research is to identify companies and institutions hiring significant numbers of students with formal training in bioinformatics/computational biology. Please list the names of companies and institutions that employed these newly hired bachelor's students (e.g. SmithKline Beecham, Pfizer, National Center of Biotechnology Information, Amgen) and the corresponding number of students hired. If you do not know the name of the hiring company or institution, identify a group such as drug company, genetic research company, bioinformatics services company, etc.

6.19 What was the average range of starting salaries for these newly hired bachelor's students?

Please select one

6.20 Did any of these newly hired bachelor's students receive signing bonuses?

- ☐ Yes
- ☐ No

6.21 What are the top three ways in which your undergraduate program recruits bachelor's students? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- _____ Your institution's website
- _____ Online marketing or announcements
- _____ Print marketing or announcements
- _____ On-campus recruitment
- _____ Other Please specify:

6.22 What are the top three reasons you think students are attracted to your undergraduate program? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- _____ Curriculum/training
- _____ Reputation of institution/program/department/faculty
- _____ Relationships of institution/program/department/faculty with industry
- _____ Career opportunities
- _____ Cost
- _____ Flexibility of program structure (e.g., course offerings)
- _____ Other Please specify:

6.23 What are the top three ways in which students in your undergraduate program search for jobs? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- _____ Recruiters that call faculty
- _____ Recruiters that visit campus
- _____ Headhunters that call faculty
- _____ Headhunters that visit campus
- _____ Students or faculty reading ads
- _____ Internships or Co-ops
- _____ Online sources
- _____ Placement services
- _____ Personal contacts

Other, please specify:

7. Does your program offer master's training? *

Yes No

7.1 Is a master's degree awarded through this training program?

Yes

No. If no, identify affiliated department/s awarding the degree:

7.2 What year was your master's program established?

7.3 What were the primary reasons for establishing your master's program?

7.4 Is your master's program a joint effort with other institutions?

Yes. If yes, please list the other institutions:

No

7.5 What proportion of your master's program is funded:

Internally: %

Externally: % By what institutions?

7.6 How many graduate students:

were enrolled in your master's program as of January 1, 2003?

were enrolled in your master's program in its first year?

7.7 How many graduate students:

_____ applied to your master's program for Fall 2002 admission?

_____ were admitted to your master's program for Fall 2002?

_____ accepted admission and enrolled for Fall 2002?

7.8 What proportion of the students in your master's program as of January 1, 2003, are enrolled part-time?

_____ %

7.9 What proportion of the students in your master's program as of January 1, 2003, are:

_____ % non-U.S. citizens?

_____ % women?

_____ % underrepresented minorities (African American, Latino, and Native American)?

7.10 Approximately what proportion of all the students in your master's program is financially supported by:

_____ % Scholarships

_____ % Fellowships

_____ % Research assistantships

_____ % Teaching assistantships

_____ % Employer

_____ % Personal resources

_____ % Other Please specify the source: _____

7.11 What proportion of the students in your master's program as of January 1, 2003, entered the program with primary training in:

_____ % Biological Sciences

_____ % Chemistry

_____ % Computer Sciences

_____ % Engineering

_____ % Mathematics

_____ % Physics

_____ % Other science disciplines (e.g., earth sciences)

_____ % Other non-science disciplines (e.g., business)

7.12 How many students graduated from your master's program during the period January 2002 until January 2003?

_____

7.13 How many students who graduated from your master's program have subsequently enrolled in a doctoral program at any institution during the period of January 2002 until January 2003?

7.14 Are placement services offered to students through your master's program or affiliated departments?

- Yes
- No

7.15 How many students in your master's program accepted a job in the bioinformatics/computational biology field during the period January 2002 until January 2003?

7.16 What proportion of these newly hired master's students completed their degree before leaving to take this job?

%

7.17 What proportion of these newly hired master's students is employed in:

% Private industry

% Not-for-profit organizations

% Educational institutions

% Government

% Other Please specify:

7.18 What proportion of these newly hired master's students is employed:

% Locally (within 50 miles)

% Regionally (within 500 miles)

% Nationally

% Internationally

7.19 A specific goal of this research is to identify companies and institutions hiring significant numbers of students with formal training in bioinformatics/computational biology. Please list the names of companies and institutions that employed these newly hired master's students (e.g. SmithKline Beecham, Pfizer, National Center of Biotechnology Information, Amgen) and the corresponding number of students hired. If you do not know the name of the hiring company or institution, identify a group such as drug company, genetic research company, bioinformatics services company, etc.

