Introduction
Women in science: Why so few?

Why are there still so few women scientists, especially at the upper levels of the scientific professions? Persisting differences between women's and men's experience in science make this question as relevant today as when sociologist Alice Rossi posed it more than three decades ago at a conference on women in science at the Massachusetts Institute of Technology (Rossi, 1965).

The years since Rossi's groundbreaking analysis have witnessed the revival of the feminist movement and the increased entry of women into many professions. Women have become lawyers and doctors in significant numbers, albeit unevenly distributed into high and low status subfields of these professions. Despite significant advances, there is a continuing disproportionate lack of women in most scientific and engineering disciplines, especially at the upper reaches of the professions.

One such scientist, Leslie Barber, a female Ph.D. in molecular biology, decided to end her career as a research scientist shortly after being awarded the doctorate. She reflected upon the mixed experience of her male and female peers in a recent article (Barber, 1995). On the positive side, she found widespread evidence of encouragement for girls and women to pursue scientific professions from the media and from parents and teachers.

On the negative side, in comparing the career trajectories of the ten members of her graduate research group, equally divided into five men and five women, Barber noted significant differences. Whether or not the men had done well in their graduate careers, they had forged ahead in their professional lives. Among the women, three 'have left research altogether, while the other two languish in post-doctoral positions, apparently unable to settle on a next step.' Barber was initially surprised that, despite the unique story that each woman offered to explain her situation, the traditional pattern of relative exclusion of females from the scientific professions had been reproduced in her graduate cohort.

A guarded professional prognosis for both men and women could well be advised for a field such as physics, where the potential numbers of qualified applicants, vastly overwhelm traditional occupational demand (Linowitz, 1996). Certainly there has been a shift away from nuclear weapons and power plants, as well as from 'big science' projects such as the cancelled Superconducting Super Collider, which once gave virtually automatic multiple choices of employment to Ph.D. physicists. Although not unemployed, young physicists can often be found utilizing their quantitative and analytical skills in the back rooms of Wall Street or even in their own financial firms.

But how can the male–female divide in following scientific research careers, as identified by Barber, be explained for molecular biology, given the proliferation of biotechnology firms with research positions in recent years? Why has the increase in women entering graduate school not been fully translated into female scientists occupying higher positions in the field? Why has science lagged other professions in its inclusion of women? The answers to these questions, and the responsibility for repairing a less than optimal outcome, can be found primarily within science and secondarily in the larger society (National Research Council, 1940; Fox, 1994).

A LIFE COURSE ANALYSIS OF WOMEN IN SCIENCE

The thesis of this book is that women face a special series of gender related barriers to entry and success in scientific careers that persist, despite recent advances. Indeed, while some of their male contemporaries view female scientists as 'honorary men', others see them as 'flawed women' for attempting to participate in a traditional male realm (Longino, 1987; Stolte-Heiskanen, 1987; Barinaga, 1993).

Female scientists have been at odds over how to respond to these invidious distinctions. Should they insist that as scientists they are not different from men? On the other hand, given that science has historically been a male-dominated profession, should not women claim that they must have their needs taken into account in how the field is organized?

We focus the greater part of this book on the quality of women's experience in academic science, on the grounds that the university serves as a gateway into the larger scientific community. Our analysis is based on extensive systematic fieldwork that focuses both on the personal accounts of female and male graduate students and faculty members, and on the statistical analysis of aggregate demographic data and survey data on person-to-person ties in departments. In interviews with us, they discussed their experience in research groups and departments as well as their interaction with male and female peers and mentors.

Athena Unbound provides a life-course analysis of women in science from early childhood interest, through university, graduate school and the academic workplace. The book is based on several studies: (1) fifty in-depth interviews with female graduate students and faculty members in five science and engineering disciplines at two universities; (2) four hundred in-depth interviews and focus groups with female and male graduate students and faculty members in five science and engineering disciplines at eleven universities; (3) follow-up interviews with a sub-sample of graduate students and post-doctoral fellows interviewed in the previous study; (4) a quantitative survey of female graduate students and faculty members in five science and engineering disciplines at one university, focusing on publication experiences; and (5) interviews with very young children on their image of the scientist as a gender-related role.

In the following chapter we will begin to address the question raised in this introduction: why so few women in science? We will present quantitative evidence documenting how women's entry into and leakage from the ranks of graduate school education and university departments differ from men's. As society becomes more knowledge-intensive, ending any exclusion of women from science and technology becomes more pressing.

