1-1-2002

The Educational Pipelinie for Women in Biology: No Longer Leaking?

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Describing the past 30 years of progress toward gender equity in science, one observer wrote: "Although optimistic about future prospects, I must also point out some daunting toads and serpents lurking in the gardens of science. These challenge the rising generation of young scientists to be no less intrepid [than past activists who catalyzed change]" (Herschbach 1999, p. 66). The failure of the sciences to attract and retain women has meant a loss of diversity, as well as a loss of talent and creativity, that impoverishes research viewpoints and limits effective communication of science with diverse sectors of society. Our awareness of this situation can be traced to at least two major influences: First, the extension of civil rights legislation to women gave credence and power to voices raising concerns in the postfeminist climate of the 1970s; second, 20 years ago, reports from the US Office of Technology Assessment pointed out that the recruitment pool of minorities and women in the physical, mathematical and computer, and biological sciences, and in engineering and economics—the "educational pipeline" for doctorates, as Berryman (1983) characterized it—was exceedingly small. Indeed, studies of the scientific work force showed that the small pool of minorities and women could not compensate for the predicted decline in the traditional pool of white male recruits (Widnall 1988). For example, at every level after high school, fewer qualified women than men advanced to the next stage of training in science (OTA 1985). The reaction to this predicted shortage in scientific "manpower" was to ask *why* the pipeline leaked and *where* it leaked. All research pointed both to the source—a failure to attract and enroll women—and to the pipeline itself—a failure to retain women in the process of training scientists (Berryman 1983, Ware et al. 1983, Manis et al. 1989, Hanson 1996, Civian et al. 1997).

Why did the pipeline leak more women than men? Two types of explanations are offered for women's underrepresentation in science: Either women act differently from men (the difference model) or they are treated differently in the culture of science (the structural deficit model) (Sonnert 1999). Until recently, the difference model emphasized deficiencies in ability, preparation, or socialization of women who chose to take up education and research in a system organized and dominated historically by men (see Sonnert 1999 for a recent discussion). Women's alleged deficiencies might involve innate biological factors—"girls' brains are different from boys'" or "girls can't do math"—a conclusion based, for example, on the fact that 12-year-old boys, not girls, achieved the highest aptitude scores in mathematics on college-entry standardized tests (Benbow and Stanley 1982). Women and girls often were weak in mathematics, their poor preparation guaranteeing that they either would be frightened of science or would fail early on. Or, socialization processes that begin early in childhood and continue into young adulthood could be important. For example, in a population of high school students with high ability who later enrolled in college, plans for a future family and personal lives inhibited women, but not men, from high educational aspirations and majoring in science. High school teachers and counselors also had a stronger influence on women's choices, in accord with the idea that girls are more often socialized to gain approval from pleasing others, although the patterns of influence were not clearly positive or negative (Ware and Lee 1988). Societal stereotypes that influenced lifestyle choices for career and family were viewed as mutually exclusive in the early 1980s, as noted in the Illinois Valedictorian Project (Arnold 1993). One group of highly talented young women perceived a conflict in a lifestyle that combined career and family and limited their career aspirations, thereby conforming to society's stereotyped roles, while another group from the same population aspired to careers, entered male-dominated professions, and were

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successful in their careers. Both groups of women ended up with similar patterns for marriage and family, showing that "[early] aspirations limit their attainment more than actual life events" (Arnold 1987).

The alternative model, that women are treated differently because of deficits in the system of science, gained acceptance when it was recognized that legal, political, and social barriers could block women's full participation in the sciences. For example, outright discrimination was a factor before equal rights legislation was enacted, as in the case of the admissions quota system at the University of North Carolina, which restricted entry of women "to those who are especially well-qualified," resulting in a 1970 freshman class of 1893 men and only 426 women (Chamberlain 1988).

Such causes for the leaky pipeline seem archaic after the period of tinkering with equal rights legislation in the 1970s, which aimed at tailoring education, training, and employment to redress women's disadvantages (European Commission 2000). However, despite progress and general awareness of these issues now, leaks in the educational pipeline, as well as gender differences in career outcomes, continue to plague science, prompting comments like Herschbach's at the beginning of this article.

A brief discussion of gender differences in "style" may help explain why science needs the contributions of women. Recent sociological research views science as a social system and finds gender differences in the practice and organization of scientific work, not in modes of thinking or scientific methodology (Fox 1999). It should be emphasized that these differences are based on statistical averages or trends for groups, and there is considerable overlap in patterns for women and men, as well as a range of diversity within each gender group. Investigators postulate complex interactions between structural deficits within the system and gender behavioral differences, rather than a single group of causes, to account for differences (Selby 1999, Sonnert 1999). In one case researchers interviewed 200 scientists out of a study group of 700 who had been awarded National Science Foundation (NSF) or National Research Council (NRC) postdoctoral fellowships and found gender differences in informal styles for "doing science" (Sonnert and Holton 1995). Women tended to select an unoccupied subfield as their niche for research, did not shy away from detailed, meticulous work, and emphasized perfection for publishing results. Men tended to want to move their field to the forefront, to make a splash in science. Men were more career oriented and more comfortable with the power afforded by success; women were less career oriented and less concerned with the political aspects of science, such as influence and power. When asked what it means to do "good science," both men and women agreed that addressing an important problem was one characteristic, with men emphasizing creativity and good presentation of research and women emphasizing integrity and comprehensiveness of projects. The conclusion? "[Women's] conformity with the formal rules of science and distance from the more informal ways of doing science appear to be two sides of the same coin—the social marginalization of women scientists" (Sonnert and Holton 1995, p. 156). This conclusion raises a broader, more critical question for the social framework of science: Namely, what determines the value standard against which different styles are measured (Fox 1999)? Can science afford not to truly incorporate gender diversity? Even within the scientific establishment, voices call for women's viewpoints to be seen as positive influences, to be valued for the sake of fairness and for the good of science (Sonnert and Holton 1995).