7.20 What was the average range of starting salaries for these newly hired master's students?

Please select one

7.21 Did any of these newly hired master's students receive signing bonuses?

- Yes
- No

7.22 What are the top three ways in which your master's program recruits graduate students? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- Your institution's website
- Online marketing or announcements
- Print marketing or announcements
- On-campus recruitment
- Other Please specify:

7.23 What are the top three reasons you think students are attracted to your master's program? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- Curriculum/training
- Reputation of institution/program/department/faculty
- Relationships of institution/program/department/faculty with industry
- Career opportunities
- Cost
- Flexibility of program structure (e.g., course offerings)
- Other Please specify:

7.24 What are the top three ways in which students in your master's program search for jobs? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- Recruiters that call faculty
- Recruiters that visit campus
- Headhunters that call faculty
- Headhunters that visit campus
- Students or faculty reading ads
- Internships or Co-ops
- Online sources
- Placement services
- Personal contacts

Other, please specify:

8. Does your program offer PhD training? *

Yes No

8.1 Is a doctoral degree awarded through this training program?

Yes

No. If no, identify affiliated department/s awarding the degree:

8.2 What year was your doctoral program established?

8.3 What were the primary reasons for establishing your doctoral program?

8.4 Is your doctoral program a joint effort with other institutions?

Yes. If yes, please list the other institutions:

No

8.5 What proportion of your doctoral program is funded:

Internally: %

Externally: % By what institutions?

8.6 How many doctoral students:

were enrolled in your doctoral program as of January 1, 2003?

were enrolled in your doctoral program in its first year?

8.7 How many doctoral students:

[ ] applied to your doctoral program for Fall 2002 admission?

[ ] were admitted to your doctoral program for Fall 2002?

[ ] accepted admission and enrolled for Fall 2002?

8.8 What proportion of the students in your doctoral program as of January 1, 2003, are enrolled part-time?

[ ] %

8.9 What proportion of the students in your doctorate program as of January 1, 2003, are:

[ ] % non-U.S. citizens?

[ ] % women?

[ ] % underrepresented minorities (African American, Latino, and Native American)?

8.10 Approximately what proportion of all the students in your doctoral program is financially supported by:

[ ] % Scholarships

[ ] % Fellowships

[ ] % Research assistantships

[ ] % Teaching assistantships

[ ] % Employer

[ ] % Personal resources

[ ] % Other Please specify the source: [ ]

8.11 What proportion of the students in your doctoral program as of January 1, 2003, entered the program with primary training in:

[ ] % Biological Sciences

[ ] % Chemistry

[ ] % Computer Sciences

[ ] % Engineering

[ ] % Mathematics

[ ] % Physics

[ ] % Other science disciplines (e.g., earth sciences)

[ ] % Other non-science disciplines (e.g., business)

8.12 How many students graduated from your doctoral program during the period January 2002 until January 2003?

[ ]

8.13 How many students who graduated from your doctoral program have subsequently taken a postdoctorate position at any institution during the period of January 2002 until January 2003?

8.14 Are placement services offered to students through your doctoral program or affiliated departments?

- ☐ Yes
- ☐ No

8.15 How many students in your doctoral program accepted a job in the bioinformatics/computational biology field during the period January 2002 until January 2003?

8.16 What proportion of these newly hired doctoral students completed their degree before leaving to take this job?

%

8.17 What proportion of these newly hired doctoral students is employed in:

% Private industry

% Not-for-profit organizations

% Educational institutions

% Government

% Other Please specify:

8.18 What proportion of these newly hired doctoral students is employed:

% Locally (within 50 miles)

% Regionally (within 500 miles)

% Nationally

% Internationally

8.19 A specific goal of this research is to identify companies and institutions hiring significant numbers of students with formal training in bioinformatics/computational biology. Please list the names of companies and institutions that employed these newly hired doctoral students (e.g. SmithKline Beecham, Pfizer, National Center of Biotechnology Information, Amgen) and the corresponding number of students hired. If you do not know the name of the hiring company or institution, identify a group such as drug company, genetic research company, bioinformatics services company, etc.

8.20 What was the average range of starting salaries for these newly hired doctoral students?

Please select one

8.21 Did any of these newly hired doctoral students receive signing bonuses?

- Yes
- No

8.22 What are the top three ways in which your doctoral program recruits doctoral students? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- Your institution's website
- Online marketing or announcements
- Print marketing or announcements
- On-campus recruitment
- Other Please specify:

8.23 What are the top three reasons you think students are attracted to your doctoral program? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- Curriculum/training
- Reputation of institution/program/department/faculty
- Relationships of institution/program/department/faculty with industry
- Career opportunities
- Cost
- Flexibility of program structure (e.g., course offerings)
- Other Please specify:

8.24 What are the top three ways in which students in your doctoral program search for jobs? Rank your responses by entering 1, 2, or 3 in the appropriate box.