1 The science career pipeline

In this chapter we discuss the 'pipeline' thesis for improving women's participation in science. This 'supply side' approach assumes that if sufficient women are encouraged to enter the scientific and engineering professions, the gender gap in science and technology will disappear.

The scientific career track, from elementary school to initial employment, has been depicted as a 'pipeline' like those for the transport of fluids and gases such as water, oil or natural gas. The rate of flow into scientific careers is measured by passage through transition points in the pipeline such as graduation and continuation to the next educational level.

Nevertheless, the flow of women into science is through, 'a pipe with leaks at every joint along its span, a pipe that begins with a high-pressure surge of young women at the source – a roiling Amazon of smart graduate students – and ends at the spigot with a trickle of women prominent enough to be deans or department heads at major universities or to win such honours as membership in the National Academy of Science or even, heaven forfend, the Nobel Prize' (Angier, 1995). Even this negative depiction of the pipeline as a leaky vessel is too optimistic. As we shall see, many women are discouraged from pursuing their scientific interests far earlier in their educational career than graduate training.

Although the rate of women entering scientific professions has improved significantly, especially in the biological sciences, the numbers reaching high-level positions are much smaller than expected. In the United States, for example, decades after the science-based profession of medicine experienced a significant increase in female medical students (currently about 40% are women), only 3% of medical school deans and 5% of department heads are women. Dr Eleanor Shore, dean for faculty affairs at Harvard Medical School, recalled, 'Originally we thought if we got enough women in, the problem would take care of itself' (Angier, 1995). But it obviously has not.

Significant numbers of women enter the 'pipeline' and then leave at disproportionate rates, or function less effectively, as covert resistance to their participation creates difficulties. At best, the picture of women's participation in science in recent decades is mixed. Indeed, the pipeline analogy is unintentionally appropriate as an implicit criticism of the way that the recruitment to science takes place.

In addition to the positive meaning of steady flow and assured delivery, a pipeline also connotes a narrow, constricted vessel with few if any alternative ways of passage through the channel. At each age grade, the entry ways for women become narrower and increasingly restrictive. As more are excluded, the talent pool for the next level to draw upon becomes smaller.

Although the genders are almost equally represented in the early stages of the pipeline they increasingly diverge at the later stages, resulting in a much smaller proportion of women than men emerging from the pipeline. At the point of career choice, many women are diverted from the academic and research tracks, even though some who are trained as scientists pursue science-related careers such as scientific writing or administration. The U.S. science pipeline runs through a distinctly different educational landscape than its counterparts in many other countries, and it is worth taking a moment to describe the system here.

THE U.S. EDUCATIONAL SYSTEM

In contrast to most European, Latin American and other countries where a specialized course of study on one or a few related areas makes up virtually the entire undergraduate curriculum, the U.S. educational system does not expect students to make an early choice of careers. Even though an increasing number of secondary and even middle schools have occupational themes such as healthcare, art and science, all offer a general education. The flexibility of the U.S. undergraduate degree allows room for secondary education to remain unspecialized.

Students typically graduate from high school after twelve years of primary and secondary education at the age of seventeen or eighteen. Where to go to college or university becomes a serious issue in the third year of high school, although student and parental anxieties about getting into a prestigious college or university have pushed these concerns ever earlier. Again in contrast to countries with national systems of examinations at secondary school leaving, the U.S. high school offers an education that can vary widely in quality among schools and even within the same school. High school is still the quintessential U.S. social scene depicted in television programs and motion pictures of a youth culture focused on peer status, looks and athletic ability. Intellectual merit is not a leading status distinction except in a very few leading public and private high schools.

Universities also vary widely in quality of education and prestige, in contrast to Europe where university-level institutions are, more or less, expected to be on the same level. There is also a tradition in the U.S. of students going to university away from home, if it can be afforded. This makes the college decision a major turning point in life. It also marks the entry of the student into a nationwide educational and prestige gradation market. To take account of the wide differences in quality among secondary schools, an external system of exams offered by a non-profit corporation rather than a government agency was established in order to help universities sort potential students from a wide variety of backgrounds. Once university intake broadened from a select set of students attending college preparatory public and private high schools, as had been the case in the 1920s, to a mass education system, uniform measures were needed and the College Board examinations were established for this purpose.

The College Board examinations focus on general abilities in mathematical and analytical reasoning and are not directly tied to the high school curriculum. Therefore, a separate educational industry has grown up offering courses and tutoring to prepare students for these examinations, whose sponsors persist in insisting that formal preparation will do no good. Through these exams, high school grades, recommendations and sometimes an essay to be written on 'life goals', 'the most influential book I have read' or some such topic, combined with interviews by an alumnus or a college admissions officer, an initial selection is made.