Update on the educational pipeline

How do women fare today? For all fields of study, they have earned over half of all bachelor's degrees since 1982 and over half of all master's degrees since 1986. In 1970, women held 13 percent of academic doctorates (PhD or EdD) and 6 percent of first professional degrees, defined by The National Center for Education Statistics (NCES) as including the first postbaccalaureate degrees in medicine, dentistry, and law, such as the MD, DMD, and the LLB; by 1998, those figures had risen to 42 percent and 43 percent, respectively (figure 1; NCES 2000, 2001). Thus, in view of women's overall educational gains in the past three decades, continuing leaks in the science pipeline would be particularly disturbing.

Indeed, when the term *leaky pipeline* was coined, increasing numbers of women were entering and continuing in science, given today's 30-year perspective. By 1996, women

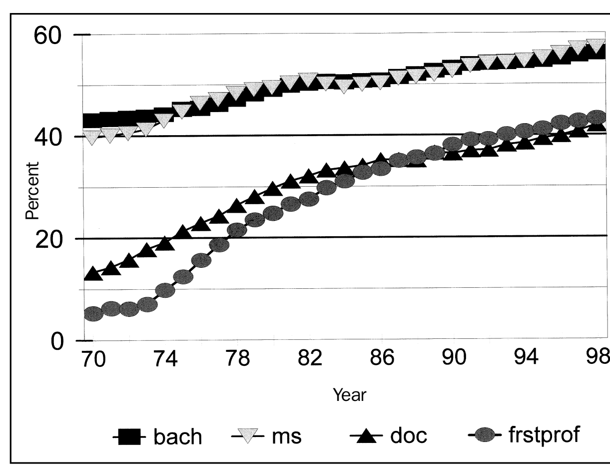

Figure 1. Percentages of all bachelor's (bach), master's (ms), academic doctoral (doc) degrees, and first professional (frstprof) degrees (medicine, dentistry, and law) earned by women from 1969–1970 to 1997–1998. Women's bachelor's and master's degrees gradually increased over the entire period. Doctorates rose more steeply during the first decade. For first professional degrees, women earned a much smaller percentage in the early 1970s, compared with other degrees. Then their percentage of first professional degrees rapidly increased until the mid-1980s and tapered off into the 1990s, reaching just over 40 percent, a pattern which paralleled and then slightly exceeded the pattern of women's gains in academic doctorates.

earned nearly half of the bachelor's degrees in all of the sciences, including the social sciences and engineering, compared to only one-fifth in 1966 (NSB 2000). During that 30-year period, women's degrees doubled in the biological and agricultural sciences, more than doubled in psychology, and increased in engineering more than tenfold (NSF 2000). Women's movement into the natural sciences was particularly striking in the biological sciences, where women earned over half of the bachelor's degrees in 1996. They also took midlevel laboratory science courses like biochemistry, genetics, and organic chemistry as often as men and studied college algebra and statistics on a par with men, while narrowing the gender gap in completion of calculus (NSF 2000). Thus, by the 1990s, leaks at the bachelor's and master's levels were no longer the major cause of women's attrition from biology. Nevertheless, farther along the biology pipeline, women still earned proportionately fewer doctorates—the degree of entry into the profession—than men (figure 2). Furthermore, some of the gains in the proportion of women resulted from a decrease in the participation of men (figures 3, 4), so women actually filled slots in biology vacated by men, as had been predicted by the demographic studies in the 1980s (OTA 1985).

These comparisons of gender participation in the scientific pipeline illustrate the difficulties in expressing such trends accurately. No single expression is adequate, so to provide a clearer picture, I have documented women's earned degrees in two ways—by numbers and by proportion (with men). I have also estimated women's interest in biology as a field of study and women's continuation in biology from a baccalaureate to a doctorate, using methods developed by the Task Force on Women in Higher Education (Chamberlain 1988).

