Filters for Women in Science

JEWEL PLUMMER COBB
Dean, Douglass College, Rutgers University
New Brunswick, New Jersey 08903

IN APRIL, 1977, the National Academy of Sciences, America's most prestigious body of science scholars, announced the election of sixty new members whose contributions to scientific research are outstanding. Only four of these were women. In fact, of the total membership of 1,208 of the National Academy of Sciences, only 28 are women.

Why are so few women elected to this prestigious academy? What are the reasons behind the fact that women, who constitute 52 percent of the population, make up only 10 percent of all scientists and engineers?[1] Women are 20 percent of the scientists but less than one percent of the engineers.

The paucity of women in science and technology points out, as does the minimal representation of minority scientists, a glaring deficiency in the health of America's scientific enterprise.

It is important to discover the reasons for this flaw and to correct it so that a population of women scientists can begin to contribute perspectives different from those of the male-dominated world of science. It is wasteful to neglect bright young female minds which have considerable contributions to make in every scientific field. It takes at least 20 years to produce a Ph.D. or an engineer. What happens to women during those years that prevents their final entry into science and engineering careers? That is the subject of this paper.

I have chosen the analogy of the filter. In the laboratory we recognize that the characteristics of the filtrate passing through a filter are determined by the size of the pores in the filter, and by the concentration and type of particles passing through. The pores of the filters passed through on the way to science careers are smaller for women than they are for men. As the filtrate (females in stages of development from birth to adulthood) is passed through successive filters, the pores become progressively smaller in real life.

We can describe essentially six important filters of science that are pre-

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sent in the life of a young woman scientist. These filters for men are either nonexistent or contain pores of larger size. The size of the pores of the filters are associated with mathematics.

The first filter is socialization in the preschool years. The socialization process begins at birth with pink blankets for female babies. The infant and preschool period is the first filter. Children learn behavior through contiguity. Sex-typed behavior is shaped very early in the home. A female child soon learns to act like her mother, usually through positive reinforcement.[2] She rapidly identifies her own sex. Verbal symbols from mother give very early instructions in sex-typed behavior. The appropriateness of certain sex-linked behavior is readily learned. As a female child enters the preschool period, she learns that dependency and passivity are generally acceptable, as are certain toys specifically designated for her sex. Physical aggression is not a behavior appropriate for female children, but it is applauded for boys. Stereotypes of female passivity for girls or masculine aggressiveness for boys develop not only from body concepts but by observation of highly visible differences in the people they see, both in the home and outside it.[3]

Almost twenty years ago, before the rebirth of the feminist movement, Evelyn Goodenough Pitcher, reported, without comment, on the difference in parental attitudes toward girl and boy children and how two- and three-year-old children conformed to their parents' expectations:[4] girls, the parents indicated, are interested in pretty clothes, domestic habit, families, and babies; boys are interested in bulldozers, trucks, cement mixers, and how things work. Even in the very subtle ways in which parents, particularly fathers, treat infants and young children—touch, tone of voice—girls and boys get different feedback from their parents.[5]

Parents who expect different interests and behaviors from their sons and daughters reinforce these expectations by the kinds of toys and games they purchase for them. Boys receive chemistry sets, erector sets, trucks, games geared to large-muscle development, sports equipment, and the like. Girls receive vanity sets, dolls, play ovens, carpet sweepers, games geared to small-muscle development, bead stringing and sewing cards.[6]

The second filter to science is the elementary school experience and its socialization effects. Mathematics, for example, is typed by our society as a "male" subject. Elementary school teachers, the majority of whom are women, are themselves rarely comfortable with math.[7] Between the

initial, serious exposure to mathematics and the expectation of female behavior lie six years of classroom conditioning that reinforces attitudes at home or elsewhere. The female child tends to identify with like-sex figures[8] . . . including the female teacher who most typically, but not always, expresses math anxiety at some point. Such exposure shapes the female student's response and reinforces the self-image of passivity and dependency. Physically, aggressive behavior in boys is seen to be rewarded in our culture, as is female nonaggressive, doll-like behavior.[9] Feminine values develop out of the need to value things that are consistent with or like the self.[10]