High school graduates are sorted into more than 3,000 institutions of higher education, ranging from four-year baccalaureate colleges to universities offering Ph.D. degrees. However, this selection is still malleable since college students increasingly take time off from their studies to travel or work for a while and then decide to apply for transfer.

Almost 70% of U.S. high school graduates now continue on to post-secondary education. This is still in sharp contrast to the U.K. which has only in the past decade seen a rise from 10% to 30%, with an expected rise to 40% of secondary school leavers continuing on to university during the next decade.

In the U.S., general education continues from high school into the university. 'Distribution requirements' insure that students take one or more courses in the various spheres of knowledge such as science, art, history, languages and mathematics. In addition, many colleges and universities require students to take certain courses, typically in writing and the history of western civilization, as part of a general education program. In other countries such broad knowledge and skills are expected to be acquired in secondary schools, leaving the university career completely to specialized and professional training.

In the U.S. specialization begins at the baccalaureate level with declaring a major. 'A major' is a group of related courses in a disciplinary area such as history or biology, although it can also be an interdisciplinary group of courses in an area such as biology and society. An individual course typically consists of a sixteen-week series of class meetings totalling around three hours per week. It may combine lectures, class discussion and laboratories. Evaluation is likely to be some combination of laboratory exercises, short examinations or quizzes, a mid-term examination and/or a final examination. A research paper may also be required.

The course is the basic building block of undergraduate education and the credits attached to it, typically three or four, are added up to the requisite 120 for the degree with the major representing perhaps a third of that total. The European model would instead be the degree course with a set of requirements, lectures and examinations geared to measuring an end result rather than discrete pieces along the way, through the course.

The science major in the U.S. follows an intermediate format between the general U.S. undergraduate and specialized European educational models. Its courses typically must be taken in sequence and a larger proportion of the student's time is required. This leaves less time for electives, those courses apart form major, distribution or general education requirements in which students may follow a non-degree interest or simply take a course that has a reputation for being interesting, easy or challenging, whatever meets their needs!

Vocational choices can be put off at least until the second year of a four-year undergraduate career, or even later, unless one is in the sciences. Even if a science or engineering major is chosen late in the undergraduate career, courses can be made up in summer school or by taking an extra year for the degree. Some universities even offer a post-baccalaureate year program to prepare humanities and social science majors who have decided after graduation that they wish to go to medical school, a post-bachelor's degree program in the U.S. A year of chemistry, biology, physics and other related courses allows them to meet the basic requirements for admission.

The U.S. undergraduate model of education, based on courses, continues on into graduate school. A Ph.D. program typically begins with a set of courses during the first and second years whose purpose is to bring everyone up to the same level of basic knowledge in the field. Now, at this late stage, the U.S. system finally begins to follow the

European model, by evaluating students through an extensive 'qualifying' examination, cross-cutting an entire field.

Indeed, students do not necessarily have to prepare for the qualifying exam, the prerequisite for beginning research for the Ph.D. dissertation, by taking a set of courses. They may also study on their own, using reading lists, or more likely, in small groups of fellow students, so-called study groups, where old exams and problems are discussed. Again, this organized system of preparation for research is in contrast to the traditional European model in which a student tackles a research problem from the outset of the advanced degree process. There, the problem is often set in advance and candidates are advertised for in the scientific press.

Although the U.S. secondary and undergraduate education varies greatly in quality, it is at the graduate level that the U.S. excels. Research groups of a professor with graduate, undergraduate students and technicians are the basic building block of U.S. academic science. Assistant professors in the U.S., who would be junior researchers under a professor in many European countries, have the responsibility for raising their own research funds through competitive grants to start their own group. Success or failure in convincing the research community to fund their proposal is the prerequisite for attaining a permanent position in a U.S. research university. However, as we shall see, women and men experience the various stages and phases of this system quite differently.

THE LOSS OF WOMEN TO SCIENCE

With this system of education in mind, we return to the 'pipeline' hypothesis. This optimistic hypothesis has been at least partially disconfirmed by the mixed experience of the most recent generation of women in science and engineering. True, a large number of women in the U.S. major in science and engineering and a significant percentage of women receive BA degrees. As a result, the proportion of science and engineering bachelors' degrees going to women has almost doubled in three decades, rising from 25% in 1966 to 47% in 1995 (NSF, 1998: