CHAPTER 1

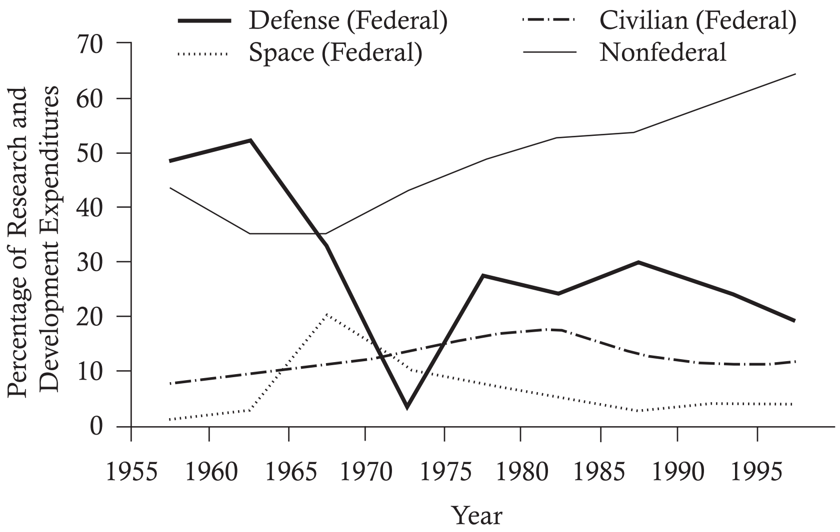
Science: The Period and the People

The scientific discovery process is always peeling away layers of an onion without ever knowing how many you have to peel before you find the core.

—Anonymous interviewee[1]

The focus of this study is the workplace experiences of men and women trained in the sciences between the mid-1960s and the mid-1990s. As a field of study and work, science has been influenced by four important changes over this period. First, and maybe most important, federal research funds, which made up two-thirds of research and development (R&D) spending at the beginning of the thirty-year period, fell to just over one-third of R&D funds by its end, as shown in figure 1.1. Second, fields of study that were most successful at attracting public attention, research funds, and new students changed dramatically during this period. Third, especially in the latter half of this period, there was an enormous influx of foreign-born scientists into Ph.D. programs and into the scientific workforce. Finally, women became a nontrivial and an increasing portion of the student body as well as the workforce in science. All of these changes had important effects on the workplace and careers of scientifically trained individuals.

Figure 1.1 *Federal and Nonfederal Research and Development Expenditures*

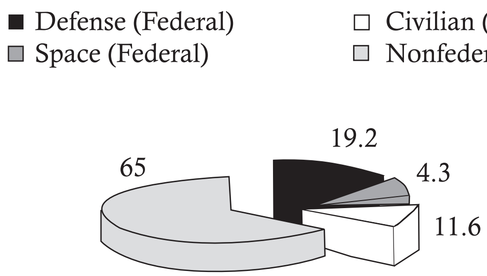


Source: Based on National Science Board 2002, table C-14.

Implications of the Changing Sources and Destinations of R&D Funding

Scientists interviewed agree that science, as a field, has lost some of the luster that it seemed to enjoy in the 1960s and 1970s. During that time, the United States was engaged in a race to explore the moon and in building a defense system to protect against threats of military action during the Cold War. Jacques Cousteau's undersea explorations were televised to adoring audiences. The environmental movement was born during the late 1960s, and this, along with the high prices and uncertain supplies of oil in the 1970s, turned the public's attention toward the possibility of alternative energy sources. Federal funding of R&D as a percentage of gross domestic product (GDP) peaked in 1964 at 1.93 percent. Approximately 65 percent of all R&D spending originated in the federal government, and over 80 percent of federal fund-

