Notices Special Issue

WOMEN IN MATHEMATICS

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In Her Own Words

Six Mathematicians Comment on Their Lives and Careers

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In her acceptance speech for the Satter Prize, Dusa Mcduff wrote about the crooked path she followed before she found her creative voice. I wandered along other crooked paths and would like to share some of my experiences with you.

I was forty-one when I received my Ph.D. and began a career as a research mathematician in academia. A plausible explanation might be that (like some of today's students) I did not discover the beauties of mathematics until I was past the traditional age, but that was not the case. Some of my earliest pre-school memories are of fascination with patterns and the way things "fit together." Moreover, in elementary and high school, I excelled in mathematics and even had some excellent teachers who encouraged and challenged me. What went wrong, and, even more, was it "wrong"?

The simple truth is that at some point during college, and more particularly at age twenty-one, when I graduated from college, the deep commitment which was required to become a professional mathematician did not seem so appealing to me. While I knew I wanted more from life than the traditional woman's role as a homemaker, I was less clear about the precise alternatives. When the opportunity came to take a math-related job which would not require the kind of total involvement which I knew must go with a full-time graduate program, I veered off to the side, beginning what stretched into a fifteen-year detour. I worked in what was called "Systems Analysis" in the aircraft industry. Later, as my three children were born, my work went down to two days a week, then one, and finally (briefly), none. I didn't have to do it that way, but it was pleasant to be with my children as they grew and developed. Moreover, it did not feel right to me to hand over a matter as important as the day-to-day supervision of my children's growth and development to strangers.

I was thirty-six when I found myself in an evening graduate course at the Courant Institute. My initial goal had been to maintain some small level of competence in preparation for an eventual return to full-time work, but I was actually unclear about where I was heading and simply did what seemed interesting and possible at the time. To my pleasure and surprise, the challenge of graduate work was wonderful! To be sure, I was rusty, but that did not seem insurmountable because, as a compensation, maturity had given me an ability to focus and to concentrate in a way which had seemed impossible fifteen years earlier. Also, I could set my own pace, taking on more as I could handle more. Eventually, I did need help at home, but that was an easier matter once children were in school all day. Also, I did much of my work at home.

I think there was lots of good luck in my subsequent experiences. I found fellow students who were tolerant of the middle-aged lady in their midst, and we worked together. When I was stuck on a difficult point, I sought and obtained the help I needed, and it was gratifying when sometimes my insights helped others. As for the faculty, most paid attention to my work and not to my age or sex. Later, my thesis topic was immediately absorbing, and when the creative ideas came and I solved the problem, it was deeply satisfying. When I received my Ph.D., the job prospects seemed dim, but with incredible good fortune, I stumbled into an excellent job at the Stevens Institute of Technology. There I found a colleague with whom I did joint work (the first of many such collaborators) and enough good students to make the teaching worthwhile. From that point on it was easy. Conferences and seminar invitations broadened my world, the research problems began to suggest themselves, and my career was on its way.

What I did was natural to my life as a woman, yet at this time I would hesitate to advise other women to follow the same route, because I tend to think my good luck was atypical. I have wondered whether, if the mathematical community welcomed older women as graduate students in a serious and non-patronizing way, and if women rejected the myth that mathematics is a young man's game, we might not see real changes in those discouragingly low numbers.

Deborah Haimo

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Two events in my life significantly influenced my career choice.

Since I dutifully complied with all that was expected of me, I was generally regarded as a good student. I did well in mathematics in first year algebra because I could follow rules, but found them very rigid, and I resented the fact that we were penalized if we attempted to reach a result by some different approach. Originality or creativity were strongly discouraged.

In my sophomore year, however, something new and very exciting happened. We started studying Euclidean geometry. Here, we had a set of axioms—self-evident truths—and based on these, and some hypotheses, we were able to establish a variety of fascinating theorems. It was all reasonable and logical, and no one was requiring that I follow some rules I didn't understand. I loved the subject and tried to obtain results beyond those assigned.

One day, we came to a theorem for which an indirect proof was given. I wondered why we couldn't prove the result directly, tried to do so, and found a proof that worked, except when the geometric figures involved were positioned in a certain way. I decided that I had found the reason for the indirect proof and didn't feel a need to raise the question further.

Some time later, we had a similar problem involving the same geometric figures, where, again, an indirect proof was given. This time, the teacher pointed out that the problem could also be solved directly, and outlined a proof that was essentially the one I had discovered earlier. I then raised the question of the difficulty that arose when the figures were positioned differently. The teacher had an immediate response, "You have an axiom that states that geometric figures can be moved in space without affecting their properties." Incredible! It was an axiom that we had not used and I had forgotten all about it. What a beautiful subject! Everything fell into place so neatly!

I entered college with great uncertainty about a major. I didn't know what I could do with mathematics. About the only career option in that area, as far as I was aware, was school teaching, and I knew I didn't want to be a school teacher—if for no other reason than the fact that, as a woman, I would not be allowed to marry and remain a teacher—at least in public schools in my area, and I knew no other.

Physics was suggested to me as a subject with greater career options and a good alternative to mathematics. My select high school, restricted to girls, did not offer physics. In college, however, I enrolled in a freshman physics course to consider it as a possible major.

In one of our early labs, we were to do the standard experiment of scattering iron filings on the lab table, placing a magnet in their midst, and noting how the filings align about each pole. Everyone in the class did the experiment very readily—everyone, that is, except for me. My iron filings refused to follow the expected pattern, and instead, kept arranging themselves in bizarre formations. One after another of my classmates, realizing what I was experiencing, came over to offer advice, and to watch the strange results. Finally, the entire class, including the instructor, was gathered around, with everyone trying to explain why my iron filings were so uncooperative. One observant girl finally solved the mystery. She pulled out a drawer that was directly under my work space, and, believe it or not, it was full of magnets!

That episode brought to mind my experience in the geometry class. I concluded that, in mathematics, we have control over our assumptions—if they are poor, our results will not be good, but we know what we are working with; in physics, there may be factors that are completely unknown to us, but can distort our results and unbeknownst to us, make them invalid.

That drawer of magnets determined for me that I loved mathematics and it would be my major, regardless of my need to be practical and to select a field with a greater number of more reasonable career options.

Susan Landau

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My husband and I married while I was a graduate student in computer science at MIT. "Don't have children until you finish," cautioned a friend, the wife of a history professor. I nodded easily. I was then twenty-five. At twenty-eight I completed my doctoral thesis. "Don't have children until you get tenure," warned a member of the faculty. I was leaving to become an assistant professor at Wesleyan University. This time the nod didn't come so easily. My husband and I wanted a family. I didn't want to wait until I was thirty-five to begin one.

Choosing which came first was not hard for me. If I had tenure at thirty-five, but was then unable to have children, the pain would have been unbearable. I knew I could handle the opposite situation. I had my first child at thirty-one, my second at thirty-three. At thirty-four I have my family even if I don't have academic permanence.

All along I felt that the choices were more mine than my husband's. We both raise the children. I'm the one who's pregnant. I have the fuzzy brain for nine months; I'm the one who can't go off to conferences during the late months of pregnancy and the early months of nursing. My work suffers, my energy flags, my batteries fade. I've lost about two years of research in the first five years after my Ph.D. (What I've gained is immeasurable—but not the subject of this essay.) So I get 51% of the vote. As it turns out, we both voted for children first, tenure second, so it was no contest. But there's a price I may yet pay in my career.

I didn't know I'd be in a state of torpor for nine months of pregnancy, but I also didn't expect the burst of creative energy that followed the birth of each child. That energy more than made up for those lost nine months. Every academic mother has a different experience, but all of us face the ticking of those simultaneous clocks of tenure and the childbearing years.

Academia doesn't help. Few universities have maternity leave. Those that do ignore what happens next. For example, my university has an excellent maternity policy (one semester's leave at two-thirds salary), but no child care facilities, despite over a decade's lobbying by male and female faculty. Thus my kids are at a center forty-five minutes away. I can't attend late afternoon colloquia or faculty meetings. Last year my husband and I were both invited to spend our sabbaticals at a university where we would have great research opportunities. Lack of day care there meant we couldn't go.

There's a touch of the priesthood in the academic world, a sense that a scholar should not be distracted by the mundane tasks of day-to-day living. I used to have great stretches of time to work. Now I have research thoughts while making peanut butter and jelly sandwiches. Sure it's impossible to write down ideas while reading "Curious George" to a two-year-old. On the other hand, as my husband was leaving graduate school for his first job, his thesis advisor told him, "You may wonder how a professor gets any research done when one has to teach, advise students, serve on committees, referee papers, write letters of recommendation, interview prospective faculty. Well, I take long showers."

When I decided to become a professor, it was because I loved mathematics. I wasn't married, wasn't thinking of children or timing, or any of the issues that are now so crucial. Had I been, my decision might have been different.

The tenure process was established in an era when men had professions and women had babies. Women now have professions as well as babies, but the academic world hasn't changed. My two maternity leaves in two years seemed like a lot to several of my colleagues. I see it as two maternity leaves over a lifetime. Even if a faculty member chooses to work half-time for ten years, that still leaves thirty years for full-time scholarship and teaching. Universities can afford to be farsighted. My university's generous maternity policy gave me time after childbirth to catch up on the research that I had been unable to do while pregnant. A National Science Foundation mathematics postdoc has just given me more time during the years when my children are young.

There are any number of complex reasons why women have not reached the top echelons in a variety of sectors. This is a simple, avoidable one. Fellowships, maternity leaves, and on-site child care can make a huge difference. Universities should be leading society on this one. As long as they make it difficult for us to be professors and mothers, they are engaging in a policy which effectively keeps a significant segment of women off the faculty.

(This piece was written in 1988 when the author was a faculty member at Wesleyan University. Wesleyan has since acquired an on-site child care facility and the author has since moved to the University of Massachusetts.)

Bhama Srinivasan

University of Illinois at Chicago

I grew up in Madras, India in a liberal and progressive family where books and education were taken for granted. There were precedents in my family for higher education in the West. My father and uncle had studied at Oxford, and a cousin did brilliantly at Cambridge, where she later became a don at Newnham College. Her brother became a radio astronomer and worked at Cambridge, Stanford, and Sydney. (A byproduct of this environment was that I learned English as a child and grew up bilingual.) However, behind the expectations of doing well at school was an unspoken assumption: education for a woman was not intended to lead to a career. Rather, the highest fulfillment for a woman came through marriage and children; her education was intended to help her be an intelligent partner to her husband and well-informed mother to her children.

I had a grandfather who was an amateur practitioner of mathematics and I was supposed to have taken after him. In any event, as a teenager it was my favorite subject at the all-girls' high school that I attended. I was fortunate to have a good mathematics teacher under whom I studied Euclidean geometry and learned to write proofs. I went on to do my BA in Mathematics at a co-educational college in Madras. The curriculum was old-fashioned and the textbooks were those that had been used in England at least 30 years earlier. I graduated from this uninspiring program and enrolled in a Master's program at the University of Madras, at which point the quality of my education changed dramatically.

An important presence in the mathematical scene at Madras was a Jesuit priest, Father Racine, who headed the Mathematics Department at Loyola College. He was acquainted with the latest mathematical developments in Europe. Several of his undergraduate students later went on to do research at the prestigious Tata Institute of Fundamental Research in Bombay. However, Loyola College did not admit women and thus women students were denied the opportunity of studying under and being noticed by Father Racine. The first piece of good luck I had was that Father Racine gave a course on abstract algebra at the University of Madras, using the great text by van der Waerden based on lectures by Emmy Noether. I also had courses on topology and other subjects from two other excellent professors. Thus I was suddenly thrust into the twentieth century, and this was an exciting experience for me. However, I did not have any ambitions to be a researcher in mathematics at this stage, or, for that matter, to pursue any serious career at all.

After receiving my master's degree I got married, as was expected of me, and followed my husband to Manchester, England, where he, a mechanical engineer, was to receive practical training. This was my second big break, for I enrolled in the Ph.D. program at the University of Manchester and started working with J. A. Green. In spite of the ever-gray skies in Manchester, I enjoyed my first exposure to western intellectual life, both mathematical and otherwise. My husband was totally supportive of my having a mathematical career and sometimes opposed his own family. So now there was no turning back.

My husband returned first to India, and I followed after completing my Ph.D. I got a position at the University of Madras. Though I did not experience overt discrimination, it was quite common for people to say to me "Your husband has a good job; why should you work?" or "Aren't you taking away a job from a breadwinner?" and so on. One well-meaning family friend said "It is a pity you don't have children; but isn't it wonderful that you have something to keep you occupied?".

During my years at Madras I had some contacts with western mathematicians. In particular, I met Armand Borel when he visited Madras and he invited me to a special year on algebraic groups and finite groups at the Institute for Advanced Study in Princeton. This was another great opportunity for my research and to make further contacts.

In 1970, I emigrated to the U.S. and started teaching at Clark University. (By this time, my husband and I had parted for reasons not connected with my career, but we remained friends.) I plunged into a new life and a new career in the U.S., and made new friends, especially with some women mathematicians in the Boston area. I moved to Chicago in 1980 when I got a position at the University of Illinois at Chicago. While keeping in close contact with my family in India, I am now very happy living and working in America.

If I think back, in midlife, to the early stages of my career, I realize that many of my decisions and advances were due to fortuitous circumstances such as being in the right place at the right time and having the right kind of support at the right moment. My male relatives and friends held as a birthright the idea that they would strive for the best professional life they could attain; for me this was a long time in coming. I welcome the changes in women's expectations that have taken place in the last decade.

Vera Pless

University of Illinois at Chicago

Despite much progress it is still more difficult for women to become mathematicians than for men, and, as I have been concerned about this situation, my history might be useful to others.

I had no ambition to become a mathematician; girls at that time aspired to be wives (of successful men) and mothers. Maybe some "unfortunate" girls never married and pursued careers but, as far as women mathematicians went, I never saw one the whole time I was a student. However, I did know about the work of Emmy Noether and it may have influenced my choice of area, algebra, although I think the teaching of Irving Kaplansky was what really inspired me. I worked for my Ph.D. (under the direction of Alex Rosenberg) because it was a more interesting occupation than the job I had while waiting for my husband to complete his Ph.D. in high-energy experimental physics. After he got his degree, he received an offer from MIT and we moved to Cambridge. I had not finished my thesis but did have a good start. Alex was amenable to my finishing by correspondence. This occurred with many helpful, humorous letters from Alex. I only went back to defend my thesis, which was about two weeks before my first child, a daughter, was born (she was early). Fortunately, everything worked out alright; Alex had warned me not to have the baby during the defense, since it would upset the janitors.

It never occurred to me to work, not even in the Boston area. Going to another city was inconceivable. My oldest son Ben was born two years later. When Ben was in nursery school at the age of three, I taught two courses at Boston University in order not to forget everything I had learned. It never occurred to me then that I was teaching the same number of courses, at the same level as full-time faculty, for a graduate student stipend. Of course, I did nothing else except teach these courses, as I still felt my first responsibility was to my small children. Even with my teaching, I found this life stultifying. We had little money, so we could not hire babysitters or household help. My husband was very ambitious, worked long hours and did not feel he should help anyway, which was common then. When the youngest, Ben, was old enough for kindergarten, I decided to take the plunge and get a full-time position—in the Boston area, of course. Naturally, I tried some of the many colleges and universities there. What were they to make of someone who had done no research but some teaching since her degree? Aside from that, I did not feel that the academic atmosphere then was conducive to women. Tufts asked me, "didn't I know that it was a men's school" and that all the calculus instructors graded exams in one room? I thought they considered it improper for a female to also be in that room. I heard at least one person say "I would never hire a woman." Fortunately, there was an Air Force research laboratory, AFCRL, nearby. And fortunately, there were mathematicians there working in a new area, error-correcting codes, who thought my algebra background could be useful. I thought the atmosphere toward women at AFCRL was much better than in the academic institutions I had seen. That was how I started working on error-correcting codes, and I have never stopped.

I had to learn how to handle leaving home—day-care was not so good or widespread then. My relatives said, "What if a child has an accident while you are away at work." Guilt was added to my other concerns. A few of my husband's physicist colleagues were working mothers, and I followed their advice closely. We even formed an organization WISE (Women in Science and Engineering) to help others. I was president of WISE for a few years. Needless to say, I did not have the time for this in addition to my family and job, but I found our "consciousness-raising sessions" valuable in enabling me to regard myself as a professional and to develop confidence in my own work and opinions. When our third child (a son) was born, I only took a few months of maternity leave.

At AFCRL, we hosted monthly workshops in coding which were attended by many coding theorists. Andrew Gleason was a regular member of these sessions, which I found quite stimulating. I stayed at AFCRL for ten years until the Mansfield amendment was passed and the laboratory was unable to continue its basic research work. I decided to return to academic life, even though I found the transition very painful. I spent three years as a research associate in MIT's Project MAC until I got my present position at the University of Illinois at Chicago. So my first regular academic position was full professor. It was wrenching to leave the Boston area as my youngest son stayed there. After five years of separation, my husband and I divorced, and my son came to Chicago to live with me. I enjoy academic life very much now and am pleased that my department contains such good people.

In retrospect, I think I was very lucky. I worked in coding from its beginning and it has developed into a fascinating mathematical topic. I have appreciated the opportunity to work with many wonderful mathematicians, in particular Richard Brualdi, John Conway, and Neil Sloane. I was able to care for my children in their younger years in a low pressure environment. I would find child rearing difficult facing the pressures our assistant professors face. Our discipline is not the only one demanding a great deal. My daughter, a medical resident with a young daughter of her own, has plenty to say about the long hours required of residents. Unfortunately, our society is probably losing valuable contributions from women for these reasons. and many women are paying a great emotional toll either in forfeiting careers or in not devoting as much time to their families as they feel they should.

Jean E. Taylor

Rutgers University

My main message is that things aren't as different now from what they used to be as many people think, in spite of twenty-five years of "women's lib" and twenty years of the Association for Women in Mathematics. Each of the following is something that happened within the past five months.

Item: A recent conversation at Rutgers with the guy in charge of assigning who teaches what in the department. Due especially to an attractive early-retirement package, many faculty members, including two women in the department, are retiring. Rutgers used to employ a large fraction of the women professors in the U.S., but we will be down to four (Barbara Osofsky, Tilla Milnor, Amy Cohen, and myself) next year, with Ingrid Daubechies making it five in 1992. In the conversation, I was bemoaning the loss of this large fraction of the women faculty, and his response was "Oh, that's all you ever think of. I'm interested in the number of bodies available to teach classes!" (The situation is aggravated by a hiring freeze imposed on the university by the state budget situation.) I responded that I too was interested in bodies, in particular in women's bodies. The conversation predictably degenerated at that comment. But still, the point is that my awareness of the problem is regarded as some personal foible of mine.

Item: Math Counts. This is a fine mathematics team competition for middle school students; my daughter has been active in it and loves it. But when I saw the list of sample problems they had to study, I was aghast: every single word problem had male names, if there were any names at all. I went to observe the regional competition, and listened to the "Count-down Round" (where the top ten students are asked questions orally). Exactly the same thing—all names mentioned were male. The only question which involved females at all (1) had no name attached to the girl (as opposed to the other questions) and (2) concerned the number of different outfits she could assemble if she had three skirts, two blouses, etc. Talk about stereotyping! I felt betrayed, that the "good guys" (as I consider Math Counts to be) should do this.

Item: The profusion of messages (e.g. on the Op-Ed page of the New York Times) about how "it is a dirty lie" to suggest to students that they can have a full-time career and a family too. The least offensive of the current phrases seems to be that "you can have it all, but not all at the same time." I agree with Jane Pauley that to "have it all" requires (1) good intelligence, (2) good energy, (3) good health, and (4) good luck. Since you haven't got much control over these factors, you certainly can't count on "having it all," and you shouldn't feel it a personal failure if you don't succeed. But it is also wrong to discourage students from trying.

Item: Retirement party for Joanne Elliot. One of my (male) colleagues reminisced about seeing Joanne as an attractive young woman in the common room at Princeton surrounded by young men eager to be near her. The comment made me feel very uncomfortable, since it placed emphasis on her attractiveness in a setting where conversations are often mathematical. If only the men had been clustered around her because they were eager to hear her theorems and conjectures! But at least as the story was related, that was not the case.

Emmy Noether

"Emmy Noether's career was full of paradoxes, and will always stand as an example of shocking stagnancy and inability to overcome prejudice on the part of the Prussian academic and civil service bureaucracies. Her appointment as *Privatdozent* in 1919 was only possible because of the persistence of Hilbert and Klein, who overcame some extreme opposition from reactionary university circles. The basic formal objection was the sex of the candidate: 'How can we allow a woman to become a *Privatdozent*: after all, once she is a *Privatdozent*, she may become a Professor and member of the University Senate; is it permissible for a woman to enter the Senate?' This provoked Hilbert's famous reply: 'Meine Herren, der Senat ist ja keine Badenanstalt, warum darf eine Frau nicht dorthin! [Gentlemen, the Senate is not a bathhouse, so I do not see why a woman cannot enter it!]' "

—from an address, "In Memory of Emmy Noether," delivered by P.S. Alexandrov, then president of the Moscow Mathematical Society, on September 5, 1935. Quoted from *Emmy Noether*: 1882-1935, by Auguste Dick. Birkhäuser, 1981.

The Past, Present, and Future of Academic Women in the Mathematical Sciences

WOMEN IN MATHEMATICS

Lynne Billard

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1. Introduction

As the proportion of women graduate students continues to increase, women will likely increase the representation in academic positions. What patterns have prevailed in the past, exist today, and can be envisioned for the future? This article attempts to review data and previous studies of academic progress of female faculty.

We consider first the educational opportunities that women have been accorded. We then investigate the career progress enjoyed by women who earned doctorates and joined the faculty ranks. This investigation includes the prospects for promotion and tenure, and also considers salary differentials. Since evaluation for promotion and tenure is dependent upon job performance, most especially publication rates, this issue receives separate attention. Finally, we try to predict the future and conclude that, in spite of persistent difficulties, prospects for the future have improved considerably and that a young woman starting out today faces fewer hurdles than did her counterparts of bygone years.

This work draws heavily upon the studies of Dix (1987) (in particular, the chapters by Debold (1987), Hornig (1987) and Zuckerman (1987)), Sandler (1986), Vetter (1981, 1987), Scott (1977, 1979), Ahern and Scott (1981), among others. In a very real sense, the present article can be viewed as a review and summary of these studies and the paths over which they lead, as they pertain to the mathematical sciences. Since little data exist for statisticians *per se*, it is assumed throughout that the quoted existing results for mathematics are reasonable estimates for those for statistics.

2. Education

Women perform significantly better than men at all levels of education from high school to graduate school, but they do not perform better in general on standardized tests such as the quantitative SAT and GRE tests. Chipman and Thomas (1985) show that gender differences in mathematics performance do not emerge until high school where more men enroll in trigonometry and calculus (26% and 8%, respectively) than do women (20% and 6%, respectively) with the same percent enrollment in algebra (66% men, 69% women) and geometry (54%). The lower standardized test scores appear to be explained by high school course selection and by demographic and socioeconomic factors and not by genetic differences (Hornig (1987)). However, high school grades in mathematics for women are not less than those for men, though men have tended to have more years of preparation in mathematics at the high school level.

Of entering freshman, essentially the same percentage of men as of women intend to major in either mathematics or statistics (see Table 1). Thus, in 1971, 2.6% of the men and 2.9% of the women declared this major, while in 1980 the corresponding percentages were 0.7% and 0.6% respectively, with the figures remaining steady throughout the 1980s. Since in 1972 and in 1986, 44% and 46%, respectively, of the bachelor degrees were awarded to women, these represent reasonable approximate percentages for both men and women. Throughout this entire period, the same proportion (0.1%) of both men and women sought statistics as a career goal.

Table 1: Education Trends since 1971.

	Freshman major in math./stat.		Bachelors to women in		Doctorates to women in Math. sciences
	Men	Women	Math.	Stat.	
1971	2.6%	2.9%	38.2%	25.3%	7.8%
1973	1.8	1.6	40.3	34.8	9.7
1975	1.1	1.1	42.1	31.9	9.6
1978	1.1	0.8	41.4	39.2	13.7
1980	0.7	0.6	42.3	42.1	12.0
1982	0.6	0.7	43.2	41.1	13.8
1983	0.8	0.8	45.7	48.7	16.1
1988	0.7	0.6	46.5*		16.2

* 1986 figure; Source: Debold (1987), Vetter (1981), NSF (1990)

Table 1 also shows the proportion of bachelor's degrees with a major in mathematics (statistics) awarded to women, as well as the proportion of doctorates in the mathematical sciences that were earned by women. In particular, we note that the proportion of bachelor degrees in mathematics to women has increased from 38% in 1971 to 46% in 1983, and the proportion of doctorates in the mathematical sciences awarded to women has increased from 8% in 1971 to 16% in 1983. In each case there has been a levelling off over the period 1983–1988. These changes are partly due to declines in the numbers of men in these categories. For example, there were 9,259 women and 14,454 men in 1972, and 5,006 women and 6,593 men in 1982 receiving the bachelors degree in mathematics; while there were 89 women and 1,039 men in 1972, and 94 women and 587 men in 1982 earning the doctoral degree in the mathematical sciences (see Weis (1985)). Thus, at least at the undergraduate level, parity seems to have been achieved, suggesting that whatever deterrants that may have existed previously may have evaporated. Presumably we can hope for a continued growth in numbers at the graduate school level, though the stability of the 1983–1988 figures may temper such expectations. Throughout this period, an approximately constant one third of the masters degrees in mathematics were awarded to women.

The drop in proportion of graduate degrees to women signals a higher attrition rate in mathematics for women between the bachelors degree and a doctoral degree (where, for example, the National Science Foundation (1986) data of parity indices show a loss from 35% of the bachelors degrees in 1977 to 15% of the doctorates in 1984). The Office of Technology Assessment (1985) report states that in 1982, 37% of the bachelors degrees but only 27% of graduate enrollments in mathematics were women. Thus, part of the decrease is due perhaps to admission procedures where standardized test scores (which underestimate women's performance) and recommendations by faculty (presumably male) weigh more heavily than does academic performance as an undergraduate.

However, a large source of this attrition is attributed to a failure to complete the stated degree objective. A major factor influencing graduate students' persistence with a degree is the availability of financial aid. Haven and Horch (1972) and the 1981 Survey of Doctorate Recipients showed that women receive less aid than men and Harris (1972) found that women tended to come from wealthier families, presumably because, in the absence of other aid, only these women could afford this education. For mathematics graduate students, a significantly higher proportion of teaching assistantships went to women and a significantly higher proportion of research assistantships supported men. However, for those graduating with doctorates in 1988 (of whom 16% were women), 17% of teaching and of research assistantships were awarded to women suggesting that some progress has been achieved. Solomon (1976) observed that the actual level of support was generally lower for women than for men. On the other hand, women tend to gain a higher proportion of fellowships (where their better scholastic performance is no doubt a major contributing factor).

While financial aid is clearly an important indicator of persistence to degree completion, it is not the only factor. In a study at the University of Illinois, Berg and Ferber (1983) found that, despite equality of financial inducements, the attrition rate for women was still higher than that for men. They suggested that women students have a lower involvement with faculty and were less likely to be treated as colleagues. This need for greater mentoring by faculty will be hard to meet until there are more women faculty. Berg and Ferber (1983) also found that women tended to have less confidence in themselves despite their superior performances.

3. Careers

In the Preface to Ahern and Scott (1981), Hornig states that, "generally speaking, women are far more likely than men to be involuntarily unemployed and underemployed; they were much less likely than men to attain senior ranks or move to management levels, and their earnings not only reflected these differences but were persistently lower even at equal ranks. Women who appeared equal to men in all respects at receipt of the doctorate had less assured careers than men with slower progress and lower ceilings." Six years later, Vetter (1987) draws the same conclusions and suggests further there has been little change since 1977. On the other hand, Zuckerman (1987) is more encouraging, noting that while gender differences are present in all categories of academic institutions, most especially at the top ranked ones, trend data suggested that the gap is narrowing, especially at the lower ranks.

By far, the most important contribution to an analysis of career attainments is the superb study by Ahern and Scott (1981). This study (to be referred to as the matched triads study, originated by Dorothy Gilford) is based on triads consisting of one women and two men matched by year and field of the doctoral degree, the institution at which the degree was earned, and race. For some analyses, there is further matching by years of full-time equivalent experience and employment sector. Taking into account perceived levels of quality proved too complicated to handle in the study. Given the difficulties encountered by women in publication rates (see below), the fact that quality could not be addressed adequately is perhaps unsurprising. The data were compiled as to the observed outcomes of 1979 of approximately 50,000 individuals for four cohorts, viz., those who received the doctorate in the period 1940–1959, 1960–1969, 1970–1974, and 1975–1978, respectively. While the entire study was concerned with academic careers over the sciences, engineering and humanities, our analysis here will be restricted to the results for mathematics (including statistics) unless otherwise stated. We shall consider the issues of employment/unemployment, rank and tenure, including progress in promotion. Issues surrounding salaries will be addressed in the next section. More complete details can be found in Ahern and Scott (1981). As we look at the study, we should bear in mind that it was not until 1972 that the legislation prohibiting discrimination in federally assisted programs (Title IX of the Education Amendment) and prohibiting discrimination in employment in educational institutions (Amendment of Title VII of the 1964 Civil Rights Act), was enacted.

Employment

In 1979, 82.4% of men and 84% of women with doctorates in mathematics were employed in educational institutions (Vetter (1981)). For the matched triads, Table 2 shows that consistently fewer women are employed full-time than are men and that, excluding the 1940–1959 cohort (where some are now retired), roughly three times as many women are unemployed, though the numbers are reasonably low. More importantly, the percent of men and women unemployed for the most recent 1975–1978 cohort is just one. For all mathematics doctorates in 1985, Vetter (1987) reports the unemployment rates have decreased further to 0.4% for men and 0.9% for women; by 1987, these rates decreased slightly for men to 0.3% but increased substantially to 1.8% for women (NSF (1990)). Approximately six times as many women as men in the matched triad study are in part-time positions. Zuckerman (1987) reports that women are more likely to be underemployed, being either in involuntarily part-time positions or in jobs outside their training. Finally, men (9%) and women (11%) in the 1970–1974 cohort were approximately equally likely to be employed in the top ranking universities (primarily due to overrepresentation of women at the lower ranks), which shows an improvement over the corresponding figures (11% for men and 6% for women) in the 1960–1969 cohort.

Rank and Tenure

For those identified in the matched triad study, the percent of the men and of the women occupying the traditional academic ranks of professor, associate professor, assistant professor, and instructor/nonfaculty positions is shown in Table 2 for each of the four cohorts. Also shown is the percent who are tenured. It is immediately apparent that, despite the fact that the data represent men and women starting out with equivalent matched credentials, women do not fare as well as men, with the women being ranked consistently lower than their male peers. Those in the first (1940–1959) cohort do eventually progress up the ranks, although twice as many women (12%) as men (5%) appear to be frozen in rank below the full professor level. For the 1960–1969 cohort, men were 1.4 times as likely to be full professors, and 97% of men but only 80% of women were tenured by 1979. Of those (in all fields) in this cohort who were tenured, the men took an estimated average of 5.9 years to attain tenure while the women took 6.3 years.

The 1970–1974 cohort spans the 1972 date of the nondiscrimination statutes, and by 1979 such individuals should have reasonably expected to be promoted and tenured. Therefore, the fact that still considerably fewer women (45%) than men (70%) have been promoted to full or associate professor suggests further analysis is warranted. The matched triad study investigated three possible explanations. Ahern and Scott (1981) found that a lower commitment to research with a corresponding heavier teaching load did not affect women differently than men in the same position. In fact, a higher percent of those whose primary activity was teaching rather than research was promoted by 1979 from assistant to associate professor (64% teaching versus 60% research for men and 48% and 32%, respectively, for women). Another commonly believed explanation, that women lost time due to childbearing, did not stand up to scrutiny. Indeed, married women with children (with 51% being promoted from assistant to associate professor) fared better than married women with no children (41%) who in turn fared better than unmarried (including widowed and divorced) women with no children (37%). Of those unmarried with children, 33% were so promoted. The corresponding figures for men were 66%, 51%, 53% and 80%, respectively. Thirdly, the perception that women are less mobile than men was not substantiated by the matched triad study. To the contrary, more women (28%) than men (19%) changed jobs between 1975 and 1979. While men who moved improved their status significantly, women who moved did not improve their status, possibly because the women moved due to a failure to receive promotion and tenure. Few faculty with tenure in 1975 changed jobs between 1975 and 1979.

Table 2: Percent men and women in mathematics – Matched triad study.

	1940-1959		1960-1969		1970-1974		1975-1978	
	Men	Women	Men	Women	Men	Women	Men	Women
Employment								
Full-time	91%	79%	96%	86%	93%*	78%*	94%	88%
Part-time	3	10	1	6	2*	12*	1	6
Postdoctoral			1	1	3*	3*	3	3
Unemployed	6	10	2	7	2*	7*	1	1
Rank								
Full Professor	90	83	52	38	2	2	0	0
Associate	5	10	38	44	68	43	8	3
Assistant	0	2	6	13	21	46	72	78
Instr./Nonfac.	0	0	1	3	7	5	13	19
Other	5	5	4	3	2	4	8	2
Tenured	98	90	97	80	52	35	15	9
Women's salary as % less than men's salary	-	<1	-	11	-	7	-	2

*All fields; Source: Ahern and Scott (1981)

Comparison of Ranks

For all four cohorts, although individuals in the matched triads started out together, differences in rank and tenure status persisted over the years. Accordingly, Ahern and Scott (1981) developed prediction equations (using stepwise regression analysis) to estimate rank and salary and to estimate the salary women should receive if paid like a man with similar characteristics. The data used here were confined to those triads for which the doctorate was earned since 1958. This analysis also included matches that had equivalent full-time work experiences. A prediction equation was established for men and was then used to predict the ranks (and salary) women in the same field and institution category should receive if rewarded the same as a man with comparable characteristics. Taking into account the possible biases of this study, Ahern and Scott opined that their method should provide good estimates of the differences for younger faculty but underestimate the differences for older faculty.

The standardized regression coefficients in the prediction equations for women and men in the MPE (mathematics, physical sciences and engineering) field are displayed in Table 3. (In this equation rank was coded as 4 for full professor, 3 for associate professor, 2 for assistant professor and 1 for instructor). The most important predictor was a weighted measure of time. For men, this was the time since receiving the doctorate, while for women, the number of full-time equivalent years experience dominated. The sum of the coefficients of these two (0.747 for men and .638 for women) estimated the average yearly increase in rank. For men, the second most important predictor was the variable indicating the person had children under 18. The effect was positive. This predictor also had a positive effect for women (in MPE, but it did not enter in the equation for other fields). For women, the prestige of the department from which the doctorate was received had a positive effect. Since the two variables—being married at the time of the doctorate, and being married at the time the data were collected in 1979—are collinear, only one of these variables usually entered the prediction equation, producing a slightly negative effect when present. Prediction equations which included sex as a predictor variable showed the effect for female to be always negative and significant, with women predicted at a rank approximately one-third lower than their matched men.

Table 3: Predictors of rank and salary in MPE field.

Predictor	Rank Regression coefficient		Salary Regression coefficient	
	Women	Men	Women	Men
Years since PhD	.242	.747*	-	.670*
Years experience full time	.396	-	.616*	-
Rating of PhD dept.	.186	.045	.189	-
Married at PhD	-	-.067	-	-
Married in 1979	-.169	-	-.257	.091
Children under 18	.100	.123*	.160	-
Bachelors from:				
Liberal arts college	-	-	-.198	.078
Research university	-	-	-.274*	.145
Foreign institution	-	-	-.150	.095
Administration	-	-	-.102	.135*

*Significant at 5%; Source: Ahern and Scott (1981)

However, while these studies show that women are promoted more slowly and gain tenure more slowly than their male counterparts, Zuckerman (1987), using the CEEWISE 1983 data, reports that over science and engineering fields, generally 67% of men and 40% of women in tenure track positions had received tenure by 1983. This suggests the gap is narrowing. More recent data on the distribution of all doctoral men and women mathematical scientists employed in 1987 at four-year colleges and universities compiled in NSF (1990) suggests this trend is continuing. From Table 4, we observe that 58% of the women but 75% of the men are either at the Full or Associate Professor rank; and 75% of the women but 85% of the men are in tenured or tenure-track positions. Of all those in the Full (Associate) Professor rank, 5% (13%) are women with 7% of both these ranks combined being women; and 7% (15%) of those who are tenured (tenure track, but untenured) are women with 8% of all those in tenure track positions being women.

Table 4: Rank and status of men and women in mathematics – 1987

% in Rank	Full Professor	Associate Professor	Assistant Professor
Men	51.7%	23.7	16.9
Women	25.0	33.3	33.3

% in Tenure Status	Assistant Professor	Tenure Track tenured	Tenure Track untenured
Men	70.3%	14.4	4.2
Women	50.0	25.0	8.3

Source: NSF (1990)

4. Salaries

Since salaries are tied to ranks, it is not surprising that for women both measures fall behind those for men. This is especially true in academia, although Zuckerman (1987), in commenting on the 1981 figures for science and engineering fields, suggests that the salary differences between men and women are largest at the full professor level, less so at the associate professor level, and are not present at the assistant professor level. Unfortunately, this optimism seems perhaps premature when one notes the figures of Table 5, which provides the percentage (of the men's average salaries) that the women's average salary falls short for ranks in the research universities for the 1990-1991 academic year. Women at public institutions seem to fare better than their colleagues at private or church related institutions. Comparable tables for the 1985-1986 and 1988-1989 salaries give essentially the same figures with very little change in these percentages over the years. New assistant professors (full professors) in the mathematical sciences received a salary at 92.7% (98.8%) of that averaged over all fields. These findings are not inconsistent with those of Vetter (1987), who conducted a study of women's salaries as a percentage of men's salaries for doctorates in the mathematical sciences. The study found that this percentage declined from a high of 87.8% in 1973 to a low of 81.3% in 1979, increased again to 87.2% in 1983, but subsequently declined again in 1985 to 83.0%. This was essentially unchanged at 83.4% in 1987 (NSF (1990)). Vetter's study also found that the salary differential widened as the number of years of experience increased. This latter observation also emerged from the matched triad study (see Table 2), which shows for mathematics the percentage of the men's median annual salary by which the women's median annual salary is lower. Notice, in particular, the lower salary for women in the 1975–1978 cohort who by 1979—that is, after only one to four years from their doctorate—are already behind by 2%. Since it is assumed starting salaries were comparable, such a lag is somewhat disturbing. These salary differentials constitute a large cumulative effect over the years, not only in absolute numbers of dollars but also on retirement benefits, which tend to be a function of salary during employment.

Table 5: Percent deficient in women's average salaries, 1990-1991 – Research Universities

	Type of Institution			
Rank	All Combined	Public	Private/ Independent	Church Related
Full Professor	10.1%	9.9%	11.6%	7.0%
Associate Professor	6.0	5.9	7.1	5.5
Assistant Professor	9.3	9.2	8.7	7.5
Instructors	10.8	9.3	10.8	13.4
Lecturer	14.9	14.0	17.8	11.8

Source: AAUP (1991)

The matched triad study included the derivation of prediction equations for salary (see the discussion on ranks). The standardized regression coefficients for the respective predictors for salary are shown in Table 3. As for rank, the most important predictor variable was the time factor, with the sum of coefficients for years since the doctorate and years of full time equivalent experience representing the average year's increase in salary. Notice once again this is less for women than for men. Interestingly, although teaching as a primary activity was a potential predictor, it never in fact entered the equation, while administration as a primary activity did enter as a positive effect on salary for men but as a negative effect for women. Being married at the time of the doctorate had a negative effect on salary for women. Receiving the bachelor's degree from a research university had a greater effect than receiving the degree from a liberal arts college or overseas, but in all cases there was a negative effect on the woman's salary but a positive contribution to the man's salary. When sex was included as a predictor in the equations, the effect for women was always negative and significant and predicted women to have a salary about $1,550 (in 1979) less than the comparable male.

These prediction equations were subsequently used to predict the salary a woman would have received had she been paid as a man (using again the matched triads of doctorates from 1958–1978). The residuals (of actual minus the predicted salary) were found for successive five year periods since the doctorate had been awarded. The residuals for the most recent group of women tended to center around zero but they shifted more negatively for each successive five year cohort, substantiating the results of the Vetter (1987) study noted above. A corresponding opposite-sex equation for men had positive residuals for men (see Scott (1977)). Thus, when compared with those of equal ability and attributes, women tend to be underpaid while men tend to be overpaid.

While these conclusions are regrettable, they are however correctable. Scott (1977) developed a higher education salary evaluation kit whereby the salaries of women in homogeneous departments (or similar units) which have about fifteen or more white males, can be flagged as being potentially inequitable. Furthermore, the amount by which the salary needs to be adjusted to bring it to the level of a comparable white male is estimated. This study investigated many sets of potential predictor variables for the resultant regression analysis. Surprisingly, the set of predictors consisting of year of birth and year of doctorate (where "year" means the last two digits only) generally served very well. Adding additional predictor variables such as number of publications, number of doctoral students, etc., did not greatly improve the prediction. A possible explanation is that, since the regression analysis is performed over the homogeneous unit itself, most individuals in that unit publish papers and produce students at a comparable rate. Therefore, these variables do not tell us very much more than is already known and so do not add any additional predictive power. Whatever predictor variables might be the most relevant for a particular unit, it is important not to use variables such as numbers of articles published, rank, tenure, administration, which are themselves biased against women.

While this evaluation kit allows identification of women receiving salaries lower than comparable males, Scott (1979) cautions that, when this method appears to identify a woman as earning an average male salary, care should still be taken as she may still be earning less than what she herself should be earning were she a male when actual accomplishments are taken into consideration. By plotting salary as a function of years since the doctorate, Scott (1979) shows that all women in a certain department were underpaid. This includes a particular woman whose salary was comparable to the men and so would not be flagged from the regression analysis. Yet, on further investigation, by any measure of merit adopted (except salary), this woman was clearly the most outstanding person in the department. Gray and Scott (1980) discuss further the dangers and misuses of the regression analysis. Billard et al. (1990) provided a statistical adjustment method to remove identified gender bias in such salaries.

5. Publications and Performance

In a major university, promotion and tenure are usually based on excellence in at least two of the following: teaching, research, and service. Since excellence in teaching graduate classes is predicated on the instructor being at the cutting edge of the subject, this presupposes excellence in research. Furthermore, the academic's reputational standing (most especially after the attainment of full professor rank) rests on research performance. The usual measures of research performance are publications and citations. Before examining these two measures in more detail, it is interesting to look at the study conducted by Davis and Astin (1987). They are investigating the factors which contribute most to an academic's reputation and the esteem in which that person is held. Their data is restricted to the "highly productive" scholars (as of 1980 and 1982) in the social sciences, where the number of papers (rather than books) was the operative measure of performance. The most significant predictor of reputation and esteem produced by their regression analysis was the number of chapters in a book (be they invited (new) papers or a reproduction of an earlier highly regarded paper), and not, in fact, the number of publications *per se* as might have been originally expected. The explanation is simple. The invitation to make a contribution to the book in and of itself presupposes the invitee has already established a reputation or level of excellence worthy of such an invitation. Although not directly addressed by Davis and Astin, the same conclusions may be made relative to invitations to serve on national boards or panels, many of which ultimately produce major publications of some description.

Although women have performed at least as well in graduate school, they publish less than do men. A study on citations showed that in mathematics 2.9% of articles classifiable by gender were written by women although 13% of the membership of professional associations were women and 7.6% of those doctorates in the mathematical sciences employed in educational institutions in 1979 were women (from Vetter (1981)). A study by Goldberg (1968) was repeated by Paludi and Bauer (1983) in which it was shown that publications perceived to have been written by women were considerably less favorably reviewed than those thought to be written by men (see Table 6). In this study, 180 men and 180 women were asked to rate comparable articles, one-third of which were "authored" by John T. McKay, a Joan T. McKay, and a J. T. McKay. The most favorable rating was one, with five being the least favorable. Upon questioning later, the majority of the raters believed the articles by J. T. McKay were in fact authored by a woman and this belief is reflected in the mean scores shown in the table. It is interesting to observe that women also rated male-authored papers more highly than they did for Joan T. and J. T. papers, but not quite as favorably as did men rate men authors.

Table 6: Mean rating scores.

Article reviewed by	Article Authored By		
	John T. McKay	Joan T. McKay	J.T. McKay
Men	1.9	3.0	2.7
Women	2.3	3.0	2.6

Source: Paludi and Bauer (1983)

Along these same lines, Lefkowitz (1979) relates how prior to 1974 papers submitted for presentation at the professional meetings (of classics) included the author's name(s). These were refereed, with the result that very few women (or younger) scholars had their papers accepted for the meetings. After 1974, the authorship was left off, with the effect that, in each of the first two years, there was a 100% increase in the number of papers written by women that were accepted. By 1978 the proportion of women authored papers accepted was approximately equal the proportion of women in the profession. As an aside, the relevant Board of Directors subsequently decided, with unanimous approval, to continue the policy of removing names before refereeing and to expand the policy to all publications.

Women are likewise disadvantaged in evaluations based on citations are made. Ferber (1986) observed that women tend to cite women and men tend to cite men more than citations of the opposite sex. In a separate study, Table 7 shows the percent of citations of women, men, and joint authors in articles in mathematics written by men and women, thus substantiating these perceptions. The larger study (covering many fields) from which these results were extracted did, however, show that this disadvantage to women decreased as the proportion of women in the field increased; so this is encouraging for the future.

Table 7: Citations.

Cited articles that were written by	Article Authored By	
	Women	Men
Women	4.8%	1.2%
Joint authors	2.2	0.8
Men	93.9	98.0

Source: Unknown

Women also tend to publish at a lower rate as their careers advance. Cole and Zuckerman (1984) suggest this is possibly due to the lack of rewards at the level they see their male colleagues enjoying. That equal rewards for equivalent research performances are not forthcoming has been substantiated by several studies, including those by

Bayer and Astin (1975) and Cole (1979), who demonstrated that such men enjoyed higher ranks than women, especially in the more prestigious universities. The improved resources that come with rank, such as better teaching assignments, greater access to graduate students, etc., are thus denied, at least to a degree, with an increasing reduction in access to these resources over time. This effect is further compounded by the fact that women tend to be less visible than men, their work is perceived to be of lower quality and rarely are women cited as having made major contributions (see Cole (1979) and Davis and Astin (1987)). This is demonstrated, for example, by the low number of women who serve as invited speakers at professional meetings.

These studies parallel those by Deaux and Taynor (1973) in which men applicants for a study-abroad program were more favorably viewed than identical women applicants, and by Fidell (1970) in which university chairs rated identical applicants, preferring those believed to be men, and, furthermore, tending to offer the men positions at the associate professor level and women at the assistant professor level. Sandler (1986) summarizes these and similar studies stating that "the same professional accomplishments are seen as superior in quality and worthy of higher rewards when attributed to men than when they are attributed to women." Nieva and Gutek (1980) provide a more indepth look at the factors behind these differences in evaluation. Deaux and Emswiller (1974) observed that when women were perceived to have performed as well as men on "male-related" tasks their good performance was due to external factors such as luck or effort whereas the man's good performance was due to internal factors such as skill or ability. Finally, men are frequently appointed to positions, most especially senior and administrative positions, on their *potential*, in contrast to women who not only had to *prove* themselves first but had to do so under intense scrutiny (Sandler (1986)).

6. The Future

It is apparent that inequalities have existed and continue to exist for all aspects pertaining to an academic career, ranging from educational opportunities, employment prospects, attainment of rank and tenure, and comparable salaries, as well as acceptance by the professional community as measured by publications and visibility. However, it is also clear that these disparities are decreasing overall and that real gains in narrowing the gap are being made.

Vetter (1987) and Hornig (1987) both conclude that women's access to graduate education has improved, especially since 1970. Thus, more women will be qualified to enjoy a greater share of the academic positions. This means, in turn, that the critical mass theory (see Debold (1987)) comes more into play, whereby more women faculty, by their very presence can also serve as role models and mentors. Sandler (1986) gives a chilling account of the subtle forms of discrimination which persist on the university campus. Fortunately, as more women are appointed to faculty positions and to administrative ranks, many of these forms will perforce disappear. In the meantime, the Sandler report serves as a useful guide, delineating many of the markers which, if observed, can assist the woman faculty member towards her own successful career attainments.

Perhaps the best summary emphasizing the real progress that has been made is the following conclusion from Zuckerman (1987): "... pertinent data, drawn from current studies, show three separate but interconnected patterns. First, there are *persisting differences* ... in role performance and career attainments ... (but) ... Second, there are signs of *growing convergence* ... in access to resources, research performance, and rewards—that is, evidence for increasing gender similarity over the last decade and a half, especially between younger men and women. Third, ... evidence for *growing divergence* ... in published productivity in some, but not all, aspects of career attainment ... ."

Acknowledgment

This work is largely a republished but updated version of Billard (1989). The earlier paper was prepared as a tribute to Dr. Elizabeth L. Scott to which the reader is referred for more details. In recognition of her very substantial role in drawing attention to the plight of all academic women, this present work is also dedicated in her honor.

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References

AAUP (American Association of University Professors). 1991. The Annual Report on the Economic Status of the Profession 1990–91. *Academe* 77 March–April Special Issue, 9–91.

Ahern, N. F. and Scott, E. L. 1981. *Career Outcomes in a Matched Sample of Men and Women Ph.D.'s: An Analytical Report.* National Academy Press, Washington, D. C.

Bayer, A. E. and Astin, H. S. 1975. Sex differentials in the academic reward system. *Science* 188, 796–802.

Berg, H. M. and Ferber, M. A. 1983. Men and women graduate students: Who succeeds and why? *J. Higher Educ.* 54, 629–647.

Billard, L. 1989. The past, present and future of women in Academia *Proc. Amer. Statist. Assoc. Sesquicentennial Invited Paper Sessions*, 645–656.

Billard, L., Cooper, T. R. and Kaluba, J. A. 1990. *A statistical adjustment to gender and race based salary inequalities.* Technical Report.

CEEWISE (Committee on the Education and Employment of Women in Science and Engineering). 1983. *Climbing the Ladder: An Update on the Status of Doctoral Women Scientists and Engineers.* National Academy Press, Washington, D. C.

Chipman, S. F. and Thomas, V. G. 1985. Women's participation in mathematics: Outlining the problem. In *Women and Mathematics: Balancing the Equation* (eds. S. F. Chipman, L. R. Brush and D. M. Wilson). Lawrence Erlbaum Associates, New Jersey.

Cole, J. R. 1979. *Fair Science: Women in the Scientific Community.* Free Press, New York.