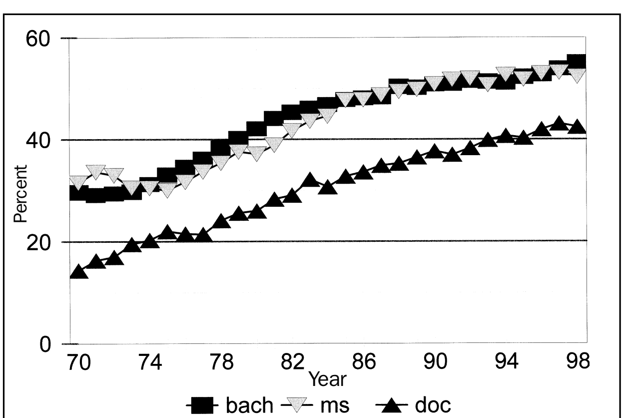

Figure 2. Percentages of all degrees in biology earned by women from 1970 to 1998. The percentages of bachelor's (bach) and master's (ms) degrees increased more rapidly in the first half of the 30-year period. Bachelor's and master's degrees rose in parallel from the mid-1980s to the end of the decade. In the early 1970s, however, master's degrees exceeded bachelor's degrees, and during the decade from the mid-1970s to mid-1980s, the converse was true. The percentage of doctoral degrees (doc) climbed steadily throughout the period, reaching just over 40 percent.

The task force calculated "parity indices" for the proportion of women choosing biology as a field of study and the proportion earning a graduate degree after completing a baccalaureate. Parity indices are useful because they avoid confounding data on women with general forces in education or in the job market that are independent of gender. On the other hand, most large-scale studies miss leaks within any given stage of the pipeline, because they are based on readily available statistics like earned degrees or total enrollment. (All calculations here are based on data for earned degrees from the US Department of Education, which defines *biology* as including biochemistry, botany, cell and molecular biology, microbiology, zoology, and other specializations like anatomy, ecology, marine biology, neurosciences, genetics, but not preparation for health care professions—neither for medicine nor for allied health fields.)

Undergraduates often change majors and career interests, and science, math, and engineering (SME) are among the fields that traditionally lose the most students (Astin and Astin 1992). Whether students enrolled in any field actually complete a degree is difficult to determine, because either the fate of individual students must be traced or trends must be sampled longitudinally. Astin and Astin (1992) analyzed US trends in a large sample of freshmen in 1985 and found that 40 percent defected from SME majors by 1989 and even more, 50 percent, defected from the biological sciences. For SME fields during that period, there was no gender difference in net losses. But in biology, the loss was proportionally greater among women, so that the flow of women *within* the biology pipeline did not keep up with the flow at the source.

Using a case study approach to the question of how persistence and attrition are linked to gender, I confirmed that the biology pipeline was leaky at Ohio University, a large, midwestern state university. Between 1989 and 1994, more women (60 percent) than men majored in biology, but a significantly smaller proportion of women (53 percent) persisted beyond freshman year, compared with men (70 percent) (Luckenbill-Edds 2001). Students who did not persist in biology switched to another field, usually a social science. There was no gender difference among students who left Ohio University during the first year. In addition, I followed the fate of a class of biology majors who enrolled at Ohio University in 1994.

Thirty-year trends in the biology pipeline

Enrollment in biology fluctuated over the past three decades as a function of many factors, some of which influenced women's enrollment. For example, during a tight job market, women are recruited to fill slots when men seek other employment (Chamberlain 1988). Data on the number of earned bachelor's degrees in biology showed the following patterns: Overall degrees in biology shot up nearly 60 percent from the early 1970s to the mid-1970s (figure 3), a period characterized by a flight from the arts and sciences (i.e., the humanities and social sciences; Bowen and Rudenstine 1992). Biology enrollments for both genders then declined for a decade, followed by another rapid increase in the 1990s to levels far above those of the mid-1970s (figure 3; NCES 1997, 2001). Men's enrollment in biology, more than women's, appeared to drive the earlier swings in undergraduate degrees, until the 1990s, when equal numbers of men and women accounted for the increases in undergraduate degrees in biology (figure 3).

On the other hand, women's enrollment did not always parallel the swings in the field as a whole. The number of women's bachelor's degrees in biology nearly doubled when enrollments exploded in the mid-1970s, but then leveled off through the

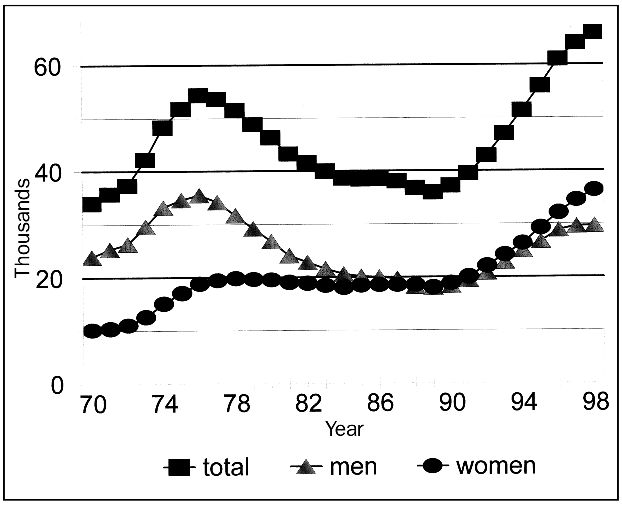

Figure 3. In biology, the number of bachelor's degrees earned by men and women increased in parallel during the first half of the 1970s, although the number of women's degrees was less than half that of men's. Beginning in the mid-1970s, the number of degrees earned by men declined, while the number earned by women held steady. In the early 1990s, degrees earned by men and women began to increase at the same rate. After the mid-1990s, the number of women's degrees rose more steeply, until women earned more biology bachelor's degrees than men. Reprinted from* ASCB Newsletter *(2000, vol. 23, pp. 18–21), with permission from the American Society for Cell Biology.

late 1970s into the late 1980s, a period when the number of biology degrees earned by men declined (figure 3). Thus, since the *number* of men earning bachelor's degrees in biology declined, the *proportion* of women earning degrees increased from the mid-1970s into the late 1980s (figure 2).

In the late 1980s and early 1990s, the situation changed. At first, equal numbers of women and men earned bachelor's degrees in biology, but after the mid-1990s, the number of women climbed faster than the number of men (figure 3), leading to a greater proportion of women in the growth spurt in the field at the end of that decade (figure 2). By the 1997–1998 academic year (the last years that statistics were monitored), women earned over half (55 percent) of the bachelor's degrees in biology (figure 2; NCES 2001), finally catching up with the proportion of women gaining bachelor degrees in all fields (figure 1).

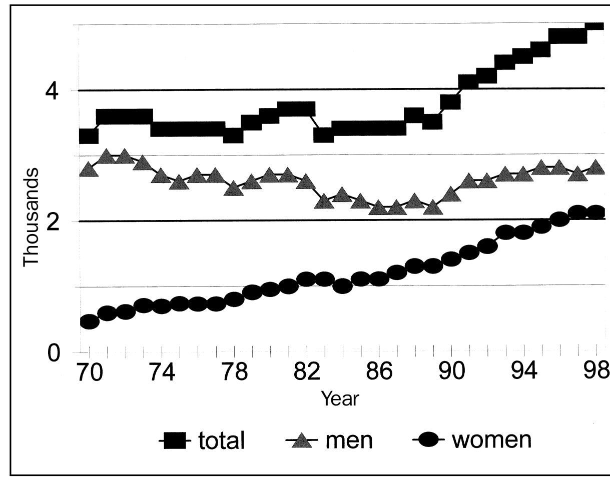

Figure 4. In biology, the number of doctoral degrees earned by women gradually increased over the last 30 years, and the number of doctorates earned by men fluctuated and showed an overall slight decline until the 1990s.

Graduate degrees in biology fluctuated less than bachelor's degrees, although there was a slight rise in master's degrees in the mid-1970s that followed the rise in bachelor's degrees (figure 5). Women earned one-third of the master's biology degrees in the 1970s and half of the degrees in the late1980s; this proportion was maintained into the 1990s (figure 2). At the doctoral level, women earned fewer degrees than men over the 30-year period but began to close the gap in the late 1970s; the numbers increased slowly and steadily in the next decade and then more rapidly in the 1990s (figure 4). Thus, at the PhD entry point into both nonacademic and academic biology professions (Chamberlain 1988), the proportion of women increased dramatically from 14 percent in 1970 to 42 percent in 1998 (figure 2) (NCES 1997, 2001). Women's increasing proportion of biology doctorates parallels their gains in doctorates in all fields (figure 1) and also reflects declining or relatively static numbers of men with biology doctorates (figure 4).

Women's choices of undergraduate fields

The source of the biology pipeline no longer seems leaky for women, as witnessed by two periods of rapid growth in absolute numbers—the mid-1970s and the mid-1990s. Currently, women earn over half the bachelor's degrees in biology and a growing proportion of doctoral degrees. However, two demographic factors contributed to women's larger proportion of biology degrees: a decline in men studying biology and an increase in absolute numbers of women in the higher educational system.

Field parity index for biology. Because these two factors cloud the interpretation of women's participation in biology, a different question should be asked. Have more women sought degrees in biology, preferring it to other fields? In other words, how is biology distributed among all fields that women study? The field parity index expresses this relation-

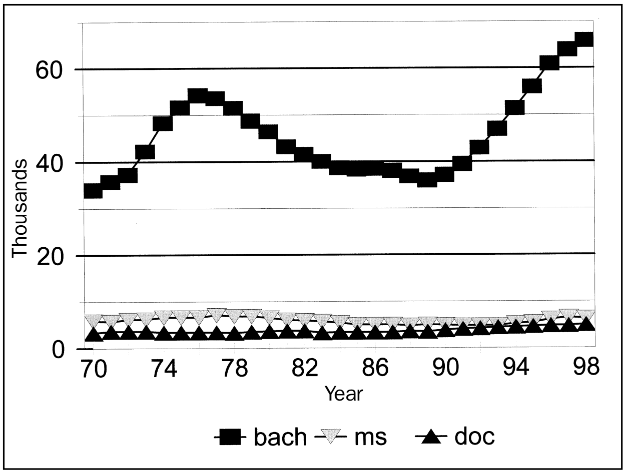

Figure 5. In biology, the total number of all bachelor's degrees (bach) peaked during the mid-1970s, declined in the decade from the mid-1970s to late 1980s, then rose rapidly in the 1990s. The mid-1970s peak correlated with small increases in the number of master's degrees (ms), whereas the number of doctoral degrees (doc) remained fairly steady until the late 1990s, when the number of doctoral degrees increased slightly.

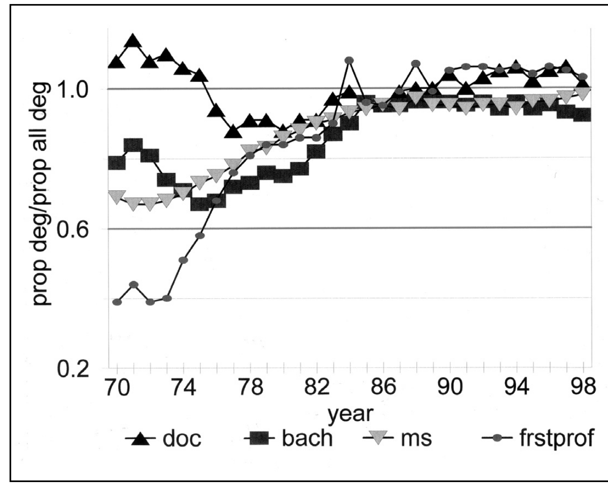

Figure 6. The field parity index for women's degrees in biology is a ratio of the proportion of women (compared to men) earning a bachelor's (bach), a master's (ms), or a doctorate (doc) in biology relative to the proportion of women earning degrees in all fields of study. Biology at the bachelor's and master's levels was a smaller component of women's fields of study, compared with men's, in the early 1970s, but gained ground in the mid-1970s to mid-1980s, rising to just above 0.9 of parity in the 1990s. At the doctoral level, biology was more popular as a field of study with women than men in the early 1970s and then decreased in the late 1970s. Women's movement away from parity for earning a biology doctorate was mirrored by a movement toward parity for first professional degrees (frstprof). By the late 1990s, women and men were on a par for choosing to earn a doctorate in biology or a registered first professional degree, out of all fields of study.

ship as the ratio between the proportion of degrees earned by women in biology and the proportion of degrees earned by women in all fields (Chamberlain 1988). (Expressing the preferences of women as a proportion of degrees automatically compares women with men.) When the field parity index reaches 1.0, the distribution of degrees earned by women in that field (e.g., biology) is the same as the distribution of degrees earned by women in all fields and is the same as the distribution of degrees earned by men studying that same field (biology).

At the bachelor's level, the field parity index in biology decreased slightly in the early 1970s and then slowly increased from about 0.7, beginning in the mid-1970s, to reach near parity in the mid-1980s, remaining at this level in the 1990s (figure 6). Thus, the perceived large increases in women's enrollment in biology departments simply mean that women are now on a par with men for selecting biology as a field to earn a degree.

For other fields of study, the 30-year patterns for field parity indices differ from biology in several ways. Fields like psychology and the allied health professions (health administration, medical personnel [medical assistants, technicians, and service people], nursing, pharmacy, and rehabilitative and therapeutic services) have indices greater than 1.0, reflecting a larger proportion of women's bachelor's degrees devoted to those fields, compared with men's, whereas fields like the physical sciences (astronomy, chemistry, geology, physics) have indices less than 1.0, reflecting a smaller proportion of women's bachelor's degrees than men's. Further, indices for academic scientific fields (biology, psychology, and the physical sciences) slowly climbed at the same rate, whereas indices for the allied health professions slowly declined over the same period. Perhaps the latter, traditionally female-dominated fields gave up part of their share of women's degrees to the formerly male-dominated fields.

Women's choices of fields in graduate school

So far, it appears that there no longer is a differential leak for women at the source of the pipeline in college, because women choose biology as a field of study on a par with men. This raises two questions: First, are women on a par with men for choosing graduate study in biology to become professional scientists? Second, how does the field parity index for graduate degrees in biology compare with the index for degrees leading to the professional practice of medicine, dentistry, and law?

Field parity index for biology doctorate. Patterns at the doctoral level followed the patterns at the bachelor's level after the expected lag in time, but from a different starting point in the 1970s. In the early 1970s, the proportion of women choosing biology for their doctorate was slightly above par with men (figure 6), that is, 12 percent to 13 percent of all doctoral degrees earned by women. Then, women's interest in biology declined and fluctuated until the 1990s. During the 1990s, women again chose biology as their field of study for a doctorate on a par with men (figure 6), that is, 11 percent of all doctoral degrees earned by women. Thus, now there is no gender difference in the way the biology doctorate is apportioned among all fields of study. Nevertheless, in the early 1970s, a time before more career options became available, women found a doctorate in biology more attractive than did men (figure 6).