- Recruiters that call faculty
- Recruiters that visit campus
- Headhunters that call faculty
- Headhunters that visit campus
- Students or faculty reading ads
- Internships or Co-ops
- Online sources
- Placement services
- Personal contacts

Other, please specify:

9. Does your program offer postdoctoral training? *

Yes No

9.1 What year was your postdoctoral program established?

9.2 What were the primary reasons for establishing your postdoctoral program?

9.3 Is your postdoctoral program a joint effort with other institutions?

Yes. If yes, please list the other institutions:

No

9.4 What proportion of your postdoctoral program is funded:

Internally: %

Externally: % By what institutions?

9.5 How many postdocs:

were in your postdoctoral program as of January 1, 2003?

were in your postdoctoral program in its first year?

9.6 How many individuals:

applied to your program for a postdoctoral position for Fall 2002?

were offered a postdoctoral position in your program for Fall 2002?

accepted an offered postdoctoral position in your program for Fall 2002?

9.7 What proportion of the postdocs in your postdoctorate program as of January 1, 2003, are:

[ ] % non-U.S. citizens?

[ ] % women?

[ ] % underrepresented minorities (African American, Latino, and Native American)?

9.8 Approximately what proportion of all the postdocs in your postdoctoral program is financially supported by:

[ ] % Fellowships

[ ] % Other Please specify the source: [ ]

9.9 What proportion of the postdocs in your postdoctoral program as of January 1, 2003, entered the program with primary training in:

[ ] % Biological Sciences

[ ] % Chemistry

[ ] % Computer Sciences

[ ] % Engineering

[ ] % Mathematics

[ ] % Physics

[ ] % Other science disciplines (e.g., earth sciences)

[ ] % Other non-science disciplines (e.g., business)

9.10 How many postdocs completed their postdoctoral term in your postdoctoral program during the period January 2002 until January 2003?

[ ]

9.11 How many postdocs who completed their postdoctoral term in your postdoctoral program have subsequently taken another postdoctoral position during the period of January 2002 until January 2003?

[ ]

9.12 Are placement services offered to postdocs through your postdoctoral program or affiliated department/s?

☐ Yes

☐ No

9.13 How many postdocs in your postdoctoral program accepted a job in the bioinformatics/computational biology field during the period January 2002 until January 2003?

[ ]

9.14 What proportion of these newly hired postdocs completed their postdoctoral position before leaving to take this job?

[ ] %

9.15 What proportion of these newly hired postdocs is employed in:

_____% Private industry

_____% Not-for-profit organizations

_____% Educational institutions

_____% Government

_____% Other Please specify: _____

9.16 What proportion of these newly hired postdocs is employed:

_____% Locally (within 50 miles)

_____% Regionally (within 500 miles)

_____% Nationally

_____% Internationally

9.17 A specific goal of this research is to identify companies and institutions hiring significant numbers of postdocs with formal training in bioinformatics/computational biology. Please list the names of companies and institutions that employed these newly hired postdocs (e.g. SmithKline Beecham, Pfizer, National Center of Biotechnology Information, Amgen) and the corresponding number of postdocs hired. If you do not know the name of the hiring company or institution, identify a group such as drug company, genetic research company, bioinformatics services company, etc.

9.18 What was the average range of starting salaries for these newly hired postdocs?

Please select one

9.19 Did any of these newly hired postdocs receive signing bonuses?

☐ Yes

☐ No

9.20 What are the top three ways in which your postdoctoral program recruits postdocs? Rank your responses by entering 1, 2, or 3 in the appropriate box.

_____Your institution's website

_____Online marketing or announcements

_____Print marketing or announcements

_____On-campus recruitment

_____Other Please specify: _____

9.21 What are the top three reasons you think postdocs are attracted to your postdoctoral program? Rank your responses by entering 1, 2, or 3 in the appropriate box.

Curriculum/training

Reputation of institution/program/department/faculty

Relationships of institution/program/department/faculty with industry

Career opportunities

Cost

Flexibility of program structure (e.g., course offerings)

Other Please specify:

9.22 What are the top three ways in which Postdocs in your postdoctoral program search for jobs? Rank your responses by entering 1, 2, or 3 in the appropriate box.

Recruiters that call faculty

Recruiters that visit campus

Headhunters that call faculty

Headhunters that visit campus

postdocs or faculty reading ads

Internships or Co-ops

Online sources

Placement services

Personal contacts

Other, please specify:

Perceptions of Your Overall Program

10. What was the most difficult challenge in establishing your program?

11. How has the interdisciplinary nature of bioinformatics/computational biology affected the establishment and administration of your program?

12. Is your program considering offering training at additional degree levels?

☐ Yes. If yes, why? 

☐ No

13. How would your describe student demand for bioinformatics/computational biology training at your institution?

Please select one

14. How well do you think your program meets student demand for bioinformatics/computational biology training at your institution? Please explain.

☐ Completely

☐ Mostly

☐ Somewhat

☐ Not at all

If you would like the opportunity to revise your responses or complete unanswered questions at a later time, only click Submit at this time. Do NOT click on the Final Submission indicator box. You can then later access the questionnaire with your saved responses and make appropriate changes at any time.