Liking and excelling in numbers in grade school is not a performance pattern that has high priority for female children. Elizabeth Fennema and Julia Sherman, in a study of the effects of sexual stereotyping on attitudes toward mathematics, conclude that girls eventually develop the idea that a female head is not much good for figures.[11] In another study by Paul Torrance of fourth, fifth, and sixth graders showed girls unwilling to approach scientific toys, protesting that they were "not supposed to know anything about things like that."[12] Although there are no measurable differences between the sexes in the early years as far as mathematical skills are concerned, after elementary school, boys begin to excel girls. By the time they take the Scholastic Aptitude Tests in high school, boys score an average of 50 points higher than girls on the mathematical portion of the exam.[13] This fact is distressing but not altogether surprising. As girls and boys proceed through school, they are subject to pressures to conform to societal expectations of sex-appropriate behavior and interests. For, after all, society's institutions reflect the values of the society in which they operate. Most educators are dedicated people, people who believe that education should provide all students with the environment and skills necessary for the realization of their full potential. At the same time, however, educators perpetuate, consciously and unconsciously, their own attitudes with regard to sex-role socialization.

In a study by John Ernest of the Mathematics Department of The University of California at Santa Barbara,[14] a sample of elementary school teachers were questioned about their attitudes toward the teaching of mathematics. Although all the teachers questioned said they enjoyed teaching mathematics better than other subjects, 41 percent felt that boys did better in mathematics and none of the respondents felt girls did better. That teachers cling to this sex-stereotype is astonishing in light

of the fact that no statistically significant sex differences in mathematical performance can be found in the testing of elementary school children.

The third filter is the junior high school experience. Female students themselves develop lower opinions of their abilities during these years. As girls and boys progress through school, their opinions of boys grow increasingly more positive and their opinions of girls increasingly more negative. Girls are more likely than boys to attribute poor performance on math tests to their own personal characteristics and habits.[15] They are less likely than male peers to be optimistic about grades they will receive.[16] Girls often suffer a loss of occupational potential. Girls' visions of occupations open to them are likely to be limited to four: teacher, nurse, secretary, or mother. Boys of the same age respond with a surprising range of things they can do when they grow up.

The loss of academic potential with particular regard to the fields of science and engineering has its basis in the differences in mathematical education offered. The study by John Ernest of USCB reveals the extent to which girls, directly and indirectly, are educated out of the math curriculum.[17] Examining elementary school and high school students' attitudes about arithmetic and mathematics, he found that preference for math as a favorite subject in the lower grades was identical for girls and boys; however, its popularity declined for both sexes in high school. Nevertheless, when mathematics becomes optional in high school, far fewer girls take it, it was discovered. Ernest concludes that boys take more math than girls because, like it or not, they are aware that such courses are necessary prerequisites to the kinds of future occupations—in medicine, technology, or science—that they envision for themselves.

Studies of differences in mathematical ability have yielded contradictory results, some showing no differences, some showing that boys do better, and some showing that girls do better. What *is* clear is that there is no consensus as to what constitutes mathematical ability. For some researchers it has meant computational proficiency, for others, geometric and algebraic aptitude, and for still others, some specific intellectual function. Boys seem to do better overall, but only slightly better, it should be pointed out, in certain spatial visualization tasks such as field independence. Field independence is the ability to perceptually separate items from their backgrounds, to overcome the influence of embedding contexts. Whether this is genetic or conditioned is not known, but it seems to me that erector sets and other construction-type

toys give children practice in developing field independence and, as we've noted earlier, it is boys, not girls, for whom those kinds of toys are bought.

This fourth and most critical filter, the high school years, results in a decline of interest in mathematics and a decline, therefore, in enrollment in mathematic courses. Three or four years of high school mathematics are required in most colleges for a major in science. College-level mathematics is a prerequisite for math, science, and engineering majors. Women students are not encouraged by family and society to "stick it out" with mathematics; men are, because certain careers they want will require mathematics backgrounds for college courses. In high school, both boys and girls show some clear evidence of sex-stereotyped attitudes regarding mathematics: According to the Ernest study,[18] 45 percent of fifth-grade students go to their mothers for help with math homework, 18 percent consult their fathers. By high school the picture is reversed, with 50 percent of both boys and girls requesting help from their fathers and 12 percent requesting help from their mothers. Clearly, by high school, both boys and girls have decided that math is a male subject.

Inadequate secondary school math preparation is the chief deterrent for women who might otherwise choose to major in one of the sciences in college, and, for that matter, in many other subjects judging from a study done by sociologist Lucy Sells, at Berkeley.[19] In a systematic sample of freshmen admitted to Berkeley in the fall of 1972, 57 percent of the male students had taken four full years of mathematics, including the trigonometry/solid geometry sequence, compared with 8 percent of the female students. The four-year mathematics sequence is required for admission to Mathematics IA, which in turn is required for majoring in every field at Berkeley except the traditionally female fields of humanities, social sciences, librarianship, social welfare, and education.

Teachers, guidance counselors, as well as parents, must reevaluate their own attitudes and prejudices about math being a "male" subject in order to more positively influence girl students. This kind of change is not likely to occur in the short run.

The fifth filter, college, is a critical period for women. It is here that pressures from the external campus and peer pressures, can be even greater than in high school. There is a lack of encouragement for most college girls who have the ability and interest to major in science. This lack of encouragement for a science career on the part of an adviser in the early college years is partly due to a realization that the employment opportunities open to woman scientists are more restricted than those open to men. The disappointing female enrollment in college mathematic courses is exacerbated by the higher attrition rate for females. As the level of difficulty increases and more time and effort is invested in course preparation, it seems reasonable to assume that college women, like their grade school sisters, are likely to conclude that a poor grade is due to a lack of math ability rather than to the lack of effort, and, accordingly, may drop the course. And so as women proceed through life and through our educational systems, the filters get finer and finer, until few manage to move through them at all.

Academic advisers play a large role in determining how many women will continue to maintain an interest in science in the high school years. Unfortunately, these advisers often labor under misconceptions regarding the nature of work in scientific fields, believing it to be more demanding of time and commitment than jobs in other fields. Such ideas, however, fail to take into account the changes that have occurred in scientific fields. Doctors, for example, may work fewer than five days a week and for relatively short hours each day, making medicine an ideal vocation to combine with the tasks of mother and homemaker. Women in science professions consistently earn less than men.[20] This may also contribute to the tendency on the part of the advisers to steer women away from careers in science.

Given the real discouragement directed at potential female science majors and the dedication and extraordinary singleness of purpose necessary for a woman to pursue a science career, such careers are seen as impossible for all but a few women. A female MIT student majoring in aeronautical engineering recounted that she had to fight all her life to retain her interest in aeronautics; her friends thought she was crazy, her mother told her she'd never find a husband, and her teachers warned her she'd never find a job. How many men would be aeronautical engineers in the face of such contrary pressure?

Colleges, also, must take into account that women generally make their career decisions later than men, and therefore must be counseled to keep as many options open as possible. Although the same number of girls and boys graduate from high school, fewer girls enroll in four-year colleges. When they do and major in the sciences, they are exceptional. Many female freshmen have eliminated science as an option because of math anxiety (filter-block) and earlier inadequate prerequisite math preparation. Lack of female professors as role-models, especially as

scientists, is clearly a problem in the majority of American colleges and universities. The sciences and engineering are considered male territories, and as such do not present congenial environments for female students who are always in the minority except at women's colleges. Even in the latter, there are usually more male professors in the chemistry and physics departments.

The decision to be a science major in college requires strong motivation and independence,[21] characteristics expected and developed in precollege years in males. Because of this, the college filter sorts out as survivors only the best and the strongest female students. It appears that this is valid, and it is evident in a study of female engineering students at Cornell.[22] These students demonstrated a very strong attraction to academic achievement, and a very strong record of successful achievement in secondary school.