Figure 1.2 *Research and Development Expenditures 1995 (Percentages)*



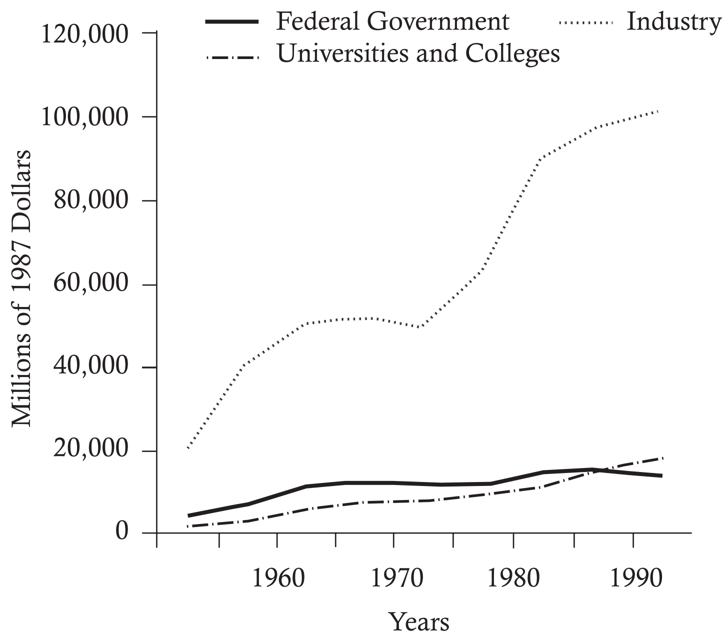
Source: Based on National Science Board 2002, table C-14.

ing of research and development was related to space exploration or defense development.

But during the 1980s and 1990s, public interest changed: the Berlin Wall fell, the fears of escalating oil prices diminished with increasingly stable supplies, the space race took a backseat to more pragmatic public issues, and concern for the environment waned. Federal funding for R&D, while increasing in absolute terms, fell to 0.89 percent of GDP, its lowest level since the mid-1950s. At the same time, nongovernment or private R&D funding, primarily financed by private corporations, increased disproportionately. Private funding, which made up little more than half of government funding in the 1960s, surpassed and nearly doubled government funding of R&D by 1994, as shown in figures 1.2 and 1.3. The federal government remained the spending leader only in basic research, the area that attracts the smallest amount of research funds. With this change in the source of R&D funds, the direction of scientific research has become increasingly dictated by market forces and by the ability to transfer knowledge to those technological advancements with a profitmaking potential.

The relatively slow growth in government funding of scientific research has had the greatest impact on careers of Ph.D. scientists as the traditional academic career path has become more difficult to realize and sustain. In the past, a scientist graduating from a university Ph.D.

Figure 1.3 *Research and Development Performance by Sector*



Source: Based on National Science Board 2002, table C-14.

program might possibly take on a two- to three-year postdoctoral position at another institution to get more research experience, land a junior academic position, and apply for grants to set up his or her own laboratory. Throughout his or her career, laboratory research would be funded by government grants from federal agencies such as the NSF, the National Institutes of Health (NIH), or the Department of Defense.

During the period from the mid-1960s to the mid-1990s, R&D funds received by colleges and universities more than tripled while the number of new Ph.D.s increased threefold. But with increasingly sophisticated and expensive equipment, competition for funds grew more intense. Labs were growing in size, and with more subordinates per grant-generating laboratory, the organizations were getting increasingly bottom heavy. Adams and associates (2003) show that between 1981 and 1999, authors per scientific paper increased from 2.8 to 4.4. New Ph.D.s were finding it harder to set up their own laboratories and increasingly took several consecutive postdoctoral positions before having the opportunity to settle into a permanent job. The proportion of new Ph.D.s who take on postdoctoral positions increased from 20 percent in 1970 to 39.4 percent in 1993. In 1993, 20 percent of life science Ph.D.s were still in a postdoctoral position four years after graduation. A young assistant professor in microbiology describes the situation: "the field of microbiology kind of grew like a cancer and one good lab gave rise to ten good post-docs who set up their own labs." After a while there was no money for new labs, but there was still demand for postdoctorals to run the existing laboratories. Graduates of Ph.D. programs moved from one laboratory to another until they got the "big break" (first authorship of a paper accepted in a high-impact journal) or they opted for another career path outside of academia. This academic career path has become especially unattractive for individuals with working spouses who may have problems finding jobs in the temporary locations of the postdoctoral appointments. Family responsibilities also take away from the "tunnel vision" and heavy time commitments that many scientists see as necessary in order to win the contest for grant money. Because women were more likely than men to have relatively immobile spouses and were less inclined to request compromises in either spouse's career or family life to accommodate job requirements, they were finding the academic career path increasingly inhospitable at the same time that equal opportunity law was opening more doors for them.

Doctoral Ph.D. students who did land permanent academic jobs found it progressively harder to survive in science careers as periodic grant renewals were no longer automatic. One Ph.D. in microbiology asserted that, during the period from the mid-1980s to the early 1990s, the percentage of grant applications being funded in her field fell from one-third to 5 percent. While this assertion may be an exaggeration, data on NIH grant-making shows that, by the mid-1990s, the success rates for both new and renewal grants were half the levels of the early 1980s. In addition, only a third of renewal grants were being funded

(Mandel 1995). A Ph.D. physicist at an Ivy League institution who began his career in the early 1970s with plentiful government funds was barely scraping by in the early 1990s. He explained, "It has a real impact on your overall productivity—because of the very large reductions [in funding] and in the people [funding agencies] we used to count on for support. So, in short, we can't help [but] be discouraged psychologically . . . you feel let down."

With R&D funds increasingly originating in private firms, industry grants and opportunities became more attractive to scientists. From 1973 to 1995, the percentage of the full-time doctoral labor force employed in the industrial sector increased from 24 percent to 35 percent (Long 2001). Because the emphasis in industry jobs is more on development and applied marketable research, they have been looked down on historically by academic scientists. As a Ph.D. chemist pointed out, one implicit measure of a professor's success is still "the number of his or her students that have gone on to become professors at big hot shot universities." He continued, "if you go off and do research at a federal laboratory or in industry, you've given in or given up." More recently there seems to be increased acceptance of jobs in industry, possibly because these workplaces are offering desirable perks, such as higher pay and more time for family life, that are not always available in academia.

Although the percentage of industry funds allocated across basic research, applied research, and development did not change, there was a real feeling by scientists that the character of research was changing. A Ph.D. in chemistry working for a successful pharmaceutical company explained:

> The pharmaceutical marketplace has changed more in the past decade [1985 to 1995] than it has ever changed before. . . . In order to be profitable in the pharmaceutical industry you have to approach research with a very different perspective than what you would have done ten years ago. The first question that is asked before committing money to a research program is "is the market there?"

He went on to describe a product that mimics the human growth hormone and that helps young children without natural growth hormones grow into normal, fully developed adults. Although the product is successful, he was confident that it would never have been developed in the environment of the 1990s because the small patient pool, children deficient in human growth hormone, guaranteed low profits. Even with the Orphan Drug Law passed in 1983, which allows firms that develop drugs for rare diseases both to have exclusive rights and to charge high mark-ups, the large pharmaceuticals have tended to stay away from these small markets. He conceded that, even in basic research, firm profits determine direction and focus.

Because science was the foundation of many government initiatives in the 1960s and early 1970s, the discipline was revered, and scientists were perceived as working for the public good. A Ph.D. physicist who grew up in the 1960s reading *Scientific American,* tried to describe the environment: "It was the time of the big space program in the sixties and there was a lot of interest in science in general in the country. . . . And a lot of technology came out of the space race—whole industries grew up from that." Another Ph.D. recipient in the mid-1970s recounted his experience in a NSF summer program for high school juniors in the early 1960s. Marveling at how active the government was in recruiting bright young people to science in the post-Sputnik period, he described a program in which sixty students from all over the country convened at a university campus for an eight-week program in chemistry, physics, and mathematics. He concluded, "I had never been around such smart people . . . and it was just glorious."

In stark contrast to the 1960s, the 1990s were a time when scientists felt neither well respected nor well rewarded. A professor of engineering recounted, "I never found any glamour in telling anyone that I was an engineer. It's much more satisfying and I get a much different response when I tell people that I'm a professor. There's not a lot of value placed on engineering in this society." A career engineer employed in industry had a similar concern: "When I go to a social gathering and they say 'What do you do?' I say 'Well, I'm an engineer.' 'Where?' they say, 'On the Long Island Railroad?' People have no idea what I'm talking about." A woman with a master's in biology lamented the differential respect afforded M.D.s and Ph.D. scientists: "Even the Ph.D. I worked for at the hospital was very envious of the M.D.s because we would be doing all the work . . . we would give them the data, and they would get all the glory." A biology graduate who worked in a laboratory before moving into business pointed out, "I don't think that our society puts enough value on research. Oh, if you find a cure you're wonderful, but [what about] the eight million other people [who] sweat and suffer?" She was disturbed that scientists put in tremendously long hours working on experiments that do not follow a time clock and get compensated by government grants with no overtime pay. Similarly, Ph.D. scientists have had to question the respect afforded them as they spend increasing number of years living on postdoctoral stipends.

The lack of financial reward was an ever-present concern for many of the scientists and engineers who saw research as driven by profit potential. As one engineer commented, "You know we're outside the flow of money in most businesses, we're usually an overhead and a necessary evil." Pay of scientists and engineers may have been low relative to other successful professionals such as lawyers and doctors. However, the scientists more often compared their own salaries to those of their managers. Many corporations have two different promotion and salary tracks: one for management and one for technical personnel. The opportunities and salaries of the technical personnel fall behind the management personnel before midcareer. A large majority of the male scientists left science for management and finance-related jobs with the hope of making more money.

The movement to market-driven R&D funding has occurred at the same time that changing national and world priorities have altered the focus of attention within science. As noted earlier, space exploration, political attention to defending against Cold War threats, developing alternative energy sources, and preserving the environment fueled the prominence of physics, astronomy, and geology in the 1960s and 1970s. By the early 1990s, these issues had receded in the public's consciousness. Over the same period there were remarkable changes in the biological sciences. The discovery of the chemical structure of DNA by Watson and Crick in 1953 created the field of molecular biology and propelled an explosion of basic research, which is having enormous impacts on contemporary medicine. Subsequent work on recombinant DNA paved the way for the biotech industry, which uses genetic engineering to create innovative products with wide ranges of uses. Meanwhile, computer technology exploded, allowing personal computers and the internet to change the structure of jobs in almost every field.

With a changing focus of public attention over the period, general funds for scientific research were reallocated toward these more popular fields, and students entering science were lured to these cutting-edge areas. During the period 1975 to 1995, the number of doctoral degrees awarded in physics increased by 20 percent, but the number of Ph.D.s awarded in math did not change. However, the number awarded in biological and agricultural sciences increased by 38 percent, and the number awarded in computer science increased a staggering 312 percent. As might be predicted by the increasing portion of R&D funds coming from industry, the number of doctoral degrees awarded in engineering also increased 89 percent (Long 2001).

Increasing Presence of Foreign-Born Students and Scientists

Since the late 1970s, there has been a marked increase in foreign-born science and engineering students and workers. Except for a period in the mid-1990s following the Tiananmen Massacre and the Chinese Student Protection Act, there was a steady increase in foreign-born students enrolling in master's and doctoral programs in the sciences and engineering. In 1999, foreign-born students made up 50 percent of all graduate students in engineering, mathematics, and computer science, an increase from roughly a third in the early 1980s. Across all scientific fields, one-third of all doctoral recipients were foreign born (National Science Board 2002). In 1980, foreign-born college graduates made up 11 percent of the scientific workforce; by 2000 this percentage had increased to 19 percent (National Science Board 2002). Sharon Levin and Paula Stephan (1999) find that in 1990 one in four doctoral scientists employed in the science and engineering workforce was foreign born, an increase from one in five ten years earlier. The impact of these foreign-born scientists on the labor market and on the workplace is bound to be significant. However, the focus of the present study is the exit of U.S.-born scientists. From the work histories and the interviews, the influx of foreign scientists seemed to have no direct impact on exit. However, if the influx of these scientists increased the supply of scientists looking for work relative to demand, there would have been downward pressure on earnings, a factor influencing exit. Also likely, the attrition of U.S.-born scientists and the increasing reluctance of domestic men, in particular, to follow a science career have made room for the influx of the foreign-born scientists into graduate programs and laboratories that were trying to grow at a faster rate than the domestic science workforce. While a correlation between influx and attrition may exist, the direction of causation is unclear.

Increasing Presence of Women in Science Degree Programs and in the Scientific Workplace

The thirty-year period from the 1960s to the 1990s was also a time of increasing education and employment opportunities for women, facilitated, at least partially, by public initiatives. The passage of Title VII of the Civil Rights Act in 1964 prohibited sex discrimination in employment, and in 1972, Title IX of the educational amendments of the Civil Rights Act barred sex discrimination in any educational program receiving federal assistance. Over this period, labor-force participation of women increased from 38 percent to 59 percent, the percentage of bachelor's and master's degrees awarded to women increased to more than 50 percent, and the previously stagnant female-to-male weekly earnings ratio rose from 0.63 to 0.75. The science field, which for all practical purposes was a "male" field in 1960, was not immune to the female demand for better and more inclusive education and employment opportunities. Women's entry into scientific fields was facilitated as well by the increasing public attention to and the growing research support of biology and life sciences, fields to which women were disproportionately drawn. Over the twenty-year period from 1975 to 1995, the percentage of bachelor's, master's, and doctoral degrees in science and engineering awarded to women all increased by roughly twelve percentage points.

With the increasing number of women in science, the character of the workplace changed. Prejudices, based on deep-rooted stereotypes that marked women as less capable in conducting science, have created gender conflicts. In the workplace, challenges of attracting women to science have broadened to challenges of retention. In a field in which occupational exit was already disproportionately high compared to other nonscience fields, women were twice as likely to leave scientific employment as men. Institutions were turning their attention to programs that alleviate the conflicts between family and work, which so often burden working women, and to policies that make science a more welcoming field to women in general.

DATA FOR THE STUDY

The remainder of this book studies careers of a group of scientifically trained individuals in an attempt to understand the character of occupational exit from science. Using statistical analysis and interview data, it explores a series of related questions: Who leaves science and who stays? What are the factors influencing attrition decisions? Are these factors different for different groups of scientists? Where do exiting scientists go, and what do they do? What are the consequences of exit and how do career paths of leavers and stayers diverge? What policy actions might improve retention and quality of life of science personnel?

The focus of the analysis is the career paths of men and women with science degrees, including life sciences, physical sciences, mathematics, and engineering. The career paths studied come from three complementary data sets. The first data set, the SSE, 1982 to 1989, was collected by the NSF and gives background data on exit for a national sample of working scientists. The survey, which asks questions concerning job, demographic, educational, and personal characteristics, was sent in 1982 to a stratified systematic sample of more than 100,000 1980 Census respondents. The full sample included a potential science sample of individuals who worked in a set of targeted science-related occupations and who had four or more years of college education, and a potential engineering sample of individuals who worked in occupations targeted as engineering and who had two or more years of college education. All respondents were resurveyed in 1984, 1986, and 1989. Only

69.7 percent of the initial respondents actually worked in science and engineering jobs and identified their occupation as in the natural sciences or engineering. These respondents contributed data on national patterns of exit from science. Table 1.1 outlines their general demographics.