When you have fully completed the questionnaire and wish to make no further revisions or additions, click Submit AND click the Final Submission indicator box. Once you click the Final Submission indicator box, you will no longer be able to revise your responses.

If you mistakenly click the Final Submission indicator box and desire to make revisions or additions to your responses, please email us at gblack@gsu.edu so we can reset your access to your questionnaire responses.

☐ **Final Submission.**

Submit

Thank you for your participation!

We appreciate your willingness to take the time to complete this questionnaire and help us gain a better understanding of bioinformatics training programs and their outcomes. If you have questions or comments regarding this questionnaire, please email us at qblack@gsu.edu. We will notify you when the results of this study are available online later this year.

Click here to return to Survey Home

Appendix C

Institutions Placing Bioinformatics Employment Announcements in *Science*: 1996-1997 and 2000-2002

Entity	1996	1997	2000	2001	2002
Private, For-Profit					
Abbott Laboratory	X	X			
Acacia Biosciences		X			
Acadia Pharmaceuticals		X			
Aeiveos	X				
Affimetrix	X	X			
Agilent Tech				X	
Agouron Pharmaceuticals			X		
Alcon Laboratories		X			
Amgen	X	X			
Applera Corporation				X	
Applied Biosciences		X			
Applied Biosystems					X
Ariad		X			
Arris	X				
Astra	X	X			
Astra Arcus		X			
Astra Bioinformatics Center		X			
Astra Boston	X				
Astra Canada	X				
Astra Draco		X			
Astra Hassle		X			
AstraZeneca				X	
Aventis Pharma Deutschland GmbH			X		
Aventis Pharmaceuticals			X		
Avigen		X			
Axon Instruments			X		
Barlex		X			
Base4	X	X			
Battelle		X			
Bayer	X	X	X		
Biogen				X	
Bios Laboratory	X				
Bochringer Ingelheim	X				
Brigham and Women's Hospital			X	X	
Bristol-Myers Squibb	X	X			
Cadus Pharmaceuticals	X	X			
Canadian Genomic Biotech	X				
Catalyst Capital LLC					X
Connolly Bove Lodge & Hutz LLP				X	

Celera			X		
Cereon Genomics			X		
Cerep			X	X	
Ceres		X			
CIBA	X				
Clontech		X			
Consensus Pharmaceuticals				X	
Corixa		X			
CuraGen	X	X			
D-Squared Bio Technologies			X		
DEKALB Genetics	X	X			
Digital Gene Technologies	X				
DNAX Research Institute		X			
Dupont Merck		X			
Eisai Research Institute of Boston		X			
Eli Lilly	X	X			
Epimmune				X	
EraGen Biosciences			X		
Exelixis	X	X	X	X	
Fair Isaac Corporation					X
GE Corporate Research and Development Center				X	
Genaissance Pharmaceuticals		X	X		
Genencor International			X		
gene/Networks		X			
GeneLogic		X			
GeneMedicine		X			
GeneProt			X	X	
Genetech	X				
Genetics Computer Group		X	X		
Genetics Institute	X	X			
Geneva Biomedical Research Institute		X			
GeneVention LLC				X	
Genome Therapeutics	X	X			
Genomed	X				
Genomics Institute of the Novartis Research Foundation					X
Geron			X		
Glaxo Wellcome	X	X			
Hercules			X		
Hoechst Marion Roussel		X			
Horst-Ariad Genomics		X			
Human Genome Sciences	X	X	X		
IDEC Pharmaceuticals				X	
Illumina			X	X	
Immunex	X	X			
Incyte Pharmaceuticals	X	X	X		

InforMax			X	X	
Isis Pharmaceuticals					X
LeukoSite		X			
Lexicon	X				
LifeSpan		X			
Lilly Pharmaceutical					X
Massachusetts General Hospital			X	X	
Mayo Clinic			X		
Memorial Sloan-Kettering Cancer Center					X
Mendel Biotechnology		X		X	
Mercator Genetics	X				
Merck KgaA	X				
Merck Sharpe and Dohme		X			
Metagenics				X	
MetaXen	X				
Microside Pharmaceuticals		X			
Millennium Pharmaceuticals	X	X	X		
Molecular Informatics		X			
Molecular Simulations		X			
Monsanto	X	X	X		
Mount Sinai Hospital			X		
Nema Pharmaceuticals		X			
Novartis		X			
Novartis Institute for Biomedical Research					X
Novartis Institute for Functional Genomics				X	
Novartis Research Foundation					X
Novo Nordisk Biotech		X			
Ontogeny		X			
Onyx Pharmaceuticals		X			
OriGene Technologies			X		
Parke-Davis		X	X		
PE Corporation		X	X		
Pfizer	X	X		X	
Pharmacia Corporation				X	
Pharmacia and Upjohn		X			
Pioneer Hi-Bred International			X		
PointOne				X	
Procter & Gamble					X
Proteome				X	
Purdue BioPharma L.P.			X		
Purdue Pharma				X	
OBI Enterprises		X			
Qiagen	X				
Regeneron Pharmaceuticals		X			
Rhone-Poulenic Rorer		X			
Ribozyme Pharmaceuticals		X			

Roche		X	X		
Rosetta Inpharmatics					X
RW Johnson Pharmaceutical Research Institute	X				
Sanofi-Synthelabo					X
S*BIO			X		
Schering-Plough Research Institute	X	X	X		
Scios	X	X			
Scriptgen		X			
Searle		X			
Senomyx			X		
Sequana Therapeutics	X	X			
Serono			X		
SmithKline Beecham	X	X	X		
St. Jude's Children's Research Hospital			X		
Structural Bioinformatics		X			
Synteni		X			
Tecolote Research			X		
Texas Biotechnology		X			
Therapeutic Genomics			X		
Transition Therapeutics			X		
VaxGen				X	
Versicor	X				
Vertex					X
Wyeth-Ayerst	X	X	X		
Xencor				X	
Zeneca	X	X			
ZymoGenetic	X	X	X		
Not-For-Profit/Academic					
Academia Sinica				X	X
Albert-Ludwigs University				X	
American Type Culture Collection		X	X		
Argonne National Laboratory			X		
Arizona State University				X	
Auburn University				X	
Ball State University				X	X
Bar-Ilan University					X
Bard College			X		
Baylor College of Medicine	X		X		
Beloit College			X		
Bergen University					X
Binghampton University			X		
Biomedical Research Institute	X				
Boise State University				X	
Boston College					X
Boston University	X		X		X

Brigham Young University					X
Brown University					X
Burnham Institute				X	
California Institute of Technology		X		X	
California Polytechnic State University					X
California State University-Channel Islands					X
California State University-Fullerton			X	X	
Cambridge University			X		
Canisius College			X		
Carleton University			X		
Carnegie Mellon University			X	X	
Case Western Reserve University			X	X	X
Catalan Institution for Research and Advanced Studies				X	
Center for Advanced Research in Biotechnology			X		X
Centers for Disease Control		X			
Center for Scientific Review, NIH				X	
Central Michigan University					X
Chinese University in Hong Kong	X				
City College of New York				X	
City of Hope/National Medical Center		X			X
City University of New York-Staten Island			X	X	
City University of New York Medical School				X	
Claflin University					X
Claremont College					X
Clark University			X		
Clark Atlanta University	X				
Clemson University			X	X	
Colorado College					X
Columbia University		X	X	X	X
Cornell University		X	X	X	
Dalhousie University			X		
Dartmouth Medical School			X	X	X
Dickinson College			X		
Donald Danforth Plant Science Center					X
Duke University				X	
DNA Learning Center, Cold Spring Harbor Laboratory			X		
East Carolina University					X
East Tennessee State University				X	X
Emory University			X	X	
Ernest Gallo Clinic and Research Center			X		
Ernest Orlando Lawrence Berkeley National Laboratory		X			
European Bioinformatics Institute	X			X	
Florida Atlantic University			X		

Florida State University		X	X		X
Forsyth Institute			X		
Fox Chase Cancer Center		X			
Fred Hutchinson Cancer Research Center			X	X	X
Friedrich Schiller University			X		
Frontier Science and Technology Research Foundation			X		
Furman University					X
Geneva Biomedical Research Institute		X			
Genome British Columbia					X
George Mason University		X	X	X	
Georgetown University				X	X
Georgia Institute of Technology	X		X	X	X
Harvard University		X	X	X	X
Hebrew University				X	X
Hofstra University			X		
Howard University				X	
Idaho State University				X	
Idaho University					X
Illinois Institute of Technology			X		
Illinois State University			X		
Indiana State University		X	X		
Indiana University				X	
Institute for Drug Development			X		
Institute for Marine Biosciences			X		
Institute for Medical Biomathematics			X		
International Diabetes Institute			X		
Iowa State University		X	X		
Johns Hopkins University	X		X	X	X
Josephine Bay Paul Center for Comparative Molecular Biology and Evolution				X	
Juniata University			X		
Karolinska Institute, Center for Genomics Research		X	X		
Kennesaw State University				X	
Kenyon College				X	
Kumho Life and Environmental Science Laboratory			X		
Kwangju Institute of Science and Technology					X
Los Alamos National Laboratory		X		X	X
Louisiana State University			X	X	X
Massachusetts Institute of Technology			X	X	X
Marquette University				X	
Max Planck Institute-Dortmund			X		
McGill University			X		
Medical College of Georgia			X	X	
Medical College of Ohio					X
Medical College of Virginia			X		

Medical College of Wisconsin			X	X	X
Medical University of South Carolina			X	X	X
Michigan State University		X	X		X
Michigan Technological University					X
Mississippi State University				X	
Missouri Botanical Gardens	X				
Molecular Research Institute		X	X		
Monell Chemical Senses Center					X
Montana State University					X
Montclair State University				X	X
Mount Sinai School of Medicine					X
Muhlenberg College			X		X
National Biotechnology Information Facility		X			
National Cancer Center			X		
National Cancer Institute		X	X		
National Center for Biotechnology Information	X	X	X		
National Center for Genome Research	X	X			
National Central University				X	
National Eye Institute			X		
National Human Genome Institute		X			
National Institute for Occupational Safety and Health			X		
National Institute of Diabetes and Digestive Kidney Disease					X
National Institute of Environmental Health Sciences					X
National Institute of General Medical Sciences				X	
National Institute of Neurological Disorders and Stroke				X	
National Institute of Standards and Technology					X
National Institutes of Health		X	X	X	
National Science Foundation	X				
National Taiwan Normal University				X	
National Tsing Hua University					X
National University of Singapore			X		
Neurosciences Institute				X	
New Mexico Institute of Mining and Technology			X		
New Mexico State University			X		
New York Medical College					X
New York School of Medicine					X
New York State Department of Health, Wadsworth Center			X		
New York University			X	X	
North Carolina State University				X	X
Northeastern University			X	X	
Northern Illinois University			X	X	
Northwestern University			X	X	

Oak Ridge National Laboratory	X		X	X	
Ohio State University		X	X	X	X
Oklahoma Medical Research Foundation			X		
Oklahoma State University			X	X	
Oregon Health and Science University				X	
Oregon State University				X	
Parker Hughes Institute			X		
Pennsylvania State College of Medicine					X
Pennsylvania State University			X		
Pomona College	X				
Princeton University			X	X	
Public Health Research Institute					X
Purdue University			X	X	X
Queen Mary University of London				X	
Richard Stockton College				X	
Rice University			X	X	
Rochester Institute of Technology		X			X
Roswell Park Cancer Institute			X		
Rush University			X		
Rutgers University			X	X	X
Saint Lawrence University					X
Saint Louis University					X
Samuel Roberts Noble Foundation			X	X	
San Diego State University			X		X
San Francisco State University				X	X
Sandia National Laboratory	X		X		
Santa Fe Institute		X			
Scripps Research Institute		X	X		
Seattle Biomedical Research Institute				X	
Shanghai Institute for Biological Sciences			X		
Sidney Kimmel Cancer Center				X	
Simon Fraser University			X	X	
Socratech University			X		
South African National Bioinformatics Institute		X			
Southern Polytechnic State University				X	
Southwest Texas State University				X	
Spelman College				X	
Stanford University		X	X	X	X
State University of New York-Stony Brook			X		
State University of New York Medical School				X	
Stephen F. Austin University				X	
Stine-Haskell Research Center		X			
Stony Brook University					X
Tel Aviv University			X	X	X
Temple University			X		
Texas A&M University			X	X	X

Texas Technology University					X
The American Museum of Natural History			X		
The Jackson Laboratory	X	X	X		X
The Keck Center				X	
The Marine Biological Laboratory				X	
The Neurosciences Institute				X	
The Scripps Research Institute				X	
The Victor Chang Cardiac Research Institute					X
The Whitehead Institute for Biomedical Research				X	
Thomas Jefferson University			X		
Towson University				X	
Tufts University			X		X
U.S. Army Engineer Research and Development Center			X		
U.S. Army Medical Research Institute of Infectious Disease				X	
U.S. Army Soldier and Biological Chemical Command				X	
U.S. Department of Agriculture, Agricultural Research Service			X	X	X
U.S. Department of Agriculture, Genetics Research Unit				X	
U.S. Naval Research Laboratory				X	X
University of Alabama-Birmingham				X	X
University at Albany, State University of New York			X		
University of Alberta			X	X	
University of Arizona			X	X	X
University of Arkansas-Little Rock				X	
University of Arkansas-Pine Bluff					X
University of British Columbia				X	
University of Calgary					X
University of California				X	
University of California-Berkeley			X	X	X
University of California-Davis				X	X
University of California-Irvine	X		X	X	X
University of California-Los Angeles	X		X	X	
University of California-Riverside			X		X
University of California-San Diego			X	X	X
University of California-San Francisco		X	X		X
University of California-Santa Barbara			X	X	
University of California-Santa Cruz					X
University of Central Florida				X	
University of Chicago			X		
University of Cincinnati				X	X
University College of Dublin					X
University of Colorado				X	X