The sixth filter is graduate school. Even though, according to the data from the National Center for Education Statistics, the National Science Foundation, and the Census Bureau, the number of women earning science doctorates increased by 59 percent between 1970–71 and 1974–75, women still lag far behind men in terms of the total number granted. In the fall of 1975, half of the first-year graduate students were women. By the end of the second year only a third were women. The pressures to drop out are enormous. For those who remain, however, the time for completion is shorter for women than for men. The female graduate student is seldom encouraged or sponsored by a graduate faculty member to begin research and to become part of a research laboratory team early on. In the past, women were not generally expected to complete the doctorate and enter a full-time research career. Hence, in a period of scarce research funds, time and effort is more often invested in the male student, who, it is calculated, will not "marry and leave science." The personal/tutorial/apprenticeship system of advanced science education takes place in a subjective male/male environment. Therefore, high attrition rates by women in graduate science programs are quite understandable.

The senior science researcher or mentor plays a pivotal role in the postdoctorate placement of a budding scientist. Encouragement is personal, subjective, and highly variable. Professor X may see women postdoctorates as scientists permanently in the marketplace and worthy of an endorsement to critical colleagues. Others, as documented from individual case histories, give little or no help to women in first-entry

career placement because they simply don't believe women should, or will, remain permanently in the laboratory rather than at home. A 1973 survey by the National Research Council showed that 2.6 percent of women with science doctorates received between 1960 and 1969 were still working in postdoctorate positions at the time of the survey, while only 0.9 percent of the men were in the same position. Clearly, then, the sixth filter is the senior scientist/adviser who controls the development of the dissertation, its ultimate acceptance and publication; controls referrals, postdoctorate job placement, and career development.

The fully mature woman scientist emerges as a productive human being capable of taking her place at the laboratory research bench in creative work. Because of the special filtering system for women in science, she is, as a type, likely to be a superior scholar, independent and tenacious, and somewhat hardened by her experiences on her way through "the system." However, she will still not move as easily as her male peers to tenured positions at top universities where the big science action takes place; nor will she find government jobs as easily , and when she does find such jobs she will most probably receive lower pay than her male colleagues.[23] Women scientists are represented out of proportion to their total numbers in teaching positions at two-year and four-year nonresearch-oriented institutions, and they are completely underrepresented in the high-paying jobs in industry.[24]

We need to formulate new activities to change attitudes of the intra- and extra-campus population to understand the importance of eliminating certain female behavior patterns, most importantly, math anxiety. This affliction among elementary school and high school teachers, college students, and young mothers is widespread. Fundamental to encouraging more women to consider careers in the sciences is the eradication of the notion that proficiency in mathematics is a gender-linked characteristic.

The first step is to call attention to the sex-role biases of parents of young children. Then we must sensitize teachers in junior and senior high schools to the need for the special supports girls need to foster and sustain an interest in science. At the college level, programs in remediation and special counseling are essential to retain the small, but increasing, numbers of girls who have made it through the first several filters but remain especially prone to drop out when the going gets rough. If we take steps now, the next decade should see a change in the depressing underrepresentation of women in the community of science and technology.

To deal with one of the early filters excluding girls from the sciences it has been suggested that a series of films should be made and distributed to be viewed by girls from grades 9–11. Films describing positive career options for women in science could be used as a jumping-off point for discussion and follow-up in conjunction with ancillary materials which are, also, available. An excellent film on women in engineering, done at Massachusetts Institute of Technology, was partially funded by the National Science Foundation. Additionally, there should be a national program for high school girls with demonstrated aptitude and interest in math and science. Early orientation and recruitment would tag these girls before college and carry them into college as special science designates. Such an honor would help to overcome the negative social impact that tends to downgrade the very bright female student at the critical dating age. Girls' organizations such as YWCAs and the Girl Scouts should be encouraged to develop and promote programs for girls in science. For example, such programs might involve the awarding of merit badges for projects in electrical engineering and study projects in various scientific fields.

Neena B. Schwartz has made a suggestion to stimulate undergraduate college women in science. Teams consisting of prominent women scientists and senior women graduate students should be sent to spend 48 hours with beginning women graduate and undergraduate students in science departments. This visit would include informal discussions, scientific seminars, and opportunities for informal discussions in which successful women scientists could explain personally how they reached points of success in scientific careers.

To assist women students at the graduate level, it has been suggested that there be established a data bank of responses of women graduate students are asked to record what happens in the science department in the early professional socialization. The material, gathered in the form of a questionnaire, would be extremely valuable. It has also been suggested that there be developed and funded a series of short or year-long refresher courses, research internships, and/or combinations of these for women scientists who want to reenter their professional fields. The model of the NSF Summer Institute could be used, except that the students would be the reentry women. This last suggestion was made by Lili Hornig.

Another suggestion is that there be developed a special subset of graduate fellowships for women with emphasis on the first year of study

in science areas where women are underrepresented. This first-year support often allows excellent women students without the necessary background, such as undergraduate majors in a tangential field, to compete successfully for a teaching or research assistantship the next year. This suggestion was offered by Vera Kistiakowsky. These fellowships would, in general, permit the women to attend higher quality schools where they might not have been successful in the competition for teaching assistantships and research assistantships, therefore providing a psychological boost. There might also be fellowships to cover the first two graduate years, but before that period is over the students should join a research group and hence be more likely to get research support. Building a mentor relationship into this program, the availability of an individual at the university with whom the student could discuss her progress and who would look out for her would probably increase the percentages of successful degree completion by women.

A number of suggestions have also been made with regard to women at teaching levels in the science disciplines. Patricia Albjerg Graham has suggested a two-year fellowship for the nontenured woman science professor in a four-year undergraduate college to facilitate research that will enhance her opportunity for tenure. This fellowship might allow her to work with a research team full time or to complete the writing of a science book. Such a fellowship at the nontenured level can be justified as "remedial" until women are at as significant a portion of senior tenured faculty at major institutions as they are of the Ph.D. pool, small though this group is. Mildred S. Dresselhaus has suggested the adoption of a faculty-development program to increase the faculty ranks in engineering at the major universities. Women with the potential to contribute in this area would be provided with partial support for a three-year period at top-ranked institutions where they would be able to acquire the kind of background that would be of value in moving ahead rapidly in their professions. The other partial support should be provided by the institutions as proof of commitment. Some preference should be given to institutions where the women grantees will have access to mentors who can be useful in support roles and in providing training in the nontechnical issues which are so important for the success of women professionals. In most cases, the grantee will move on to a permanent position elsewhere, and, in this way, can contribute in a supportive capacity to the training of another crop of woman professionals.

A number of other suggestions are directed at the specific difficulties

that women encounter in entering job markets. Part-time support has been suggested for junior faculty women. This would not increase the overall numbers of women in the field but would certainly increase the numbers who are upwardly mobile. This sort of program could actually be a four-faceted one: (1) Offering seed money to start research programs; (2) permitting young mothers to remain active in research by paying part of their salary and thus reducing their teaching commitments or permitting them to work part time; (3) permitting women in nonresearch-oriented institutions the released time and financial support to set up programs of their own or to work with groups in other institutions; (4) offering re-entry support to women who have temporarily withdrawn from professional life. It has also been suggested that the NSF, for example, could also establish a special category of grants to individuals who move with their families. Such persons are usually women and need time to establish an institutional affiliation. This grant would be conditional on their being able to make a suitable institutional connection, if they have their own money because of the grant. Applications in this category, of course, would be prescreened under the usual procedures and then subjected to the existing review-processing. The reviewer would also receive a statement of the personal circumstances that may make this kind of application necessary. This suggestion was made by Lili Hornig.

A further recommendation was to fund a program that would conduct extensive training programs in math for volunteer mothers in elementary schools. This program could also send women who are math professionals into the schools to work an hour or two a week with students, especially with students who show an aptitude for arithmetic. This suggestion was made by Mary Gray, Department of Mathematics, Statistics, and Computer Science, The American University, Washington, D.C.

A career development award specifically aimed at young Ph.D. women has also been suggested. Such an award would give full salary and prestige, and give a university a free slot for five years. This suggestion follows the NIH model.

The need for a full spectrum of programs directed at increasing the proportion of women in science careers is painfully obvious. The time for putting such programs into action is long past due. The actions that must be taken range from the subtle socialization processes to specific programs for funding women in scientific research. It is only through

such wholesale effort that we can begin to eliminate the system of filters that operate to keep women out of careers in science.

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