The greatest differences between men and women in this sample are the discrepancies in age, marriage, and children. The men are older, more likely to be married, and more likely to have dependents. Because only a handful of women successfully entered the science and engineering professions before equal employment opportunity laws came into effect in the 1960s, the older cohorts in this national sample are almost exclusively male. Furthermore, engineering was slower in attracting women than even the natural sciences, so the female engineers in the sample are especially young. The difference in age of men and women most likely contributes to the difference in family characteristics. However, multivariate analysis of the data show that, after controlling for age, female engineers are 4 percent more likely not to have been married and 25 percent less likely to have had children than male engineers. Similarly, female natural scientists are 13 percent more likely to never have been married and 20 percent less likely to have had children than their male counterparts. Working women may choose not to marry or have children since the woman is the partner in the dual-career marriage most likely to shoulder the double responsibilities of family and outside employment. The biggest difference in the educational distributions across the sexes occurs for natural scientists seeking Ph.D.s, with the percentage of men earning Ph.D.s about ten points higher than the percentage of women. The percentage of both scientists and engineers who finish their education with a bachelor's degree is about six points higher for women than for men. Because the working engineer, in contrast to other scientists, needs only an associate's degree, educational cells do not sum to one for the engineering columns.

Although analysis of the national data set is particularly helpful in establishing national patterns of exit during a specified time period, the survey has several limitations. First, because it observes the scientific workforce at one point in time, there is a sample selection bias since the workforce includes only those individuals who identify their occupation as a science or engineering field and survived in the workforce un-

Table 1.1 Descriptive Statistics for National Sample of Employed Scientists and Engineers, 1982 (Standard Deviations in Parentheses)

	Natural Scientists		Engineers	
	Women	Men	Women	Men
Age in years	36.6	41.5*	32.3	42.8*
	(9.7)	(10.9)	(8.7)	(11.2)
Percentage never married	29.5	10.6*	31.1	9.2*
Percentage with children	33.4	54.0*	25.8	53.6*
Percentage with bachelor's degree	46.5	40.9*	63.0	57.7*
Percentage with master's degree	33.9	30.2*	19.7	21.8
Percentage with Ph.D.	18.9	28.2*	2.2	3.6*
Sample size	2913	8915	1839	24292

Source: Author's compilation.
*The male mean is significantly different from the female mean at the .01 level.

til the time of the survey. Many eligible workforce participants have already left the science and engineering workforce. Although all the individuals have a college degree, that degree is not necessarily in science or engineering, so it has attracted a group of individuals without formal training in science and engineering. Second, the survey observes each individual four times during the period between 1982 and 1988. These snapshots only give information on labor market and personal characteristics at the time of the observation without providing any information on the individual during the periods between surveys. Finally, information on each individual is limited by the scope of the survey.

In response to these limitations, the university database that contains in-depth information on careers of a set of relatively homogeneous individuals was developed. These data are the result of a work history survey sent to the population of active female alumnae and a random sample of active male alumni who received degrees in science, math, or engineering from a large public university in the northeast from the time of its establishment in the mid-1960s until 1991.[2] The survey asks questions with the goal of describing the complete educational, personal, and workforce histories of the respondents. It also collects information on factors affecting the respondents' career decisions. Of the 5,200 surveys mailed, roughly 400 were returned due to out-of-date addresses, and 1,688 were completed, for a response rate of 35 percent.[3] The survey is unique because it tracks each respondent's complete career progression since college graduation. Other researchers have successfully followed the careers of a set of scientists. For example, J. Scott Long and associates (Long 1978; Long, Allison, and McGinnis 1979; Long and McGinnis 1985) analyze career productivity and progression of male biochemists who earned Ph.D.s during a four-year period in the late 1950s and early 1960s. The present survey allows a more complete examination of attrition because it begins each observation at graduation from college, and it analyzes men and women in a host of different scientific fields. Extensive information is collected for each job. Every separation from the labor force and from a job is documented, and the explicit reasons for exit are identified. The individual's family history is also tracked to identify when in the career marriages, births, and divorces take place.