Field parity index for first professional degrees. The decline in the field parity index for women's doctorates in biology during the mid-1970s could have been the result of competition for students with the professions of medicine, dentistry, and law, fields that opened up for women at that time (Chamberlain 1988). Between the mid-1970s and the mid-1980s, the percentage of first professional degrees earned by women rose more rapidly than did the percentage of all doctorates earned by women (figure 1). Also, this idea of competition for women doctoral students is supported by the mirror-image relationship between field parity index curves for biology doctorates and those for first professional degrees in the 1970s (figure 6). In the mid-1980s, the slower rise of field parity indices for both biology and first professional degrees paralleled each other, to reach just above par in the 1990s (figure 6).

How can one account for the rapid rise in women's participation in medicine, dentistry, and law in the 1970s, compared with the decline in women's biology doctorates? Women might have wanted to exploit the potential for jobs in new, high status, more lucrative fields, compared with academic fields like biology, thus creating a force that might have been independent of the general job market for the field. Other factors attracting women to the professions of medicine and dentistry could involve explicit, well-formulated career paths that motivated them to persist in science courses. This was true in the case study done at Ohio University of preprofessional health care undergraduates, who studied the same introductory curriculum as the science students. This result ties in with women's preference for applying their knowledge to a specific task and for fashioning coherent lifestyles with respect to education, career, and personal priorities, such as the timing for starting a family (Seymour and Hewitt 1997). Thus, once medicine, dentistry, and law opened up for women in the 1970s, these options may have fulfilled women's preferences and appeared more attractive than a more open-ended degree in science.

Some aspects of the process for getting a degree in medicine, dentistry, veterinary medicine, and even law parallel those for a doctorate in biology, such as mastery of a highly technical body of knowledge, the requirement of an apprenticeship, and a series of qualifying hurdles to become certified. Other aspects of the two types of degrees differ—research for the biology doctorate is unpredictable by definition and alternatives to an academic career may be unclear, in contrast to the familiar, prescribed career path for the medical and law professions. In addition, becoming a scientist takes longer. Based on NRC data from the 1990s, the median "registered time to degree" (RTD) was 7 years from the bachelor's to the doctorate in biology (Henderson et al. 1998). This 7-year median for biology, compared with 3–4 years postbaccalaureate study for the professions, makes earning a doctoral degree in biology more time consuming. Both aspects of training for the biology doctorate—the time involved and the indeterminancy of research—may deter women, more than men, from seeking to become professional biologists since, in the case study of Ohio University undergraduates, women preferred well-defined career goals and a course of study explicitly linked to these goals, making professional careers in medicine or allied health fields more appealing than careers in science.

Women's entry into the profession

Currently, it appears that the *source* of the biology pipeline no longer leaks for women in biology, because they choose biology as a field of study in equal numbers with men. In short, biology is as attractive to women as to men at all levels of study, even more so in the case of undergraduate degrees.

Degree parity in biology and other professions. Nevertheless, does the pipeline leak if one assesses *continuation* from the baccalaureate to the doctorate, the entry-degree to the field? To answer this question, I calculated the degree parity index that was used by the Task Force on Women in Higher Education (Chamberlain 1988). This ratio is the proportion of graduate degrees that women earn, divided by the proportion of bachelor's degrees they earn. It incorporates an average lag time between the two sets of degrees to approximate following a cohort. Indices for the first professional degrees (medicine, dentistry, and law) represent the ratio between the proportion of those degrees earned by women and the proportion of bachelor's degrees in all fields earned by women, since no specific undergraduate field of study prepares students for the group of first professional degrees. (Note that Department of Education data before 1965 were not used, because they included first professional degrees in the bachelor's category.)

The lag period between bachelor and doctorate (RTD) increased over the 30-year period for both men and women and varied by field from 5 to 8 years (Thurgood and Weinmann 1990, table 6, 1991, table 5, Ries and Thurgood 1993a, table 6, 1993b, table 6, Simmons and Thurgood 1995, table 10, Thurgood and Clarke 1995, table 9, Henderson et al. 1996, table 8, Henderson et al. 1998, table 15). Women took slightly longer to earn degrees than men, but the difference was minimal within broad fields of study (Henderson et al. 1998). Tuckman and colleagues (1990) looked into why RTDs have continued to increase in recent decades and found longer times in registration for the doctorate (i.e., time enrolled in educational programs between receipt of the "bac" and receipt of the doctorate), not in time out for work or family, as might be suspected. For women and men in biology in the 1970s, the RTD was 5 to 6 years, 6 to 7 years in the 1980s, and in the 1990s, 7 years. The lag period for first professional degrees was accepted as 4 years, even though a law degree takes only 3 years. The RTD is an approximation of averages that seems best for dealing with retrospective data, but it needs to be viewed cautiously, as only an indication of a trend. Bowen and Rudenstine (1992) showed that a statistical artifact is produced by basing RTD on the cohort of completed PhDs, rather than on the cohort of entering students with bachelor's degrees. Thus, when numbers of bachelor's degrees fluctuate markedly, this lengthens the apparent RTD.

In a traditionally female-dominated field like education, women have been on a par with men since 1979 for continuing on to earn a doctorate (PhD or EdD). In the humanities, they have been on a par since 1983, and in the social sciences since 1986 (Chamberlain 1988). What do the 30-year trends reveal about women's entry into professional life as biologists? In the decade from the mid-1970s to the mid-1980s, a period of civil rights legislation, affirmative action, and attention to women's issues, the degree parity index for women in biology rose nearly to 0.9 (figure 7). That decade was also one of overall decline in the numbers of men earning doctorates in biology (figure 4). Then, curiously, the degree parity index for women in biology slowly declined to 0.8 by the mid-1980s and has been level since then (figure 7).

Why did women's degree parity in biology decline in the mid- to late 1980s? Since the degree parity index is based on a complicated relationship, scanning the inputs to the ratio and mentally incorporating the appropriate RTD may help explain what is behind the trends. For example, in figure 2 the proportion of bachelor's degrees in biology earned by women rises more steeply from the mid-1970s to the mid-1980s than the rise in women's doctoral degrees in the succeeding decade, when that cohort would have completed the PhD. Thus, gains at the undergraduate level were not succeeded by gains at the doctoral level to the same extent. This situation has resulted in a holding pattern for women's doctorates in biology, which hovered around 0.8 of degree parity in the 1990s, compared with the early 1980s, when women already in the pipeline appeared to be moving into the profession on a par with men (figure 7). One fascinating question is whether the spectacular rise in bachelor's degrees earned by women in biology in the 1990s will be matched by degree parity and entry into the profession in the next decade.

Patterns for degree parity in biology contrast strikingly with those for the practice of medicine, dentistry, and law. Thirty years ago, women were far below parity in those professions (figure 7), earning only 6 percent of the three professional degrees. Then, in the decade from the mid-1970s to the mid-1980s, women with bachelor's degrees increasingly entered those professions, so that the first professional degree index climbed toward parity, rapidly at first, then more slowly into the 1990s (figure 7). The dramatic rise toward parity for first professional degrees shows how women seized the opportunity to occupy professional niches when these professions were opened up for them. However, the move toward degree parity for first professional degrees tapered off in the 1990s and stabilized at about 0.8 of parity with men by the end of the decade (figure 7; NCES 2001a).

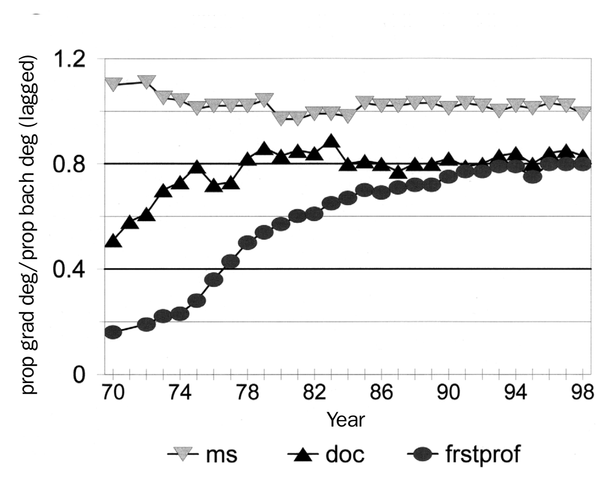

Figure 7. The degree parity index for women's degrees is a ratio of the proportion of women (compared to men) earning a graduate degree relative to the proportion of women earning an undergraduate degree, the recipients of the latter degree lagged for the average time it takes to complete the graduate degree. Women in biology have been on a par with men for continuing to a master's degree (ms) throughout the 30-year period. For the doctorate in biology (doc), women moved toward parity with men in the 1970s, nearly attained parity in the mid-1980s, then moved away and remained around 0.8 of parity into the 1990s. The index for first professional degrees in medicine, dentistry, and law (frstprof) was very low in the early 1970s, rose rapidly in the following decade, and converged with biology doctorates at the 0.8 index of parity with men in the 1990s. Reprinted from **ASCB Newsletter** ***(2000, vol. 23, pp. 18–21), with permission from the American Society for Cell Biology.***

Role of the culture of science

Women earning a doctorate in biology nearly reached 0.9 parity with men in the mid-1980s, but then moved away. Likewise, the degree parity index for women earning professional degrees moved upward until the 1990s but never reached degree parity with men. Thus, in the 1990s, trends for both sets of degree parity indices appeared to be stalled around 0.8 of parity with men.

This lack of parity is disappointing because the perspective of the educational pipeline shifts from "creeping toward inclusivity in science" (Herschbach 1999, p. 66) to "some brake on women's participation continues to be imposed" (Chamberlain 1988, p. 206). If biology doctorates and first professional degrees both arrest at 80 percent of parity with men, then this may mean that society as a whole imposes constraints on career women who are unwilling to let professional entitlement completely modify plans for a family (Kaufman

1995, Crittenden 2001). For example, in the case study of university freshman biology majors described above, a small group of women opted for a lifestyle that put family considerations before career, and a significant proportion of them continued to hold this view as juniors. If lifestyles in all professions continue to impose heroic demands on women with families, then degree parity may remain at the 0.8 index, as some women are deterred from obtaining the professional credential.

However, if women's degree parity in biology stabilizes at only 0.8 of men's, while women's first professional degrees continue to rise to parity, then this could mean that the culture of science itself is to blame. Influences on women during college, when most students first encounter scientists, may affect their continuation in undergraduate biology studies, as well as doctoral studies. How can biologists encourage women—and also men—in the undergraduate science environment?

First, emphasize career counseling in the sciences. Scientists should inform even beginning students about possible career paths. With no single lock-step route available to a career in science, in contrast to the health care professions, science students may conclude that teaching and research in academe are their only choices, and therefore choose to go into another field. Although explicit career paths motivate undergraduate majors to persist in biology, women who want a practical outcome to their education may feel particularly restricted and ignorant about how the path to a science career works. For example, personal influences from family, teachers, and other significant adults had been more important for women than men who majored in science, mathematics, or engineering in college, and entering women also had less clear ideas about what they wanted from their college major in terms of a career (Seymour and Hewitt 1997). Also, in Sonnert and Holton's (1995) study of scientists with high potential, four times more women than men recalled having vague or unclear career aspirations when they began in science.

Second, provide mentors and appropriate role models, coupled with opportunities for research experience, throughout college, all of which are factors notable for inspiring undergraduates, especially women, to become scientists (Civian et al. 1997). In the Ohio University case study, women biology majors described positive experiences in the laboratory components of the introductory courses, echoing the huge impact that hands-on experiences in "real science" can have on the career goals of budding women scientists (Sonnert and Holton 1995).

Third, consider that the undergraduate educational process itself can inhibit women's participation in the sciences. An analysis of US undergraduate science education (1985–1989) showed that, "compared to faculty in other fields, science faculty use more hierarchical and authoritarian approaches in the classroom than do their counterparts in other disciplines and are less likely to be student centered in their pedagogy," a style that provides fewer opportunities for meaningful contact between students and faculty and one that can create an environment that leads to alienation and discouragement of students (Astin and Astin 1992, pp. 9–12). In another study, poor pedagogy in college introductory science courses made learning difficult and repelled bright students who had proven excellent in other fields (Tobias 1990). Moreover, in the case study of first year biology majors at Ohio University, a series of interacting factors, including inadequate counseling in the face of academic difficulties and the perception of a weeding-out educational atmosphere, deterred more women than men from persisting in the biology major. More important, these factors in the introductory science environment made continuation difficult even for the women who stayed in the science field. Could these same factors dampen women's enthusiasm for remaining in the pipeline to become professional biologists? If so, understanding that these factors can discourage women will be important for stanching leaks at the entry level to the profession.

Women may become discouraged from pursuing science to the highest level when they do not recognize the cues for surviving in an elite, male model of science education in the introductory courses of the pipeline (Seymour and Hewitt 1997). Seymour and Hewitt (1997) postulate that the process of childhood and adolescent socialization renders young men, but usually not young women, familiar with the process of induction into the system of science, with its challenges to respond with "self-sufficiency and stoicism and to show independence from the need for nurturing" (p. 266). In treating young women the same as young men, "by challenging everyone in the class to 'prove' their 'manliness' by standing up to the harshness of their teaching methods, curriculum pace, and student assessment system in introductory classes, faculty are sending out a meaningless message to the female minority [i.e., minority in all sciences and engineering]" (p. 261). Alternatively, women may recognize those cues but prefer not to continue in a field they deem basically unfriendly to their style and values.

Fourth, scientists can emphasize the value in different career paths and remove a brake on women's participation in the form of subtle accreditation practices. Eisenhart and Finkel (1998) suggest that women reproduce their subordinate status in science when they choose not to pursue a doctorate, but turn instead to master's level certification and to teaching or technical posts, thereby giving up full professional responsibility for the direction of science. As previously discussed, women have been on a par with men for earning master's degrees in biology for the past 30 years but still lag behind at the doctoral level (figure 7).

Conclusion

I propose that further progress toward a totally inclusive practice of biology can only come with changes in how we think about who will become a professional biologist. Usually, we assume that scientific talent is a relatively rare gift and that survivors of intense competition are more fit and committed to be scientists. This mentality tends to weed out potential future scientists in the introductory science courses

(Seymour and Hewitt 1977) and devalues the contributions of people who do not become elite researchers.

Thus, we need to get rid of the weed-out model because it fosters poor pedagogical practices, like grading on a curve, and promotes a highly competitive environment that stymies cooperative learning and fosters unethical behavior like cheating. Such competition is not necessary to maintain high academic standards. In addition, we must continue to value different career patterns in biology, including part-time careers for women and men, coupled with expectations for part-time productivity in a part-time career when tenure is considered. It also means valuing different career paths in science, including teaching, employment in industry, and community and government service. "Women have always included technology and science in *their* choices and successes. But not until today do we hear voices raised to say...that science and engineering enterprises must choose women for their own successes.... The goal is, simply, to enable good people to do good things. Ultimately, everyone will benefit" (Selby 1999b, pp. xiii, xiv).

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