Cole, J. R. and Zuckerman, H. 1984. The productivity puzzle: Persistence and change in the patterns and publications of men and women scientists. In *Advances in Motivation and Achievement* (eds. P. Maehr and M. W. Steinkamp). JAI Press, Connecticut.

Davis, D. and Astin, H. S. 1987. Reputational standing in academe. *J. Higher Educ.* 58, 261–275.

Deaux, K. and Emswiller, T. 1974. Explanations of successful performance on sex-linked tasks: What is skill for the male is luck for the female. *J. Personality and Social Psych.* 29, 80–85.

Deaux, K. and Taynor, J. 1973. Evaluation of male and female ability: Bias works two ways. *Psych. Reports* 31, 20–31.

Debold, W. K. 1987. Women in engineering and science: An undergraduate research perspective. In *Women: Their Underrepresentation and Career Differentials in Science and Engineering* (eds. L. S. Dix). National Academy Press, Washington, D. C.

Dix, L. S. 1987. *Women: Their Underrepresentation and Career Differentials in Science and Engineering*, (ed.). National Academy Press, Washington, D. C.

Ferber, M. A. 1986. Citations: Are they an objective measure of scholarly merit? *Signs* 11, 381–389.

Fidell, L. S. 1970. Empirical verification of sex discrimination in hiring practices in psychology. *Amer. Psych.* 25, 1094–1098.

Goldberg, P. A. 1968. Are women prejudiced against women? *Transaction* 5, 28–30.

Gray, M. W. and Scott, E. L. 1980. A "statistical" remedy for statistically identified discrimination. *Academe* 66, 174–181.

Harris, S. E. 1972. A statistical portrait of Higher Education. *Report to the Carnegie Commission on Higher Education*. McGraw-Hill, New York.

Haven, E. W. and Horch, D. H. 1972. *How College Students Finance their Education*. College Entrance Exam. Board, New York.

Hornig, L. S. 1987. Women graduate students: A literature review and synthesis. In *Women: Their Underrepresentation and Career Differentials in Science and Engineering* (ed. L. S. Dix). National Academy Press, Washington, D. C.

Lefkowitz, M. R. 1979. Education for women in a man's world. *Chronicle of Higher Educ.* August 6, 56.

NSF (National Science Foundation). 1986. *Women and Minorities in Science and Engineering*. U. S. Gov. Printing Office, Washington, D. C.

NSF (National Science Foundation). 1990. *Women and Minorities in Science and Engineering*. U. S. Gov. Printing Office, Washington, D. C.

Nieva, V. F. and Gutek, B. A. 1980. Sex effects on evaluation. *Acad. Manag. Review* 5, 267–276.

Office of Technology Assessment. 1985. *Demographic Trends and the Scientific and Engineering Work Force: A Technical Memorandum*. U. S. Gov. Printing Office, Washington, D. C.

Paludi, M. A. and Bauer, W. D. 1983. Goldberg revisited: What's in an author's name. *Sex Roles* 9, 387–390.

Sandler, B. R. 1986. The campus climate revisited: Chilly for women faculty, administrators, and graduate students. *Project on the Status and Education of Women*, Association of American Colleges, Washington, D. C.

Scott, E. L. 1977. *Higher Education Salary Evaluation Kit*. American Assoc. Univ. Prof., Washington, D. C.

Scott, E. L. 1979. Linear models and the law: Uses and misuses in affirmative action. *Proc. Amer. Statist. Assoc. Social Sci. Section*, 20–26.

Solomon, L. C. 1976. *Male and Female Graduate Students: The Question of Equal Opportunity*. Praeger, New York.

Vetter, B. M. 1981. Women scientists and engineers: Trends in participation. *Science* 214, 1313–1321.

Vetter, B. M. 1987. Women's progress. *Mosaic* 18, 2–9.

Weis, L. 1985. Progress but no parity: Women in higher education. *Academe* 71, Nov.–Dec. 29–33.

Zuckerman, H. 1987. Persistence and change in the careers of men and women scientists and engineers: A review of current research. In *Women: Their Underrepresentation and Career Differentials in Science and Engineering* (ed. L. S. Dix). National Academy Press, Washington, D. C.

Sophie Germain

"...Sophie Germain, who has been called one of the founders of mathematical physics, was born in Paris on April 1, 1776, the daughter of Ambroise François and Marie Germain. She grew up during the impassioned social, economic, and political conflicts of late-eighteenth-century France.

"In 1789, Sophie was thirteen years old when the Bastille fell, turning Paris into a bedlam. The streets were filled with discontented Parisians demonstrating their revolutionary sentiments, foraging for food, and reveling in the general anarchy...

"Sophie's family was relatively wealthy and could shield her from the revolutionary violence of the streets, but the cost of this protection meant long hours of solitude for the young girl. These hours were spent in her father's ample library, and it was here that she came across the legend of Archimedes' death as recorded by J. E. Montucia's *History of Mathematics*.

"It was easy for a lonely young girl to romanticize the fate of Archimedes, killed while absorbed in a geometry problem by a ruthless Carthaginian soldier. She reasoned that if geometry was so very engaging, it must hold wonders worth exploring, and starved as she was for mental stimulation, she was eager to investigate these new wonders...

"The study of mathematics became a passion for her, one that no amount of familial pressure could smother. Alone and untutored, she went through every book her father's library afforded on the subject.

"Her parents, concerned for her health and threatened by the customary wild stories of young girls who were too studious, took desperate measures: They denied her light and heat for her bedroom and confiscated her clothing after she retired at night in order to force her to sleep. Sophie played through this authoritarian charade docilely, but after her parents were in bed, she would wrap herself in quilts, take out a store of hidden candles, and work at her books all night.

"After finding her asleep at her desk in the morning, the ink frozen in the ink horn and her slate covered with calculations, her parents finally had the wisdom and grace to relent, freeing Sophie to study and use her genius as she wished. It was a fortunate decision, and Sophie, still without a tutor, spent the years of the Reign of Terror studying differential calculus."

—from *Women in Mathematics*, by Lynn M. Osen. MIT Press, 1974.

Top Producers of Women Mathematics Doctorates

Allyn Jackson

Allyn Jackson is the staff writer for the AMS.

Recently, *Science* magazine reported on two surveys among astronomers that pointed to the "chilly environment" women have found in that discipline (*Science*, 21 June 1991, pages 1604-1606). In June, surgery professor Frances Conley resigned from her position at Stanford University, which she had held for 25 years, to protest the appointment to chair of a colleague who she says harrassed her for years with demeaning remarks and attitudes (*New York Times*, 12 June 1991). Mathematician Jenny Harrison has brought a suit against the University of California at Berkeley, in which she claims that she was denied tenure while men with equal or lesser qualifications were granted tenure (*Science*, 28 June 1991, pages 1781-1783). A recent *New York Times* article looked into the reasons why, despite their increasing numbers in science and mathematics, women rarely reach the top of their fields (*New York Times*, 21 May 1991).

These national news stories point up the still uneasy nature of women's involvement in science and mathematics research. Why aren't there more women in mathematics? Despite the feminist movement, the percentage that women make up of the new crop of Ph.D.s in mathematics each year has hovered around the 20% mark for around ten years. Some claim that there are biological reasons why men tend to outperform women in mathematics, but that debate—which typically centers on data from the precollege level and may have little bearing on talent for mathematical research—is far from being settled. What does seem clear, however, is that women find the social environment of mathematics and science to be something less than welcoming. The common wisdom is that women drop out of graduate school in mathematics in greater proportions than do men. Therefore, graduate school is a good place to look for ways to keep more women in mathematics.

An examination of data from the Annual AMS-MAA Surveys over the last ten years provides some thought-provoking information. These data are supplied to the AMS by mathematical sciences departments in the U.S. and Canada. Finding the appropriate data to answer the question "Which schools produce the most women doctorates in mathematics?" is not a simple matter. Table 1 (see next page) shows the top sixteen departments in terms of the total number of women doctorates. Table 2 (see next page) shows a ranking according to percentage. Care is needed in the interpretation of both tables. For example, in Table 1, MIT and Berkeley top the list primarily because those two departments were overall the largest producers of doctorates in that ten-year period; but in terms of percentage of women doctorates in that period, those two departments fall below the 17% average for all departments of mathematics with doctoral programs. However, looking at straight percentages is also problematic: the small numbers of doctorates at some of the departments mean that the percentages are unstable. (There are other problems as well; for example, Illinois State, the school with the highest percentage of women doctorates over the past ten years, awards only the doctorate of arts degree in mathematics, which does not require a mathematics research thesis.)

To try to balance the percentages with the total number of doctorates produced, schools having more than ten doctorates between 1980-1981 and 1989-1990 were divided into sets according to the size of their doctoral programs (where size is the total number of Ph.D.s produced over the last ten years). For each set of schools, Table 3 (see page 718) lists the three with the highest percentages of women over the last ten years. Because the majority of mathematics doctorates come from Group I departments, Table 5 (see page 720) lists comparable data for all departments in Group I (the definition of groups used in the survey are described in the accompanying box). Table 4 (see page 718) shows the average percentage of women doctorates from Groups I, II, and III. A higher concentration of women is found in Group II and III departments than in Group I.

Looking at fall 1990 graduate school enrollments, one also finds a lower concentration of women in Group I departments: 23% of the first-year students are women, compared to 34% and 37%, respectively, for Groups II and III. (Among all students, not just first-year students, the analogous figures are 21%, 29%, and 33%.) A similar pattern can be found in the composition of mathematics faculties. The latest AMS-MAA Survey Report (*Notices*, May/June 1991) shows that women make up 6.0% of those Group I faculty members holding a Ph.D., 6.5% in Group

The data in the tables below were reported by departments responding to Annual AMS-MAA Surveys of New Doctorates from 1981 to 1990. In a few cases of nonresponses, attempts were made to contact departments for missing data. Names and thesis titles of new doctorates are published annually in the November issue of *Notices of the AMS*. For Annual AMS-MAA Survey reports, departments are divided into groups according to the highest degree offered in the mathematical sciences. Groups referred to in the following tables:

Groups I and II include the leading departments of mathematics in the U.S. according to the 1982 assessment of Research-Doctorate Programs conducted by the Conference Board of Associated Research Councils in which departments were rated according to the quality of their graduate faculty.[1]

Group I is composed of 39 departments with scores in the 3.0–5.0 range

Group II is composed of 43 departments with scores in the 2.0–2.9 range.

Group III contains the remaining U.S. departments of mathematics reporting a doctoral program.

[1]These findings were published in *An Assessment of Research–Doctorate Programs in the United States: Mathematical and Physical Sciences*, edited by Lyle V. Jones, Gardner Lindzey, and Porter E. Coggeshall, National Academy Press, Washington, D.C., 1982. The information on mathematics, statistics and computer science was presented in digest form in the April 1983 issue of *Notices*, pages 257-267, and an analysis of the above classifications was given in the June 1983 *Notices*, pages 392-393. For a listing of departments in Groups I and II see the April 1988 *Notices*, pages 532-533.

TABLE 1. Leading U.S. doctorate-granting departments of mathematics by number of women doctorates, from academic year 1980-1981 to 1989-1990

	Total Women Doctorates	Total Doctorates	% Women
Massachusetts Institute of Technology	32	209	15.3
California, University of (Berkeley)	30	295	10.2
Maryland, University of	26	120	21.7
NYU-Courant Institute	19	155	12.3
Rutgers University, New Brunswick	17	77	22.1
Wisconsin, University of	16	152	10.5
California, University of (Los Angeles)	15	108	13.9
Illinois, University of (Urbana-Champaign)	15	105	14.3
Massachusetts, University of (Amherst)	15	44	34.1
Michigan, University of	14	115	12.2
Notre Dame, University of	14	53	26.4
Texas, University of (Austin)	14	60	23.3
California, University of (San Diego)	13	79	16.5
Carnegie Mellon University	13	46	28.3
Pennsylvania State University	13	64	20.3
Pittsburgh, University of	13	57	22.8

TABLE 2. Leading U.S. doctorate-granting departments of mathematics* by percentage of women doctorates, from academic year 1980-1981 to 1989-1990

	% Women	Total Doctorates	Total Women
Illinois State University	54.5	11	6
Oklahoma, University of	41.7	12	5
Memphis State University	38.9	18	7
Adelphi University	38.5	13	5
Missouri, University of (Rolla)	38.5	13	5
American University	36.0	25	9
Florida State University	35.3	17	6
Auburn University	34.8	23	8
Massachusetts, University of (Amherst)	34.1	44	15
Lehigh University	33.3	21	7
South Carolina, University of	29.2	24	7
Dartmouth College	28.6	21	6
Carnegie Mellon University	28.3	46	13
Kansas State University	27.3	22	6
Texas, University of (Arlington)	27.3	33	9

* Departments granting at least ten doctorates during the ten-year period.

II, and 8.8% in Group III. In fact, the highest concentration of women in mathematics faculties is found among master's and bachelor's degree-granting departments, where women make up 14% and 17%, respectively, of the faculty holding doctoral degrees. The analogous figure for Group I, II, and III combined departments is only 7%. (It is interesting to note, too, that the highest percentages of women among mathematics faculties occurs among non tenure-eligible appointments.)

Notices queried faculty from a number of departments that, based on this data, were among the higher producers of women doctorates in mathematics, and asked about the reasons for their success. Most faculty expressed surprise that their department was doing a good job, and many had no idea why. Most of the departments had no organized programs for recruitment or retention of women students, and data on women students was not easily at hand. Some faculty seemed surprised that the issue was even raised; one chair remarked that this is not the kind of thing a mathematics department usually pays attention to. Despite the lack of clarity of the factors at play, two general themes emerge.

First, most of the departments reported efforts to create a good atmosphere for all students. For example, Bruce Palka, who has been the graduate advisor at the University of Texas at Austin for a number of years, points to the "warm, friendly" atmosphere of the department. A very high percentage of the students who come to visit the department end up choosing it for graduate school, he says. Faculty member Martha K. Smith reports that each semester she holds a reception for women graduate students and faculty. With forty-two women out of a total of 163 graduate students, Smith says there is a "critical mass" of women that tends to mitigate feelings of isolation. At the University of Maryland, faculty member Rebecca Herb reports that she has made efforts to bring the women graduate students and faculty together. There is a women's discussion group that meets monthly and a mentorship program that brings new women graduate students together with those who have been in the department a while.

The University of Massachusetts at Amherst has actively recruited students over the past ten years, many of them women. According to faculty member Tim Cook, who has been instrumental in the recruitment drive, the faculty personally contacted students showing interest in and potential for doctoral work. Although no special effort was made to attract female students, Cook believes that the personal touch made a difference. "We tried to make the department as comfortable and as friendly a place as possible," he declares. Prospective female students meet female faculty members, and in the department there is a great deal of personal attention paid to the students. In addition, the department tries to insure that its rules are flexible enough to facilitate the students' chances at success. In a number of instances, for example, the department made allowances for coursetaking schedules and teaching loads for women students who had families or who had long commutes.

Andy Magid, chair of the mathematics department at the University of Oklahoma, also points to a "warm, welcoming department" as a key factor in retaining women students. "In a relatively small, relatively young program like ours, doctoral students are like junior colleagues, and we try to lead each one to completing the degree," he says. "If we've had unusual success with women students, I'd say it's because we've been pretty good about eliminating barriers for all students." The department makes no special recruitment efforts to bring women into the Ph.D. program, but such national programs as the Department of Education's Patricia Roberts Harris Fellowships have supported women students in his department.

The second important factor seems to be having women on the faculty. The departments having a high percentage of women doctorates pointed to the visibility of women on the faculty as having a positive effect on the women students. For example, Rutgers University is an institution known for having an unusually large number of productive women researchers on the faculty. According to Rutgers faculty member Amy Cohen, these women "provide an existence proof and a happier climate" for the women students. A graduate student association, a prelim-exam preparation seminar, and a T.A.-training program help to bring students together and create a community atmosphere. In addition, Cohen says that, in part because of Douglas College, a women's college on the Rutgers campus, there is generally a high degree of awareness of encouraging the aspirations of women students.

Mary W. Gray of American University attributes the large percentage of women doctorates from her department to having nearly one-quarter women on the faculty. "Seeing women who are succesful, and our efforts to be supportive, make a difference," she says. She also notes that they get many of their women students through "word of mouth"—faculty at other institutions know that American has women on the faculty and is successful at producing women Ph.D.s. And finally, Gray reports, "We don't lose women." She says that most of the women who come with the intention of getting a Ph.D. make it through the program and do not drop out at the master's degree level.

(Sometimes perceptions about the effect of women on the faculty are mixed: In one department with a faculty of about fifty, a male professor said that a major factor in their success at producing female doctorates was having three tenured women on the faculty, while a female professor said the number of women probably was not a major factor, because there were only three.)

It can sometimes be difficult to find a direct connection between having tenured women on the faculty and producing women doctorates. According to information provided by departments for the latest AMS-MAA Survey, for example, Carnegie Mellon University has no tenured women faculty, but, among Group I departments, that institution produced the highest percentage of women doctorates over the past ten years (see Table 5). Similarly, the largest overall producer of women doctorates, MIT, has no tenured women faculty.

TABLE 3. Percentage of women among doctoral programs of comparable size

For this table, departments of mathematics were divided into categories of comparably-sized doctoral programs, where size is defined to be the number of doctorates awarded by the department between 1980-1981 and 1989-1990. The size categories are given in the leftmost column. For each size category, the table lists the three departments having the highest percentage of women doctorates in that ten-year period. The rightmost column gives additional information about the departments in each size category.

Size of Department	Top three departments by % women doctorates	% women doctorates	Average % women doctorates for departments in this group
Depts granting 100 doctorates and above	Maryland, University of	21.7	13.3% for 8 departments
	Massachusetts Institute of Technology	15.3	(167 women out of a total
	Illinois, University of (Urbana-Champaign)	15.0	1259 doctorates)
Depts granting 80-99 doctorates	Ohio State University	12.6	10.5% for 5 departments
	Chicago, University of	12.5	(46 women out of a total
	Princeton University	9.8	436 doctorates)
Depts granting 60-79 doctorates	Texas, University of (Austin)	23.3	17.4% for 8 departments
	Rutgers University, New Brunswick	21.1	(96 women out of a total
	Pennsylvania State University	20.3	551 doctorates)
Depts granting 40-59 doctorates	Massachusetts, University of (Amherst)	34.1	17.2% for 21 departments
	Carnegie Mellon University	28.3	(175 women out of a total
	Notre Dame, University of	26.4	1019 doctorates)
Depts granting 20-39 doctorates	American University	36.0	20.3% for 50 departments
	Auburn University	34.8	(278 women out of a total
	Lehigh University	33.4	1367 doctorates)
Depts granting 10-19 doctorates	Illinois State University	54.5	19.0% for 41 departments
	Oklahoma, University of	41.7	(109 women out of a total
	Drexel University	40.0	573 doctorates)

TABLE 4. Percentage of women doctorates granted by U.S. departments of mathematics (Groups I, II and III) 1980-1981 to 1989-1990

Group I	14.6%	(435 women/2972 total doctorates)
Group II	18.4%	(230 women/1248 total doctorates)
Group III	20.7%	(229 women/1107 total doctorates)

Indeed, the Group I departments having no tenured women faculty produced 30% of the the women doctorates coming from Group I departments. Nonetheless, it is sobering to note that, among those Group I departments that produced less than 10% women doctorates over the last ten years, the number of women on their faculties is just four out of a total of 197, or 2%. Among faculty in all Group I departments, 5% are women. (For all of the previous statements concerning faculty, it must be noted that the figures leave out four Group I departments that did not respond to the 1990 Departmental Profile Survey.)

Some institutions whose departments of mathematics produced low percentages of women doctorates in mathematics show up high on the list for applied mathematics and statistics departments. For example, Harvard University, which had one of the lowest percentages of women mathematics doctorates among Group I departments, produced the largest percentage, 17%, of women in applied mathematics over the past ten years. Similarly, Rice University, which also had a low percentage of women in mathematics, produced 24% in applied mathematics. Some have speculated that women tend to prefer applied mathematics over pure because of the wider range of employment opportunities available. (Because of inconsistent reporting from applied mathematics departments, the data for applied mathematics are incomplete, and it is difficult to draw many conclusions.)

In the Annual Survey data on doctorates in probability and statistics, women have a high representation. Since 1985-1986, the percentage of women among those receiving doctorates in the fields of probability and statistics varied from 29% to 38%. As with applied mathematics, some of the schools having low percentages of women mathematics doctorates showed higher numbers in statistics and probability. Data supplied by doctorate-granting departments of statistics are incomplete because of nonresponding departments; however, it appears that the top producers of women doctorates in statistics, biostatistics, and biometrics departments are University of North Carolina at Chapel Hill, Cornell University, Harvard University, University of California at Berkeley, University of Michigan, University of Washington, Iowa State University, Ohio State University, University of California at Los Angeles, and University of Wisconsin. In addition, women make up 13% of faculty members holding the Ph.D. in statistics, biostatistics, and biometrics doctorate-granting departments, a much higher figure than the 7% for Groups I-III combined.

It is difficult to discern from statistics alone why certain departments have been more successful than others at producing women mathematics doctorates. Many of the factors at play are complex, involving the "climate" in the department and social interactions that can elude quantitative analysis. A study of a number of exemplary departments—including interviews with faculty, students, and administrators—could bring successful ideas and new thinking to other departments that are trying to improve the climate for their women students. Such improvements would, in the end, benefit all students.

A Hot Topic: Math and Sex

"A few years ago, a friend phoned me for some advice. His ten-year-old daughter was upset because she had just heard on the radio about the hot new discovery that boys are genetically better at math than are girls. Girls, she had heard, would be less frustrated if they recognized their limits and stopped their fruitless struggle to exceed them.

" 'Daddy,' she had said, 'I always wanted to be a math professor like you. Does this mean I can't?'

"My friend wanted to know if I had read the article. 'Is it true? What can I tell my daughter?'

"Just two days before, I had seen the same report in the *New York Times*. One day before, the mail carrier had dropped through my mail slot the issue of *Science* magazine containing the short research article by Drs. Camilla Benbow and Julian Stanley, which I had seen summarized in the *Times*. Within the week, radio advertisers hawked the latest issues of *Time* and *Newsweek*, telling me even as I sleepily brushed my teeth in the morning to buy the magazines because they contained new evidence about 'male math genes.' And so it went. The *Time* article even had an illustration in case we couldn't get the written message. The cartoon portrayed a girl and a boy standing in front of a blackboard, with a proud, smug-looking adult—presumably a teacher—looking on. The girl frowns in puzzlement as she looks directly out at the reader. On the blackboard in front of her stands the multiplication problem 8 x 7, which she is clearly unable to solve. The boy looks with a toothy smile toward the adult, who gazes back at him. The cause for the satisfaction? The correct answer to the multiplication problem 7,683 x 632. Interpreting the image does not require a degree in art history, and the aftershocks from the *Science* article and subsequent press coverage still rumble beneath our feet.

"Clearly, math and sex is a hot topic."

—from *Myths of Gender: Biological Theories about Women and Men*, by Anne Fausto-Sterling. Basic Books, 1985

TABLE 5. Group I departments of mathematics: women doctorates from 1980-1981 to 1989-1990

Department	% Women Doctorates	Number of Women Doctorates	Total Number of Doctorates
Brandeis University	20.0	8	40
Brown University	14.6	7	48
California Institute of Technology	9.4	3	32
California, University of (Berkeley)	10.2	30	295
California, University of (Los Angeles)	13.9	15	108
California, University of (San Diego)	16.5	13	79
Carnegie Mellon University	28.3	13	46
Chicago, University of	12.5	11	88
Columbia University	12.1	7	58
Cornell University	21.0	12	57
CUNY Graduate School	24.1	7	29
Harvard University	8.0	7	87
Illinois, University of (Chicago)	18.5	10	54
Illinois, University of (Urbana-Champaign)	14.3	15	105
Indiana University at Bloomington	16.9	10	59
Johns Hopkins University	22.2	6	27
Maryland, University of	21.7	26	120
Massachusetts Institute of Technology	15.3	32	209
Michigan, University of	12.2	14	115
Minnesota, University of	9.8	8	82
New York University-Courant Institute	12.3	19	155
North Carolina, University of (Chapel Hill)	25.0	6	24
Northwestern University	15.5	7	45
Ohio State University	12.6	11	87
Pennsylvania State University	20.3	13	64
Pennsylvania, University of	22.6	7	31
Princeton University	9.8	9	92
Purdue University	11.8	9	76
Rice University	14.3	2	14
Rutgers University (New Brunswick)	22.1	17	77
Stanford University	13.6	8	59
SUNY at Stony Brook	18.7	12	64
Texas, University of (Austin)	23.3	14	60
Utah, University of	13.3	6	45
Virginia, University of	20.7	6	29
Washington University	14.6	6	41
Washington, University of	8.8	5	57
Wisconsin, University of (Madison)	10.5	16	152
Yale University	12.9	8	62

Mathematics and Women: The Undergraduate School and Pipeline

WOMEN IN MATHEMATICS

D. J. Lewis

D. J. Lewis is chair of the department of mathematics at the University of Michigan.

About two years ago, partly in response to urging from Uri Treisman of the University of California at Berkeley, our department decided to get involved in a summer program for undergraduate women. We were motivated to do so because of our concern for the small number of Americans earning doctorates in mathematics. While the number of Bachelors degrees in mathematics awarded by U.S. institutions plummeted from nearly 25,000 per year in the 1970s to 10,078 in 1980-1981, they had slowly risen and stabilized near the 16,000 mark in the late 1980s, with women approaching nearly half that number (about 7,500). On the other hand, the number of women earning doctorates at U.S. institutions seemed stuck near 125. (In the last two years, there have been 156 and 158 doctorates awarded to women, still less than 20% of the total—861 and 892, respectively. The percentage of women among U.S. citizens earning the doctorate is above the 20% mark and is climbing as the number of men doing so continues to decline). Clearly, a likely place to recruit additional doctorates who were U.S. citizens was from amongst women.

That men and women were completing the bachelor's degree in near equal numbers was striking to us, since considerably fewer women than men arrive at college with four years of secondary mathematics, far fewer take advance placement exams (though convergence in numbers may be possible in the near future), and a far larger percentage discontinue the study of mathematics after a year (this is partially explained by the fact that large numbers of women interested in science enter college planning to study biology or medicine, which have low mathematics requirements). We recognized the near parity in numbers stemmed in part from the failure of men to return to mathematics as quickly as women. Still, however you cut the cake, among the women there was a sizable pool of individuals who were persisting to a Bachelor's degree and, under the right circumstances, might go on to the doctorate.

We were also motivated by the fact that, during the 1980s, only five Michigan alumnae received the Ph.D., while in the sixties we regularly sent that many women to graduate school each year. (Other universities had not done much better, only four reached double that number: Berkeley with 14, MIT and Chicago with 12, and Texas with 11.) An added inducement was the discovery that mathematics and physics doctorates are quite likely to have done their undergraduate studies at a research university (40% of the mathematics, 49% of the physics doctorates in the 1980s did so; the figures for women are 32% and 41%). The doctorates in other scientific fields, the humanities, and the social sciences came from a more dispersed set of undergraduate institutions. Clearly we had a responsibility and a challenge.

We realized the social context within which mathematics is now studied and done is quite different from that of the 1960s. In those days, morale was high. Science and mathematics were universally held in high esteem and were well supported. Classes were small and faculty could know their students and their capabilities. Men and women arrived equally prepared, with enthusiasm and willingness to work, and all, as they report, were treated as equals. Today, women find it much easier to gain admission to the old line professional schools of law, medicine, and business and have reached parity with men in enrollments in these schools. We compete with these professions for the same women. One could explain the drop in interest in mathematics at Michigan by our having students well tuned to societal norms. Still, it was a puzzle why a generation of women, raised and steered in the feminist movement, should have withdrawn from mathematics, as seemed the case at Michigan. We hoped we might change the situation.

When we sought funding, we met a cool reception from the agencies. Some funding agencies questioned if there was a need. Some wondered whether interventions and special programs were based on anything but hope and whether there was any evidence they had accomplished their stated goal. The discussions ended with a challenge by Sam Goldberg of the Sloan Foundation to survey the literature concerning undergraduate women in mathematics and physics to see if there were well based principles upon which to base a program for women. With the help of Professor Patricia Gurin of the psychology department, Pat Shure of mathematics, and Carol Hollenshead, director of the Center for the Education of Women, as well as several part-time postdoctorates from psychology, we set to work.

We found that most of the research on women in science and mathematics concerned elementary and secondary students; there is a paucity at the collegiate level. What there is concerning the collegiate level is some what marginal—often one-time snapshots of a local group of student's perceptions or anecdotal reports. Little can be said to be scientific. Except for a few National Science Foundation (NSF) statistical reports, there are no large scale or national studies, and there have been no longitudinal studies. There may well have been critical evaluations of some intervention programs, but they are not reported in the literature. Still, after surveying the literature, one arrives at a number of factors effecting undergraduate student behavior and decisions regarding mathematics and which probably impact more on women than on men. They suggest a number of hypotheses and actions which merit serious testing and which could suggest some modifications in the way mathematicians teach. In addition, we conducted three studies on Michigan students that tended to point to the same factors.

Self-confidence regarding mathematics appears to be the most distinguishing characteristic separating collegiate men and women. There are clear indications that at every level, from middle school to the doctorate, women generally are less confident in their mathematical abilities than men. Successful women report receiving encouragement and assurance of their abilities at several critical junctions from parents and instructors. Women peers rate women mathematicians as far more self-confident, self-reliant, persistent, risk-taking, and imaginative than other women. Yet, despite excellent performances, for many successful women in mathematics, there is always a doubt that they are as good as they are. Perhaps some of this self-doubt arises because the general public has come to view mathematics as masculine and early on women perceive themselves as being outsiders to the mathematical world. If we are to increase the number of women doctorates we will need to find methods to give them honest feedback and reassurance throughout the collegiate experience.

Surprising to me is the evidence that present day women studying mathematics are extremely job oriented and a large proportion at both the bachelor's and master's level chose programs that lead directly to employment, which they then take rather than pursue further education. In this regard, they respond as first generation college graduates, although women earning mathematics degrees are generally children of college graduates having professional mothers. This is a curious finding that surely merits study. Does it spring from lack of confidence? From counselling? From not being expected or encouraged to take the more challenging courses? We found that Michigan women thought the degree requirements too easy!

While it is difficult to obtain hard data, there is strong evidence that women constitute only about 30% of those pursuing a curriculum that leads directly to a doctoral program. Thus, the fact that women constitute about 25% of U.S. citizens earning a mathematics doctorate would indicate we are not losing many well qualified women at the doctoral level and that to increase the number of women doctorates requires getting them into appropriate undergraduate programs.

Women respond more negatively than men to what they perceive to be poor instruction. There is some evidence that quality of instruction is the principle factor in the decision of so many to discontinue the study of mathematics. As already noted, women need feedback on their accomplishments and not just at the end of term. They have a greater need to be recognized as individuals. Further, there is some evidence that women respond negatively to mathematics because of a perception it is a bag of rules and tricks to be applied quickly and mechanically—qualities that may often characterize calculus instruction and examination. Women appear to prefer discussive, discovery modes of learning and to dislike the advocacy style of many mathematics lectures. As a rule, women decide their area of concentration much later than men: in mathematics, at the end of the second year or into the third. Their experience in the first two years directly effects their choice. When you examine what is being conveyed by these statements, probably the only way to provide ideal instruction for women (and men also) is via small classes where the instructor has considerable freedom and the size permits regular feedback and interaction between student and professor. Such was the case in the 1960s, and, if we could do so again, undoubtedly the number of women completing the doctorate would climb. Would it change the percentages? Probably not—I expect in that situation men would also respond positively and enthusiastically. We surely need to conduct some scientific studies to determine how to attract and retain the mathematically gifted. Perhaps with good documentation we could persuade deans and government agencies that investing in mathematics instruction would and probably is the only way to meet the nation's mathematical needs.

Two phrases that appeared frequently in the literature coupled with negative responses to mathematics by women were "competitiveness" and "chilly environment." These phrases were rather ill-defined and usually were left to questionnaire respondents to define in their own way. In some instances "competitiveness" was equated with "personal comparison," at other times as the antithesis to cooperative group learning and study, and still other times with stress associated with the first year or two of study. Whatever it is, the literature suggests that women find mathematics classes and programs infused with competitiveness and find it distasteful. No doubt we need to determine more clearly what is being disliked and whether we can eliminate it and still achieve our objectives. Concern about the competitive environment also shows up in studies of the first year of graduate school. It is not clear that women find the first years of graduate study anymore stressful than their male peers or their peers in law, medical, and business administration schools, where women enrollments are now on a par with that of men. Probably as much of the stress comes from the need to adjust to a new locale, give up old friends and make new ones, and to impress a new set of faculty, as comes from the move to another, tougher level of learning.

The term "chilly environment" seems to sum up the totality of micro-inequalities women experience. These are situations or experiences that are subtle, hard to measure, and often based on perceptions. Though each in itself may be minor, they can in totality create an unfriendly environment. There has been no significant study of the "chilly environment," but many women assert its existence within mathematics. Perhaps with today's heightened social awareness, individuals are more apt to respond openly to unintended slights than in the past. The phrase "chilly environment" appears sufficiently often that it warrants systematic study. If it is turning off students, we had better investigate it and develop strategies to create "warm environments."

The learning environment affects all students, but women still in the process of deciding what to study and for what duration are more effected by the environment in which they will work. The literature indicates women seek good student-faculty interactions, a peer support system, and a sense of community. Faculty undoubtedly need to examine both the social and the physical environment within their departments and seek ways to provide an environment that attracts, supports, and encourages students.

In recent years, considerable emphasis has been put on the role of research internships in helping students form career commitments. The assessments of the Research Experiences for Undergraduates (REU) program of the NSF, as well as smaller internship programs, suggest that some research experience can be a key factor in encouraging uncertain students to seek a research career. The NSF study indicated 80% of those in REU programs found the experience heightened their interest in research. At Michigan, for each of the last several years we have had twenty plus undergraduates participate in the REU program. In addition, about the same number took summer internships in industry. Almost all of the REU alumni enrolled in graduate school, and there is an excitement that carries through the following academic year. At least five publications by students have been submitted. Many women approach internships differently than men. They use them to test whether research is for them. It is especially gratifying to see their growth in confidence and in mathematical maturity in the course of a summer internship. By summers end, most know they can do research and that it is challenging and fun. We do not know all the dynamics occurring during the course of the internship. Some women observers have suggested that confidence and self-assurance stems from the support and individual intimacy that occurs in working together.

Thirty years ago, I did not believe undergraduates could assist in a research project. The computer has changed this forever. I have come to the conclusion that in the future the best academic mathematical research will be done by teams consisting of senior faculty, postdoctorates, graduate students and undergraduates working together on a related set of problems. The undergraduates can be very useful to the others in testing hypotheses, seeking patterns, crunching numbers. The postdoctorates can and should play a significant role, in a supportive way, in the education of the graduates and undergraduates. Such groupings flourish in the other sciences, and we will need to learn from them. If we solve the problem of making the first two years of college mathematics attractive, I believe that this group approach, when perfected, will remove the remaining obstacles that now seem to lie in the road to women's success in mathematics and to our attracting the American student to this most beautiful and challenging subject.

"Scientific" Mythmaking

"Nineteenth century biologists and physicians claimed that women's brains were smaller than men's and that women's ovaries and uteruses required much energy and rest in order to function properly. They 'proved' that therefore young girls must be kept away from schools and colleges once they begin to menstruate and warned that without this kind of care women's uteruses and ovaries will shrivel and the human race die out ... [T]his analysis was not carried over to poor women, who were not only required to work hard, but often were said to reproduce *too* much. Indeed, scientists interpreted the fact that poor women could work hard and yet bear many children as a sign that they were more animal-like and less highly evolved than upper class women...

"But this kind of scientific mythmaking is not past history ... [B]eginning in the 1970s, there has been a renaissance in sex differences research that has claimed to prove scientifically that women are innately better than men at home care and mothering while men are innately better fitted than women for the competitive life of the market place.

"Questionable experimental results obtained with animals (primarily that prototypic human, the white laboratory rat) are treated as though they can be applied equally well to people. On this basis, some scientists are now claiming that the secretion of different amounts of so-called male hormones (androgens) by male and female fetuses produces life-long differences in women's and men's brains. They claim not only that these (unproved) differences in fetal hormone levels exist, but imply (without evidence) that they predispose women and men *as groups* to exhibit innate differences in our abilities to localize objects in space, in our verbal and mathematical aptitudes, in aggressiveness and competitiveness, nurturing ability, and so on..."

—from "Science, Facts, and Feminism," by Ruth Hubbard. *Feminism and Science.* Nancy Tuana, Editor, Indiana University Press, 1989.

WOMEN IN MATHEMATICS

Merging and Emerging Lives: Women in Mathematics

Claudia Henrion

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In the nineteenth century, there was a common belief that "as the brain develops the ovaries shrivel," implying that women's participation in the life of the mind would impair their ability as mothers [1]. This was part of a long tradition of identifying intellectual pursuits, particularly math and science, with men, and domestic responsibilities with women. Inevitably, these two spheres were hierarchically ordered: the life of the mind was considered far more important than life of the home.

As Plato said in the *Symposium*, "Those whose creative instinct is physical have recourse to women, and show their love in this way, believing that by begetting children they can secure for themselves an immortal and blessed memory hereafter for ever; but there are some whose creative desire is of the soul, and who long to beget spiritually, not physically, the progeny [of?] which it is the nature of the soul to create and bring to birth" [2]. The dichotomy is clear: one pursues a life of the mind, or one has a family, but one cannot do both. The hierarchy is equally clear: "everyone would prefer children such as these [from the soul] to children after the flesh" [3]. Plato does not consider the possibility of a woman leading a life of the mind. Kant continued in this tradition, defining math as the realm of men, saying that "women should not worry their pretty heads about geometry—that they might as well have beards" [4].

The image that "as the brain develops the ovaries shrivel" was one that feminists had to combat in establishing formal education for women at the college level in nineteenth century America. They argued that women's access to higher education would make them better mothers for their sons, the future leaders of the country [5]. Although this strategy was successful in opening the doors to a life of the mind, it did not question the deep-seated dichotomy between the intellectual sphere and the domestic sphere. Indeed, those women who worked in American women's colleges in the 19th and early twentieth centuries were forced to choose between a professional life (as teachers) and a personal life (if they chose to marry), for the two were not compatible. As Rossiter reminds us: "It went without saying that according to the mores of the time, all candidates [for professorship] had to be of good Christian character and not only single but in no danger of marrying. Married women were not even considered for employment at the early women's colleges, even, it seems, when they were clearly the best candidate available ... Male faculty at the women's colleges, on the other hand, were expected to be married" [6].

Those seem like ancient times, and we breathe a sigh of relief that things are different now. Women have access to all kinds of formal education, they are able to secure good jobs even in such traditionally male fields as math and science, and they can choose to marry without sacrificing their jobs. Not only do women have access to formal institutions, but their numbers at these places are beginning to represent their proportion in the population. For example, nearly 50% of the math majors in this country are now women [7] (though this trend is sometimes hidden because many of the students who take lower level math courses are from engineering, physics, and computer science, fields that are still predominantly male).

But in the upper ranks, the percentage of women in mathematics declines dramatically. Women make up only 20% of those receiving doctorates [8], and less than 6% of tenured professors in mathematics [9]. Do these declining percentages simply reflect problems of the past? Is it just a matter of time before women come through the ranks and assume equal representation in the mathematics community? Or do these data indicate persistent problems that create unnecessary obstacles to women's full participation in mathematics—subtle barriers that make it less likely that women will pursue mathematics in graduate school and beyond?

These less visible barriers are what I am interested in examining, to see why many women who have "succeeded" in mathematics often do not feel like equal and central participants in the mathematics community. What contributes to this sense of being an "outsider," experienced by many contemporary women in mathematics? To what extent is there still a tension between their lives as mathematicians and their lives as women? [10]

The very concept of a woman mathematician begins to break down the sharp dichotomy between the professional/public/intellectual sphere and the private/personal/domestic sphere—a dichotomy that was solidified in the 19th century, and that still influences much of our society today. As women "cross-over" into the world of the mind, and science in particular, tensions arise, both internal tensions that women experience as they try to balance their personal and professional lives, and external tensions as the mathematics community continually shifts and adjusts to a new population of inhabitants.

One response to these tensions for women in mathematics is to say that women must learn to adjust to this new environment, that conflicts arise because they have not entirely broken ties with their traditional responsibilities. Once they learn to do so, their lives as mathematicians will be easier. But this response assumes that it is possible and desirable to create and maintain a split between personal and professional life. I will argue that such a separation is increasingly unrealistic for both men and women. An alternative response to these tensions is to try to break down the barriers between the two spheres, acknowledging the interconnection and inseparability of personal and professional life.

This article draws on my research on contemporary women mathematicians involving intensive interviews with ten prominent women in mathematics. Their lives help make visible what has previously been invisible: the traditional reliance on a support structure that allows us to maintain the myth that it is possible to separate our personal and professional worlds. At the same time, their lives suggest ways of striking a balance between the two.

I approach this subject with caution for two reasons. First, the only thing that can be said with certainty about all women in math is that they are all different. Any attempt to generalize leaves out specific women and specific details. Nonetheless, there are themes that emerge often enough in interviews with women mathematicians that they warrant attention.

The second reason for caution is that, in any discussion of the difficulties for women in mathematics, there is a temptation to conclude that women should not go into mathematics—either because math is not a hospitable place for women (so they would inevitably be miserable), or because women are not cut out for mathematics. I reject both of these overly simplistic conclusions. The problems discussed in this article are not inherent in mathematics or in women. They are problems that can be remedied, and to do so would benefit the entire mathematics community. The first step towards change is to articulate the problems and make them visible.

Stereotypes of Women, Stereotypes of Mathematicians

The subtle tensions between being a woman and being a mathematician arise in part from the images that, from childhood onward, are all around us. We are all influenced to varying degrees by images, stereotypes, and messages of our society. The degree to which we internalize these messages depends on many factors: family, friends, educational experience, interests, community, age, and life experience. But, to a certain degree we are what we read and we are what we see.

Media images of women traditionally fall into three categories: wife/mother, sex object, and girl. In the last fifteen years, the "career woman" image has emerged, but even this image makes some concessions to the traditional roles of women as wife/mother or sex object. Carolyn Heilbrun, in *Writing A Woman's Life*, conveys the power of what she calls the "romantic/marriage plot" that most women are raised with, whether or not they choose to pursue it. These images continue to influence both women and men even when they are trying to define new paths. As women's roles expand to new arenas like business or science, they are still expected to also fulfill their domestic responsibilities, giving rise to the modern "super-mom" syndrome.

What do these images have to do with mathematics? Absolutely nothing—and that is the problem. None of the images of women are compatible with images of a mathematician. First and foremost, mathematicians are portrayed as completely unconcerned with anything on the material plane. We are often reminded of mathematicians who would become so absorbed in their work that they would forget to eat for days. They certainly think nothing about their clothes or physical appearance, and while they might have family, it is seen as peripheral to the focus of their lives. Certainly one's image of a mathematician does not include changing diapers or comforting a colicky baby, much less cleaning house or making dinner. Their life follows what Heilbrun describes as the "adventure or quest plot," as contrasted with the marriage plot.

But what do mass media images and stereotypes have to do with reality? Though we may be tempted to once again respond "absolutely nothing," these images affect—and reflect—our lives more than we care to admit. Most women have not extricated themselves from domestic responsibilities. And many mathematicians still praise those individuals who transcend the material world and lose themselves in their work, dividing personal and professional life in a way not feasible for most women. As Halmos says in his "automathography," to be a mathematician, you must love mathematics more than anything else, more than family, more than religion, more than any other interest [11].

> I do not mean that you must love it to the exclusion of family, religion, and the rest . . . A spouse unsympathetic to mathematics demands equal time, a guilty parental conscience causes you to play catch with your boy Saturday afternoon instead of beating your head against the brick wall of that elusive problem—family, and religion, and money, comfort, pleasure, glory, and other calls of life, deep or trivial, exist for all of us to varying degrees, and I am not saying that mathematicians always ignore all of them. I am not saying that the love of mathematics is more important than the love of other things. What I am saying is that to the extent

that one's loves can be ordered, the greatest love of a mathematician (the way I would like to use the term) is mathematics. I have known many mathematicians, great and small, and I feel sure that what I am saying is true about them.

This passage illustrates that men mathematicians do indeed have personal lives and responsibilities. At the same time, the message is clear: although family and other interests may be tolerated, they are secondary to one's mathematics. However, this ordering is only possible if there is someone else who can take care of the children while the mathematician does mathematics. It assumes a traditional family structure of a professional and his supportive wife. Since it is extremely rare that a woman mathematician can rely on a supportive spouse to assume the domestic duties, the kind of ordering that Halmos suggests may not be possible, or even desirable. For women, such a vision can lead to a decision of exclusion: family or mathematics, rather than a decision about priorities.

Even, however, when women mathematicians do observe the priorities of their profession, they are still judged by society's standards and evaluated in terms of stereotypically female attributes. In Weyl's memorial to Emmy Noether, for example, he remarks on her appearance that "the graces did not stand by her cradle." A common issue that arises in discussions of Sofia Kovalevskaia's life is her performance as a mother, and whether she neglected those responsibilities. How often do we read a memorial of a male mathematician that discusses whether he was attractive, or whether he spent enough time with his children? [12]

Navigating Personal and Professional Life

As mentioned earlier, for the nineteenth-century women with academic careers in science, the professional and domestic spheres were completely disjoint. Almost all academic jobs open to women were in the women's colleges, and it was assumed that a female professor was single. If she married, she had to quit her job. This was not challenged until 1906, when a physics professor at Barnard College refused to resign when she announced her engagement to be married. "I think it is a duty I owe to my profession and to my sex to show that a woman has a right to the practice of her profession and cannot be condemned to abandon it merely because she marries. I cannot conceive how women's colleges, inviting and encouraging women to enter professions, can be justly founded or maintained denying such a principle." But the trustees countered that a married woman should "dignify her home-making into a profession, and not assume that she can carry on two full professions at a time" [13].

For contemporary women, the story is of course quite different. A wide variety of women have pursued mathematical careers, each with a very different story to tell. Each has navigated a distinct course through her personal and professional life. Some have had children, some have not. Some are single, some are married, many have had more than one spouse or partner. They came to mathematics in various ways and at different points of their lives, from as early as elementary school, to as late as graduate school. Most have experienced both supportive mathematical environments and less hospitable ones. But for almost none was there an obvious, natural path, one that easily fused their professional and personal lives. Virtually none had role models or examples of women who had "made it" in mathematics. In this way, most of these women were pioneers, forging a path that would accomodate the multiple aspects of their lives. For a few this was not problematic, but for most, being a pioneer meant dealing with periods of alienation, confusion, doubt, conflict, and compromise.

What is most striking in studying the lives of women in mathematics, now and in the past, is the lack of a traditional pattern. Few followed the standard path that is clearly outlined for male mathematicians: undergraduate major in math, graduate work, post-doc, tenure track job, tenure, full professor. There are certainly cases of men who do not follow this norm—notable examples include Persi Diaconis who began as a magician, and skipped undergraduate work; and Ramanujan, who had very little formal training—but these are exceptions. With women, the exceptions are the ones who follow the traditional, linear path. For a variety of reasons, women's lives are more accurately characterized by a kind of veering and tacking [14]. Although from the outside this is often seen as a lack of commitment, from the women's perspective, it is their way of accomodating the many pressures, needs, and desires of their lives. Often personal issues must be resolved before a woman is ready to immerse herself full-time in research. For some, this means entering a long-term relationship, for others it means having and raising children, or caring for dependent adults.

In addition to personal issues, professional factors have also prevented women's careers from following a traditional pattern, factors that women were not in a position to control. These include overt obstacles, such as nepotism rules, as well as subtle ones, such as not being seen as a serious mathematician because of one's sex. One prominent research mathematician was not able to work with the professor most suited to be her advisor because he thought she should be a high school teacher and would not take her seriously as a mathematician. In addition, a woman is often invisible in the math community and can have more difficulty forming connections with the main network of researchers in their field [15].

All of these factors, both personal and professional, affect the timing of women's lives. If we look, therefore, at the "time-line" of a woman's life—what she accomplishes when—it can look quite different from that of her male colleague's. Such differences in time-lines can give rise to difficulties in being accepted as a "real" mathematician.

In studying lives of women mathematicians, what emerges is a picture of a wide variety of time-lines, rather than a single standard. Joan Birman, a topologist at Columbia University/Barnard College, did not get her Ph.D. until she was forty years old. Lenore Blum returned to mathematical research in her forties, after years of teaching at Mills College and involvement in national programs to promote women in mathematics. Mary Ellen Rudin, who managed to stay professionally active even while raising four children, is finding that she is doing some of her best work in her fifties and sixties, now that most of the children are grown. She worked part-time as a lecturer until she was almost fifty, when the University of Wisconsin promoted her from a lecturer to a full professor. Judy Roitman did not decide to pursue mathematics until she was already enrolled in graduate school in a logic and methodology program. Though she had always enjoyed math, she had been given messages all her life, both subtle and not so subtle, that women didn't do math. Vivienne Malone-Mayes taught in a small Black college for years before having the courage to pursue a Ph.D. in math, a path that many in her community thought was absurd for a black woman, and certainly not practical for getting a job.

Clearly, each of these women had to "compose a life" of her own. These are examples—and there are many others—of women who succeeded. But there have also been many talented women who were not able to fit their unique lives into the world of mathematics, often because their life time-lines did not mesh with what is expected of a mathematician.

Integrating Children with Professional Life

Having children and integrating them into one's professional life provides a vivid illustration of how women's life time-lines differ from that of their male colleagues, and of the conflicts that can result. I choose this topic *not* because it is a given that all women will choose to have children, or can have children. Many women in all walks of life, including mathematics, have rich and rewarding lives without children. However, this topic brings into focus issues that arise for women with respect to many aspects of their lives—issues of timing, relationships, connection to math community, personal and professional conflicts—all of which apply to women with and without children [16].

Simply deciding whether or not to have children is difficult for many women, but timing is particularly problematic. Women hear three strong, conflicting messages. They are told that, biologically, the ideal time to have children is as early as possible. However, the present social climate dictates that fewer people are marrying or having children early in life; there is social pressure to wait until when one is established in a relationship and a career. Professionally, the ideal time is to wait until after tenure. So these three pressures—biological, social, and professional—must be considered in turn.

Many women mathematicians did indeed have children early in their lives and felt that was a good decision. For example, two mathematicians, Lenore Blum and Fan Chung, each had a child in their later years of graduate school. And like many women at this time, they played down having a child for fear of not being taken seriously in their professional lives. In fact, when one of Lenore's professors saw her with her four-month old baby, he said "where did that child come from? Whose is it?" He had been oblivious to her pregnancy and birth. When Fan had her second child in her second year at Bell Labs, her manager wondered what she was going to do. Would she quit now that she was having a child? He was unaware that she already had a child who was two years old who was clearly not interfering with her work. In both cases, it was crucial that they had access to full-time child care and supportive husbands. Joan Birman had three children before and during graduate school. She returned to graduate school at New York University later in life, starting part-time in a Master's program. Realizing her ability and desire to work full-time towards a Ph.D., she was able to get graduate support, most of which went toward caregivers for the children.

These women found ways to have children early in their lives and still continue with their mathematical development. This was during the 1960s and 1970s, a period when most women had their children early in life. But today, those who marry tend to do so later in life. And those pursuing higher education rarely think in terms of having children early in their lives.

If, however, one waits until one is settled personally and professionally, other problems can arise. Women in their late 30s and early 40s have more trouble conceiving, more complications with pregnancy, and higher incidence of Down's syndrome or other genetic disorders, and are likely to be more physically exhausted once the child is born. It is also more difficult to adopt a child after 40. This is not meant to be alarmist; many women have children later in life without problems. Nonetheless, many women do experience the profound disappointment and frustration of having waited to have children and discovering at this later stage of life that they are unable to do so.

Given the biological issues of having children late and the changing social realities that make having children early very unlikely, only the middle period remains—after graduate school, but before tenure. But, as everyone knows, this is professionally the most pressured period of all. In a few short years, one has to establish oneself in one's field, make connections, go to meetings, publish, and teach many courses for the first time. Very often women also assume a disproportionately high administrative and service workload. Having children during this period is clearly risky business. If the pregnancy is easy, the birth smooth with no complications, and the child a happy, healthy one who likes to sleep a lot, and if the parents are willing and able to put their child in full-time day care, then one's professional career can stay on track. However, if any one of these factors goes awry, the consequences can be extreme because the cost of not staying professionally productive is very high.

In addition, it is still common to be perceived by colleagues as not fully serious about one's work if one has a child. At the early stages of one's career, judgment by one's peers and colleagues can have enormous impact. The implicit message—that either one is a mathematician, or one is a mother, but one cannot do both—is tied to the assumption that it is men who do the mathematics and women who do the mothering.

So, from the perspective of a young woman who wants to become a mathematician, there seems to be no period of her career that would be favorable for having children. This is why a career in mathematics and having children seem to be in conflict. These problems are not unique to mathematics or even to academia. Still, the mathematical community needs to fashion for itself ways of dealing with this conflict, for there are at least two aspects of the discipline of mathematics that exacerbate this problem.

First, there is the pervasive myth that mathematicians do their best work at a very young age. Philosophy professors may be entering their prime in their 50s or later, but this is rarely the image of a productive mathematician. As G. H. Hardy says in *A Mathematician's Apology*, "If then I find myself writing, not mathematics but 'about' mathematics, it is a confession of weakness, for which I may rightly be scorned or pitied by younger and more vigorous mathematicians. I write about mathematics because, like any other mathematician who has passed sixty, I have no longer the freshness of mind, the energy, or the patience to carry on effectively with my proper job" [17]. He goes on to say, "No mathematician should ever allow himself to forget that mathematics, more than any other art or science, is a young man's game" [18]. This powerful myth of the young, virile mathematician contributes to the pressure young women (and men) feel, despite the fact that there are many examples of prominent mathematicians who did excellent work in their later years [19]. In fact, most of the women I interviewed found that their work improved as they got older.

Second, academic careers in general, and mathematics in particular, exacerbate the problem because of the linear trajectory of career development: graduate school, postdoctoral study, assistant professor, associate professor, full professor. Any deviation from this norm is suspect. In particular, people strongly believe that to take a couple of years off in mathematics makes it very difficult, if not impossible, to return. As a result, there are very few reentry points to a career in mathematics. The consequences are more severe for women than for men since women are more likely to take a year or two off, for example, to have children.

As more and more men assume an equal share of domestic responsibilities, the more these problems will affect men as well as women. Increasingly, men face serious conflicts between personal and professional life. For this reason, the entire mathematical community should be concerned with these issues. In general, though, women still assume more of the domestic responsibilities and are still the ones that bear children. Traditionally, men who have pursued careers in mathematics have not had to choose between their professional life and personal life. Even now, as the traditional structure of "wife at home, husband at work" becomes rarer, we still do not expect a man to choose between his career and having a family. We should not ask a woman to make that choice either.

Looking to the Future

How can the mathematical community address these problems? As I see it, several options must be explored simultaneously.

- **Multiple entry and reentry points into mathematics.** For example, the Ada Comstock program at Smith College allows older women who left school in order to raise a family to finish their "bachelor's" degree. Certain graduate programs, like the one at New York University, are receptive to older students or those who have taken some time off. Joan Birman would not have been able to get a Ph.D. at a school like Columbia, where she is now a professor, because her personal circumstances necessitated starting out on a part-time basis, and Columbia does not allow part-time graduate students in mathematics. The National Science Foundation has a program for women in mathematics who are returning to research.
- **Part-time options.** There should be ways for mathematicians to have a part-time status during certain periods of their careers, perhaps in graduate school or as a professor. This is one way of allowing people to have children and yet remain professionally active, even if it is at a reduced pace for a few years.
- **Optional extension of tenure clock.** For extenuating personal circumstances, such as having children, the tenure-track period could be lengthened. Many colleges and universities are already beginning to institute such policies.
- **Support systems.** Day care at mathematics meetings, flexible teaching schedules, and regular day care at colleges and universities are important.
- **A change in attitude in the mathematics community.** Informal factors, such as attitudes, can be as important as formal policies in determining the feasibility of women returning to mathematics. As long as taking time off is frowned upon, women who attempt to return will have a very difficult time being accepted or succeeding.

When the mathematics community conveys a clear message that having children is not in conflict with a career in mathematics, we will have gone a long ways toward fully embracing women in mathematics.

Conclusion

Living in a world which sends strong messages about the roles of women and of men, we often internalize these messages unwittingly. We must recognize our hidden assumptions and bring them into open discussion. Only then can we make conscious choices about how to live our lives and define new images of what it means to be a woman and what it means to be a mathematician. There is no inherent reason for these images to conflict.

Balancing personal and professional life is a challenge for everyone, both men and women, and there is no one right way to strike that balance. Given that there is no longer a single prevailing model—in which the man is the professional and the woman stays home with the children—we need to be more flexible in our structures and recognize a multiplicity of models.

In focusing on access to the public roles that were once the almost exclusive domains of men, the women's movement of the early 1960s and 1970s failed to deal with the tensions of combining this public/professional life with the continued demands of personal life. The next stage, therefore, involves taking down the barriers that make these two spheres disjoint, seeing the interactive nature of personal and professional life and discovering how they can be effectively interwoven. We must recognize that personal life is a professional matter and professional life is a personal matter.

References

[1] Fausto-Sterling, Anne. *Myths of Gender*. New York: Basic Books. 1985.

[2] Plato. *The Symposium*, translated by Walter Hamilton. London: Penguin Books. 1951. 208e.

[3] Ibid. 209.

[4] Paraphrase from Immanuel Kant's *Observations on the Feeling of the Beautiful and the Sublime*. Berkeley: University of California Press. 1960, p. 78-79.

[5] Soloman, Barbara Miller. *In the Company of Educated Women*. New Haven: Yale University Press. 1985.

[6] Rossiter, Margaret. *Women Scientists in America*. Baltimore: Johns Hopkins University Press. 1982. p. 16.

[7] "Everybody Counts," Washington, D.C. : National Academy Press. 1989. (National Research Council document).

[8] "Everybody Counts."

[9] AMS *Notices*, November 1988, p. 1310-1312. According to this survey, only 5.4% of the full professors in the mathematical sciences are women. For doctorate granting departments, Group I-III, the percent drops to 2.9%.

[10] I examine these and other questions in depth in my forthcoming book on contemporary women in mathematics.

[11] Halmos, Paul. *I Want to Be a Mathematician*. New York: Springe Verlag, p. 400. 1985.

[12] There are a few instances where such issues are raised in biographies of male mathematicians. See, for example, Constance Reid's biography of Hilbert.

[13] Rossiter.

[14] Aisenberg, Nadya and Harrington, Mona. *Women of Academe*. Amherst: The University of Massachusetts Press. 1988.

[15] These ideas are developed in more depth in my book.

[16] Other topics such as women caring for elderly parents, or sick or dependent adults are also very important and give rise to similar conflicts as having children.

[17] Hardy, G. H., *A Mathematician's Apology*. Cambridge: Cambridge University Press, 1940, 1985. p. 63.

[18] Hardy, p. 70.

[19] See for example the AWM Newsletter, Vol. 21 #2, p. 11.

Grace Chisholm Young

"By 1893 Grace [Chisholm] had taken both her final examinations and qualified for a first-class degree at Cambridge. At this time she had high hopes for a carreer as a mathematician. But despite her outstanding work at Cambridge, she could go no further there. Women were not yet admitted to graduate schools in England.

"Göttingen, a pleasant little German university town, was considered at the time to be the major center for creative mathematics in Germany, and probably the world. Gauss had lived and worked in Göttingen. The leading mathematician there now was Felix Klein. He was to be Grace's advisor and close friend for many years to come...

"Now the final oral examinations were all that remained for Grace to complete. An amusing incident relates to this. She writes that she had ordered a carriage in time to take her to the examination. I '...was sitting in the window (waiting) for the carriage to drive up, when to my surprise I saw a carriage drive away from my house. [I thought] he must be going to turn round, but instead of that it drove away.' Looking at her watch she realized she was going to be late. Checking with the maid it turned out that the carriage driver *had* called at the house to ask for the *gentleman* who had ordered the carriage. He had assumed it was a gentleman since he was told he was bringing someone to take a doctoral examination. The maid had sent him away. There was no gentleman in the house. 'I had to go on my legs as fast as I could, and of course I lost my way, but after wandering around several triangles and squares I go to the Aula very hot and five minutes late.' But no one was quite ready, so no harm had been done.

"The examination went well, and then it was over. She was a doctor—the first official doctorate granted a woman in Germany in any subject whatever. 'I was almost stupified,' she wrote. She was presented with an exquisite bouquet of flowers from one of the professors. 'The next moment Miss Winston [a friend and colleague] arrived; we used the occasion to execute a war dance of triumph. Then the professors came congratulating and beaming.' "

—from *Math Eauals: Biographies of Women Mathematicians and Related Activities*, by Teri Perl. Addison-Wesley Publishing Company, Inc., 1978.

WOMEN IN MATHEMATICS

The Escher Staircase

Jenny Harrison

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Mathematicians, be they men or women, beginners or stars, love mathematics. They endure perennial anxiety for the joy of occasional moments of discovery. It is only natural for people enamored of the beauty and perfection of mathematics to expect the mathematical community to reflect, in its behavior and ideals, the perfection of mathematical thought. And so we mathematicians expect to be able to admire our colleagues' honesty as much as their precision and enthusiasm. We assume we will find ourselves in a tolerant, trusting community, held together by a passion for mathematics. It would seem that anyone who loved mathematics would be welcome. Given this commonly shared belief, it is surprising that women drop out of mathematics in greater proportion than men.

Some mathematicians are not comfortable with this topic because it involves issues of social inequities that run counter to the basic assumption of collegiality. The majority of male mathematicians are decent people who find it difficult to believe that some of their colleagues do not welcome women into the profession as equals. And yet, because of social factors, women have a particularly difficult time developing their mathematical talents and pursuing their mathematical ambitions. Like the people on Escher's famous staircase, they feel as if they're climbing and climbing, but never quite reaching the top.

The scenes I will refer to are largely not my own story; most were told to me by students and faculty at Berkeley, Oxford, Princeton, Yale, and Warwick. Most women will not have experienced all of them, but most will have experienced some. Each incident, on its own, may sound minor, but over the years they can build up to leave deep feelings of isolation and alienation.

To the young women who will read this: I find myself in a dilemma. If I minimize the problems, there is a risk you will be unprepared for what might be avoided. On the other hand, I would urge you not to be discouraged in view of the increasing number of successful women in mathematics. With foresight, support, and luck, one can overcome most obstacles and have a rewarding and challenging career as a mathematician.

Childhood

Picture an enthusiastic, confident girl, brilliant in many subjects and with exceptional mathematical talent. At age nine she is taught how to calculate square roots and works out her own algorithm for computing cube roots. She is obsessive and loves to solve problems. But life is hard for geniuses, especially when they reach puberty, and especially when they are girls. She learns quickly that her friends distance themselves unless she sacrifices the path entirely or adopts a lightweight style to mask her brilliance. She learns that mathematics is not considered to be feminine at a time when her femininity means so very much to her and her peers. Mathematics is not for sociable people [1] and she, as a girl, has been trained to be sociable. Boys stay away from her, and, if she persists, she fears losing the relationships that she is taught are central to a woman's life. Still, she takes the risk—more mathematics courses.

Many studies have shown that in high school, teachers favor boys, asking them harder questions and giving them more encouragement and attention [2, 3, 4, 5]. Parents, teachers, and friends all expect boys to be better at math than girls [6]. Counselors discourage girls from taking advanced courses [7] and do not give them crucial information about mathematics requirements [8]. At home, fathers, not mothers, are authority figures when it comes to mathematics homework [9]. Many women mathematicians have told me that their fathers were important early mentors and taught them that a cute little girl also could be a scholar. This helped them to weather peer pressure so that their self-confidence and enthusiasm, essential for success in mathematics, survived for the next round.

College

In college, it is more acceptable for women to be smart, and nowadays about half of all bachelor's degrees in mathematics go to women. The peer-pressure problems greatly diminish, but now the difficulties center on the teachers. Women students have almost no role models and fear acting too silly, motherly, aggressive, flirtatious, talkative, or shy. Harassment, from inappropriate flirtation to outright sexual assault, is a major problem that sometimes forces women to transfer or leave mathematics entirely. After her teaching assistant kept a regular vigil outside her house, a Berkeley woman transferred to another university. Another teaching assistant offered a woman a preview of the final exam in exchange for sexual favors. She became severely depressed and dropped out of school. Sometimes male graduate students find themselves, as teaching assistants, in a position of authority over some attractive women and they take advantage of it. A department chair at a major university claims that the biggest problem he has with new male graduate students is their making inappropriate overtures to female undergraduates.

Faculty and teaching assistants fresh from foreign cultures sometimes express unacceptable views more freely [10]. One such professor handed back tests saying, "Even the women did well."

Some of the professors neglect the women as students. Warwick students complained about one professor who completely ignored the women in class—he would not even answer their questions. An Oxford professor would regularly address a mixed audience as "gentlemen." At Berkeley, the students noticed that some professors, when asking questions of the class, would not make eye contact with the women students. Some women withdraw into shyness and are ignored even more. Only a rare individual will excel in such circumstances.

It is possible to change classroom dynamics dramatically with subtle body language and voice cues. A woman professor saw a typical pattern in her undergraduate class in real analysis—the most vocal students were men. The women students sat at the back of the room; they seemed intimidated and said nothing. She decided to try an experiment: to use verbal and body language to encourage the women. To succeed, she felt she needed to make space for the women and quiet the men. For example, she made regular eye contact with women to show that she expected them to know the answers, and she toned down her enthusiasm for the men. If a woman responded, the professor tried to refer to the student's ideas later in the lecture. Invariably, the student would beam and be more eager to participate the next time. The professor told no one what she was doing, and no one seemed conscious of it. By the middle of the semester, the class had turned around. The women had moved to the front row and were avid participants in the class. She knew something was happening when her grader commented, "It's amazing—your women students do so well." The class average (based on tests and homework) was a C+ but the women all made As and Bs.

This experiment was not fair to everyone. But one has to bear in mind that ordinarily the social climate is the reverse—it favors the men. This experiment shows that the atmosphere and social interactions in the classroom make a big difference in how well and how confidently the students grasp the material and produce good work. It's not simply a question of talent and desire to learn—the environment has to be right.

One of the most critical times of a woman's college days comes when she discusses her future plans with her adviser. The paucity of women faculty [11], especially in highly ranked mathematics departments [12], deprives female students of mentors who could help direct their career decisions. When a first-rate Berkeley undergraduate discussed the options with her male adviser, she let him know of her self doubts, and he questioned the sincerity of her desire to be a mathematician. He advised her not to go to graduate school unless she was absolutely sure. What she needed was validation of her ability and approval to move forward. She came to me for advice, and with my support and encouragement, she went on to get a doctorate and a job at a major university. Another honor student reported her adviser's response, "If you persist in this graduate school idea you will make some young man very unhappy." Another Berkeley student was advised to take up nursing despite her straight As in mathematics.

The student and adviser often compromise on a plan to try out graduate school in the master's rather than the Ph.D. program. The student does not realize that this tentative choice will label her for the next few years as not serious. I have rescued several women from this trap and got them into Ph.D. programs. One is now a postdoc in a top research department. An extreme case is a woman who was finishing her undergraduate work at Cambridge, having placed at the top each year she was there. No faculty member had suggested that she go to graduate school. I advised her to see an Oxford professor who became her thesis adviser, and she is now a tenured member of the Oxford faculty. A tenured faculty member at Warwick was never advised to go to graduate school. She only went to Harvard because her husband was encouraged to go there.