Demographic characteristics displayed in table 1.2 paint a different scientific portrait from the national sample largely because of the differing populations. Since this particular public university opened its doors in the 1960s, the university data set does not include the cohort of older, largely male scientists and engineers. Therefore, even though many of the characteristics are statistically different for men and women in the university sample, the magnitude of differences is smaller than in the national sample. On average, men are less than a year older than women; the difference in male and female labor-market experience is only slightly more than a year for respondents with a science degree but increases to three years for respondents with engineering degrees. Roughly the same proportion of men and women are married, however a larger percentage of men than women have children. For respondents with degrees in science, women are slightly less educated

Table 1.2 Characteristics of Respondents to University Survey, 1992 to 1994 (Standard Deviations Are in Parentheses)

	Natural Scientists		Engineers	
	Women	Men	Women	Men
Age in years	35.4	36.4*	33.5	34.8
	(7.2)	(6.6)	(7.6)	(6.5)
Experience in years	9.4	10.7*	7.1	10.3*
	(6.0)	(5.8)	(4.2)	(6.4)
Time at current job in years	5.8	6.6	4.8	6.1
	(5.0)	(5.1)	(3.4)	(5.6)
Percentage highest science degree: bachelor's	72.7	59.6	47.3	60.5*
Percentage highest science degree: master's	19.4	16.9	47.3	34.2*
Percentage highest science degree: Ph.D.	12.9	23.5*	4.8	5.2
Percentage never married	33.3	29.0	36.9	36.8
Percentage with children	47.5	54.2	42.2	49.1
Sample size	782	421	185	290

Source: Author's compilation.
*Female statistic is significantly different from the male statistic at the .01 level.

than men, with a higher percentage of women earning bachelor's and master's degrees and a higher percentage of men earning Ph.D.s; these findings are similar to those in the national sample. For engineers, there is a larger percentage of respondents with master's degrees in the present sample than in the national sample, possibly because the university has a large engineering master's program, and perhaps surprisingly, women are more likely than men to have earned master's degrees in engineering. The 1980s national data show that men in engineering were slightly more likely to earn master's degrees than women in engineering.

The third data set, containing information from interviews, was designed to understand more fully the factors behind occupational exit of men and women in the sciences. Twenty-six pairs of women from the original university sample were selected to participate in interviews concerning both their education and career experiences. In the original survey, respondents were asked if they would be willing to give an interview; 71 percent responded positively. From the willing respondents, the 52 women were initially selected to mirror the age, education, and family distribution of the respondents to the original survey.[4] The subsample was altered slightly after initial interviews revealed that career concerns varied by degree level, family status, and whether the woman was an engineer. The women in the interview sample, therefore, are slightly more likely to have Ph.D.s, to have studied engineering, and to be married with children than the full sample of women. Within each pair, the two women are similar in age, degree level, field of degree, and family circumstances. The difference between the two women in each pair is that one of the women has left science and one has stayed. The purpose of this pairing process is to help isolate the important factors behind exiting or continuing scientific careers that cannot be identified using standard statistical techniques. Twenty-six pairs of men were also identified and interviewed. The male pairs are matched to the female pairs so that individuals in the two pairs have the same age, family characteristics, level of degree, and subject of degree.[5] Because the occupational exit rate is lower for men than for women, it was not possible to have a stayer and a leaver in each pair. However, approximately 80 percent of the male pairs include both an individual still employed in the sciences and one who has left.

For the purposes of this book, the interview data are especially enlightening. In particular, the interviews identified the major topics to be explored. They also fill in the details, allowing us a deeper understanding of these topics than could have been obtained through statistical analysis. Finally, the interviews bring the topic of working in science to life, as the quotes give us a glimpse of the insights, concerns, humor, and general humanity of the scientists themselves.