University of Dayton					X
University of Delaware					X
University of Idaho				X	
University of Florida		X	X	X	X
University of Georgia				X	X
University of Houston		X	X	X	
University of Illinois-Chicago			X	X	
University of Illinois-Urbana/Champaign			X	X	
University of Iowa			X	X	
University of Kansas Medical Center				X	
University of Kentucky			X	X	
University of Kentucky-Lexington				X	X
University of Louisiana- Monroe					X
University of Louisville			X		
University of Maryland				X	X
University of Maryland-Baltimore County			X		
University of Maryland-College Park			X	X	
University of Massachusetts					X
University of Massachusetts-Amherst	X				
University of Massachusetts-Lowell			X	X	X
University of Massachusetts Medical School				X	
University of Miami					X
University of Michigan		X	X	X	X
University of Minnesota			X	X	X
University of Missouri-Columbia			X		
University of Missouri-Kansas City			X	X	
University of Nebraska			X		
University of Nebraska-Lincoln				X	X
University of Nebraska-Omaha					X
University of Nevada				X	X
University of New Mexico	X	X	X		
University of New Orleans					X
University of North Carolina-Chapel Hill			X	X	X
University of North Carolina-Greensboro			X		
University of North Dakota					X
University of North Texas					X
University of Oklahoma					X
University of Oslo				X	X
University of Pennsylvania	X	X		X	
University of Pittsburgh			X	X	X
University of Puerto Rico					X
University of Rochester				X	X
University of Southern California		X	X	X	X
University of Sydney	X				
University of Tennessee-Health Science Center					X
University of Tennessee-Knoxville			X		

University of Tennessee-Memphis			X		X
University of Texas-Austin		X	X	X	X
University of Texas-Dallas				X	
University of Texas-El Paso			X		
University of Texas-Houston			X		X
University of Texas-M.D. Anderson Cancer Center				X	
University of Texas-San Antonio				X	X
University of Texas-Southwestern Medical Center		X		X	
University of the Sciences in Philadelphia					X
University of Toledo					X
University of Toronto				X	
University of Utah				X	X
University of Vermont			X	X	
University of Victoria				X	
University of Vienna			X		
University of Virginia	X	X		X	
University of Washington	X			X	X
University of Wisconsin-Eau Claire				X	
University of Wisconsin-Madison			X	X	X
University of Wisconsin-Milwaukee					X
University of Wisconsin-Parkside			X		X
University of Wisconsin-River Falls				X	
University of Wyoming			X		
Uppsala University			X		
Vanderbilt University	X		X	X	
Vassar College			X	X	X
Virginia Bioinformatics Institute					X
Virginia Commonwealth University			X	X	X
Virginia Polytechnic Institute and State University			X		X
Wake Forest University			X	X	X
Washington State University				X	
Washington University	X		X	X	X
Weill Medical College of Cornell University			X		
Weizman Institute of Science					X
Wellesley College				X	
Wesleyan University				X	
West Virginia University					X
Western Michigan University			X	X	
Westminster College				X	
Whitehead Institute	X	X			
Wichita State University					X
Wistar Institute					X
Worcester Polytechnic Institute					X
Worcester State College				X	
Wright State University				X	
W. M. Keck Center		X			

Yale University	X	X	X
Yeshiva University		X	X
Yonesi University		X	
York University	X		

Appendix D

Institutions Placing Employment Announcements on www.monster.com,
June 2003-February 2004 (Excluding October 2003)

Private, For-Profit
Affymetrix
Agilix Corporation
Alfred I. DuPont Childrens Hospital
Amersham - Biosciences
Amylin Pharmaceuticals
Applera Corporation
Applied Biosystems
Atlantis Partners
BASF Corporation
Beyond Genomics
Boehringer Ingelheim
CIBER
Celera
Cengent Therapeutics (Structural Bioinformatics Inc.)
Children's Hospital Boston
Children's Hospital of Philadelphia
Chiron Corporation
Comforce
Constella Group
Cubist Pharmaceuticals
Delta Search Labs
EDGE Technologies
ENVIRON Corporation
GenPath Pharmaceuticals
Gene Logic
Gene Network Sciences
Genomatica Inc.
GlaxoSmithKline
IDC
INCOGEN
IVAX Corporation
Illumina
Infoquest Consulting Group
Insightful Corporation
Intel
Invitrogen
Johnson & Johnson Pharmaceutical Research and Development LLC
Kemin Foods LC
Management Science Associates
Memorial Sloan-Kettering Cancer Center

Merck & Company
Nestlé USA
Novartis Pharmaceuticals
Odyssey Therapeutics
Orion Genomics
Paracel Inc.
Paradigm Genetics
PerkinElmer
Perlegen Sciences
Pfizer
Procter & Gamble
Roche Molecular Systems
Roche Pharmaceuticals
SAIC
SRA International
Sagres Discovery
Sanford Rose Associates
Scientific Systems Company
Sensor Technologies
Siemens Corporate Research
Taj Technologies
Tanabe Research Laboratories
Terrapin Systems
The KEVRIC Company
Thermo Electron Corporation
Wyeth Pharmaceuticals

Not-for-Profit, Academic:
California Institute of Technology
Carnegie Institution
Cystic Fibrosis Foundation
Indiana University
Massachusetts Institute of Technology
Southern Research Institute

Recruiters:
Adecco Technical
Corva Consulting
CyberCoders
DCRI/Texcel
Erdman Biotech Recruiters
HGI
HireMinds LLC
Kelly IT Resources
Kelly Scientific Resources
Management Recruiters International

Management Systems Designers Inc.
Manpower Professional
Quantum Resources Corporation
Smith Hanley Consulting Group
TAC Worldwide Companies
TriStaff Group
Triton Consulting Group
Yoh Scientific

Appendix E

Institutions Placing Employment Announcements on www.bioplanet.com, 2002-2003

Institution	2002	2003
Private, For-Profit		
3rd Millennium	X	
454 (Curagen)	X	
ADL	X	
Accelrys	X	
Affymetrix		X
AgResearch		X
Agilent Technologies		X
Amgen		X
AstraZeneca	X	
AxCell Biosciences	X	
BASF Plant Science GMBH	X	
Bell Atlantic	X	
Biosentients	X	
Biozentrum	X	
CARTA	X	
CCL	X	
Celera	X	
Computercraft	X	X
CottonWood CyberVentures		X
Diversa	X	
engeneOS	X	
Fair Isaac and Company	X	
Ferring Research Institute	X	
Flexione	X	
ForScience		X
Friedrich Miescher Institute	X	
GE Global Research Center		X
GenPath Pharmaceuticals		X
Gene Logic	X	X
Genencor International	X	
Genentech	X	
Heliomics		X
IBM	X	
Ingenuity Systems	X	X
Itrac	X	
LION Bioscience Research		X
Lipomics Technologies	X	
Lockheed Martin	X	

Maxonic		X
Meriture		X
Monsanto		X
Myriad Proteomics	X	
New Discovery	X	
Novartis Institute for Tropical Diseases		X
Ocimum Biosolutions	X	
Organon Laboratories	X	
Paradigm Genetics	X	X
Paradigm Therapeutics		X
Perlegen Sciences		X
Pfizer		X
Pharmacia	X	
Physiome Sciences	X	
Proctor and Gamble Pharmaceuticals	X	
Schering-Plough	X	
SciGenium	X	
SciNova Informatics	X	
Siena Biotech		X
Silicon Genetics	X	
Terrapin Systems		X
Torrey Mesa Research Institute	X	
United Devices	X	
Yoh Scientific		X

Recruiters

A. E. Feldman Associates	X	
Alexus	X	
BI-Careers	X	
Bluespeed Technology	X	X
CC & Associates		X
Cameron Craig Group of Recruiters		X
Critical Path	X	
Hess Associates	X	
Hire Efficiency	X	
HireSource Solutions		X
IPS America		X
Imphasis	X	
Katonah Group	X	
KOB Solutions	X	
MRI-Fresno	X	
Manpower NC	X	
Profluence		X
Recruitment Enhancement Services	X	
Sanford Rose Associates		X
Sharp Recruiters	X	

Strategic Software Solutions	X	
Systems Consultants	X	
TAC Worldwide		X
Tech Find	X	
The Cambridge Group	X	X
The Pittman Group		X
Work Wonders Staffing	X	X
Not-For-Profit		
Aberystewyth Research Centre		X
Bioinformatics Institute	X	
CNRS		X
Consorzio Mario Negri Sud	X	
Institute of Bioinformatics		X
John Innes Centre		X
Michael Smith Genome Sciences Centre		X
National Marrow Donor Program		X
Rothamsted Research		X
Stowers Institute	X	
Government		
Institut National de Recherche en Informatique et en Automatique	X	
Los Alamos National Laboratory	X	
Oak Ridge Ridge National Laboratory		X
Universities		
Anna University		X
CompuTech of Chicago	X	
Cornell University	X	X
Duke University	X	X
George Mason University		X
George Washington University		X
Georgetown University	X	X
Keck Graduate Institute of Applied Life Sciences	X	X
Northeastern University	X	
Northwestern University		X
Purdue University		X
Tokyo Institute of Technology	X	
University College Dublin		X
University of Basel		X
University of California-San Diego		X
University of California-Santa Cruz	X	
University of Hawaii		X
University of Illinois at Urbana-Champaign		X
University of Kansas	X	X

University of Medicine and Dentistry of New Jersey		X
University of Newcastle		X
University of Nijmegen	X	
University of South Florida		X
University of Tennessee Health Science Center		X
University of Tokyo	X	
University of Westminster		X
Washington University		X