Many studies have documented the high drop-out rate of women graduate students. To quote just one source, the National Research Council report, "A Challenge of Numbers," says that less than one-tenth of women continue on for a doctorate from a master's degree, while nearly one-quarter of the men do. In addition, the report notes that "the attrition of women along the path from the bachelor's to the doctoral degree is significantly higher in the mathematical sciences than in other science fields" [23].

Graduate School

In graduate school, only about 25% of the students are female. Men and women alike arrive full of hope, enthusiasm, and energy. I have vivid images of the bright young faces during their first few days of graduate school at Berkeley. The women do not know that many of them will give up within a couple of painful years.

Graduate school is difficult and demanding for both men and women. However, I would argue that circumstances conspire to raise the hurdles even higher for women students. In graduate school, more than at any other time, role models and a support system are crucial. Unfortunately, the community of female mathematicians is still too small and dispersed to be of much help to young women [12].

Male mathematicians can be mentors for female students but they cannot be role models. A man can encourage, inspire, and teach women, but a woman cannot identify with him in the countless ways that distinguish women from men. Furthermore, an aggressive speaking style, minimal social skills, and blatant egotism—acceptable for men—are not suitable for most women to adopt. Finally, because most men have not experienced the subtle prejudice and often long-term discouragement women mathematicians do, men are less likely to be able to counsel women with the perspective needed to survive and flourish.

Three ingredients are needed for success in graduate school—talent, training, and confidence. If a student has had first-class undergraduate training, the course material will not pose a problem. Consider, though, a student who comes with straight As from a college without a strong mathematics program. The student will likely know much less than someone with four years of training from a strong department. Whether male or female, the student is likely to have some self doubts. But a female student is more likely to internalize these feelings of inferiority and to believe they reflect a lack of ability, while a male student is more likely to credit his failure to bad luck [14]. Peers and professors probably will make the same judgments due to the same social influences. If a woman student has good counseling—and that is a big if—the effect can be defused, but it is nonetheless very difficult for most. Her precious confidence quickly subsides. Of the three ingredients needed for success in graduate school, she now has only one.

It is common for a female graduate student to get far more attention for her femaleness than for her mathematics. This occurs in part because of the imbalance of numbers. In addition, a male postdoc conjectured to me that a female mathematician represents an ideal to many male mathematicians: not only can they make love to her, they can talk mathematics to her. She can understand them. The power difference between her and a male professor can worsen sexual tension, and the onus is on the professor, who may be older and one hopes wiser, to minimize this. If the faculty member is flirtatious, the student has to be on her guard for any changes of behavior. The inevitable silences in their conversations may make her feel so uncomfortable she stops thinking clearly and wants to leave the room. Women students are disturbed by interest based on their sex rather than mathematical ability. (I have heard many complaints about this.) Kindness, warmth, friendliness are fine, but the vast majority of women don't want their lives complicated with romantic overtures from their professors. One student's adviser was emphatic that he would not work with her unless they became sexually intimate. The power difference put her into a terrible bind. If she refused him, where would she go, would he retaliate? If she complied, could she live with herself? "One event can have a devastating effect on a woman. One uncurbed man can affect the careers of many women" [16]. But even when a faculty member is not overtly attracted to a female student, subtle differences in attention can profoundly curtail the educational opportunities offered to women.

Sometimes the mathematical side of a woman is belittled. A graduate student at Warwick gave a ride to a visiting star in her field. She started to talk to him about his lecture and saw him chuckling to himself. She asked him what was funny and he bent over double, laughing, "A woman, talking mathematics, and foliations, it's too much!"

In an unfortunate bifurcation of reality and perception, some men who observe women getting attention for their femaleness become jealous. They feel that any attention is good attention and believe that attractive women have some unfair advantage over them. A male graduate student at Berkeley complained that female students have an easier time getting advisers because of course the professors (mostly male) would prefer to be working with a woman. This can be taken to an extreme: a worldclass mathematician justified his vicious opposition to a female competitor because of all the attention she received as a woman.

These problems diminish when there are enough women around. The men are more accustomed to their presence and the women have each other for support. Last year, a third of the graduate students in one seminar group at Yale were women and the atmosphere was quite genial. The women told me what a pleasure it was to look around the seminar room and sometimes find themselves a majority.

I observed this critical-mass phenomenon at Berkeley in our dynamical systems group which a male professor and I led. Over a period of seven years, a third of the students were women. Again, the atmosphere was healthy. Even when potentially intimidating guest speakers would arrive, we would all take them out for a beer and talk about mathematics. We noticed no generic differences in talent between the male and female students in this group. They all got good degrees and good jobs. Some of the women were outstanding (so were some of the men!).

Shyness is the biggest difference between female and male students, and I have seen it everywhere. None of a woman's training has prepared her for the combative, schoolyard games she encounters in graduate school, and she may adopt shyness as an escape. One Berkeley student would only talk to her adviser from his office doorway for most of a year. Her adviser worked around these problems with great care, and she wrote an excellent thesis. A Yale woman literally trembled during her weekly appointment with her adviser. He had observed her reticence (luckily he did not confuse it with a weak intellect) and discussed with me constructive ways around it.

Female students can be especially quiet in seminars. A student at Berkeley couldn't answer a question directed to her by the speaker, although she knew the answer perfectly well—she had recently proved it in her thesis. Sociolinguist Deborah Tannen has an explanation for quiet women [13]. She believes that men speak and hear a language of status and hierarchy whereas women speak and hear a language of connection and support. "Many men are more comfortable than most women in using talk to claim attention." She notes that most women who want to ask a question or make a comment after a lecture need time to muster their courage, formulate their words carefully, then wait to be recognized by the speaker. Men are more comfortable interrupting and saying whatever is on their minds when there is an audience. "For most men, talk is primarily a means to preserve independence and negotiate and maintain status in a hierarchical social order. This is done by exhibiting knowledge and skill, and by holding center stage through verbal performance." Linguist Marjorie Swacker recorded discussion sessions at academic conferences. The length of the women's questions averaged less than half that of the men's. The men (and not the women) often began with a statement, asked more than one question, and followed up the answer with another question or comment [17].

Women can learn to be more assertive. When I visited Warwick in 1988, I found the female students and faculty regularly gave lectures to each other. I tried this at Yale, and it was remarkable how much more comfortable the women felt, both as speakers and as members of the audience. The woman who had trembled before her adviser gave an eloquent lecture to this group. Later she gave a similar talk in her adviser's seminar and found that her practice session enabled her to speak with clarity and confidence.

Faculty

A true colleague should be part of an academic family—never left out, never feeling left out, not suffering from a sense of isolation. Having just left the advisers/parents, postdocs' professional self-images are vulnerable. Their ideas need to be recognized and their thoughts validated as worthwhile. Women are too often ignored at this point in their careers. One Berkeley faculty member recounted the many luncheons at which her remarks were ignored unless a male present repeated them word for word: "Did you hear what she said? It was really interesting." Then and only then would her thoughts be discussed. Another faculty member at a prestigious department avoids faculty meetings because she believes that her male colleagues don't listen to her. She sends her comments to the meeting with a male friend, believing the department will listen to him. Karen Uhlenbeck wrote in 1988 that overt discrimination was only a small part of the problem. "One of the most serious problems women ... have is conceptualizing and acting upon the subtle non-articulated lack of acceptance." [18].

"Inclusion brings confidence. Exclusion brings emotional damage, withdrawal from discourse. Still, some succeed. They do so in less competitive departments or within supportive subgroups within competitive departments. Some manage by working in complete isolation, producing nothing for a few years and then announcing a major, innovative result" [19]. Uhlenbeck, speaking at the 1988 AMS meeting in Atlanta, said, "I cannot think of a woman mathematician for whom life has been easy. Heroic efforts tend to be the norm" [19]. Judy Roitman, at the same meeting, said, "Women's achievement in mathematics has been too often accompanied by heroic feats of character. Think of Julia Robinson, unsalaried, sharing a corner of her husband's office for so many years, and consider the strength of mind and will that kept her focused on her work, and unconcerned about her career" [19]. Many men would find it difficult, if not impossible, to be productive under the conditions in which most female mathematicians routinely work [15]; yet the comparatively small number of women mathematicians is often attributed to innately inferior talent.

Joint work can present unusual problems. Intense intellectual intimacy is necessary for success in mathematical collaboration [20]. When the collaborators are of the opposite sex, they may run up against social taboos—too often they are suspected of sexual intimacy and the man is credited for the work [14]. A female postdoc reported that her male postdoc collaborator got all the invitations to speak about their work. Male collaborators may suffer from unconscious bias. Two women told me their collaborators appeared not to notice their ideas but later claimed credit for them.

As a woman gets older, many of these cultural problems lessen in their impact on her and it is easier for her to be a mathematician. She gives more lectures, and men talk to her because they are primarily interested in her work. Her male competitors are also more relaxed. Some of them have stopped doing research.

At what age do women do their best work? I made an informal survey and found that ten years is typically added to the answer a male mathematician would have given: 35-50 instead of 25-40. When asked, the women said it was a matter of confidence. The inequities not only decrease but the older woman is less dependent on the approval of others. She has tenure, she has publications, she has prestige. Her salary may not be as high [21] as that of a man; it is probable that her department is not as prestigious as that of a man [12]; and she has to confront the myth that mathematics is for young people [22]. But this is small potatoes compared to what she has been through.

Periodically, over the last 15 years, many have predicted significant increases in the percentages of women in the top math faculties. Despite these predictions and hopes of young women of yesteryear, this has not yet come to pass. Today, out of 303 tenured faculty in the ten most highly ranked U.S. mathematics departments, only four are women; among assistant professors, one out of eighty-six is a woman.

To the young women mathematicians who read this article, I hope it gives you an opportunity to consider ways in which you might respond to the kinds of predicaments I have described, so that, should they happen to you, you will not withdraw into your shell or blame yourself. Finding kindred spirits with whom to discuss the problem and share your emotions will help you to prepare a swift, dispassionate, sophisticated response.

I am indebted to Patricia Kenschaft for her excellent booklet, "Winning Women into Mathematics" [16] from which many of the references in this article were taken.

References

1. Keith, S., "Interest Inventories and Mathematics," unpublished article, Dept of Math., St. Cloud State University, MN 56301, 1991.

2. Good, T.L., Sikes, J.N., and Brophy, J.E., "Effects of Teacher Sex and Student Sex on Classroom Interaction," *Journal of Educational Psychology*, 65, pp. 74-87, 1973.

3. Becker, J.R., "Differential Treatment of Females and Males in Mathematics Classes," *Journal for Research in Mathematics Education*, 12, pp. 40-53, 1981.

4. Fennema, Elizabeth and Peterson, Penelope, "Autonomous Learning Behavior: A Possible Explanation of Gender-related Differences," *Mathematics in Gender-related Differences in Classroom Interaction*, eds. L.C. Wilkinson and C.B. Marret, Academic Press, New York, pp. 17-36, 1985.

5. Fennema, E. and Reyes, L.H., "Teacher/Peer Influences on Sex Differences in Mathematics Confidence," University of Wisconsin, Madison, Dept of Curriculum and Instruction, 1981.

6. Ernest, J., "Mathematics and Sex," MAA, Washington, D.C., April, 1976.

7. Haven, E.W., "Factors Associated with the Selection of Advanced Academic Mathematics Courses by Girls in High School," *Research Bulletin* 72, Princeton Educational Testing Service, 1972.

8. Kenschaft, P.C., "Confronting the Myths about Math," *Journal of Career Planning & Employment*, 48, pp. 41-44, 1988.

9. Eccles, J., et al., "Self-Perception, Task Perceptions, Socializing Influences, and the Decision to Enroll in Mathematics, " *Women and Mathematics: Balancing the Equation*, eds. S. Chipman, L. Brush and D. WIlson, Lawrence Erlbaum Associates, Inc, Hillsdale, NJ, 1985.

10. Sandler, Bernice R., "The Campus Climate Revisited: Chilly for Women Faculty, Administrators, and Graduate Students," *Project on the Status and Education of Women*, Association of American Colleges, 1818 R St., NW, Washington, DC 20009, 1986.

11. The Annual Report on the Economic Status of the Profession, 1989-90, ACADEME, *Bulletin of the American Association of University Professors*, 76:2, p. 24, March-April, 1990.

12. Selvin, Paul, "Does the Harrison Case Reveal Sexism in Math?," *Science*, 252, pp. 1781-1783, June 28, 1991.

13. Tannen, Deborah, *You Just Don't Understand*, William Morrow and Co., Inc., New York, 1991.

14. Keith, S. and Keith, P., editors, "Proceedings of the National Conference on Women in Mathematics and the Sciences," St. Cloud, MN, 1990.

15. Helson, R., "Women Mathematicians and the Creative Personality," *Journal of Consulting and Clinical Psychology*, 36, pp. 210-220, 1971.

16. Kenschaft, P.C., editor, "Winning Women into Mathematics," Mathematical Association of America, 1991.

17. Swacker, Marjorie, "Women's Verbal Behavior at Learned and Professional Conferences," *The Sociology of the Languages of American Women*, eds. Betty Lou Dubois and Isabel Crouch, San Antonio: Trinity University, pp. 155-160, 1976.

18. Private communication, Oct., 1988.

19. *Association for Women in Mathematics Newsletter*, 18:3, p. 1988.

20. National Research Council, "Mathematical Sciences: a Unifying and Dynamic Resource," National Academy Press, Washington, DC, pp. 1-10, 1986.

21. Vetter, B.M., "Women's Progress," *Mosaic*, 18, pp. 2-9, 1987.

22. Stern, Nancy, "Age and Achievement in Mathematics: A Case-Study in the Sociology of Science," *Social Studies of Science*, 8, pp. 127-140, 1978.

23. "A Challenge of Numbers," Committee on the Mathematical Sciences in the Year 2000, National Research Council, p. 47, 1990.

24. Helson, R., "The Creative Woman Mathematician," *Women and the Mathematical Mystique*, eds. L. Fox, L. Brody, and D. Tobin, Johns Hopkins Press, pp. 23-54, 1980.

Women in the Early AMS

"By 1888 women had already made important contributions to mathematics [in the U.S.]. They had been college teachers of mathematics for a quarter of a century. Christine Ladd, who had completed a dissertation under Charles Sanders Peirce but been denied a Ph.D. at Johns Hopkins because of her sex, had published in the *American Journal of Mathematics* and elsewhere. In 1886, two years before Thomas Fiske and his friends met at Columbia to start the New York Mathematical Society [later to become the AMS], Winifred Edgerton had received her Ph.D. cum laude in mathematics from Columbia, the first American woman to be granted a Ph.D. in mathematics.

"For the first two and one-half years the New York Mathematical Society had no women members, although the desire to publish a journal, the *Bulletin*, provided impetus for a major membership drive. Hence, in 1891, upon invitation, the first six women joined the NYMS. The first, admitted in May of that year, was Charlotte Scott, holder of a doctorate from the University of London and head of the mathematics department at Bryn Mawr College. Scott, a distinguished geometer, became one of the most active and recognized women in the AMS in the early history of the Society, serving on its Council and as vice-president...

"[In the 1920s,] two women were highly visible as scholars and members of the Society. Anna Pell Wheeler published in functional analysis, directed seven Ph. D. dissertations at Bryn Mawr, and was actively involved in the AMS. In the 1920s, she served on the original Board of Trustees, served on the Council, and was the first woman to give an invited address and to deliver the Colloquium Lectures. [Since then, two other women, Julia Robinson in 1980 and Karen K. Uhlenbeck in 1985, have presented AMS Colloquium Lectures.]

"Another Chicago Ph.D., Olive C. Hazlett, was a noted algebraist who worked in the areas of modular invariants and linear associative algebras. Of the many papers she gave, one was delivered at the International Congress in Toronto in 1924, another at the International Congress in Bologna in 1928... Hazlett also served as cooperating editor of *Transactions*. The only other woman who served in that editorial position during the AMS's first fifty years was Caroline E. Seely, a 1915 Columbia mathematics Ph.D. and clerk to the secretary of the AMS..."

—from Jeanne LaDuke's contribution to the panel "Centennial Reflections on Women in American Mathematics," held during the AMS Centennial. Providence, August 1988. Quoted from the *AWM Newsletter*, November-December 1988.

WOMEN IN MATHEMATICS

Mathematics and Women: Perspectives and Progress

Alice T. Schafer

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The 1989 National Research Council report, "Everybody Counts," says (page 23) that, "gender differences in mathematics performance are predominantly due to the accumulated effect of sex-role stereotypes in family, school, and society." Of course, such a statement would not have been surprising had it appeared in the *AWM Newsletter*—women have been saying this for years. But it was refreshing to see it in such a report. The report also quotes Workforce 2000 (page 18) as saying, "White males, thought of only a generation ago as the mainstays of the economy, will comprise only 15% of the net additions to the labor force between 1985 and 2000." The report identifies women as one group that will be needed to fill a gap left by the absence of white males. What is being done to welcome women into mathematics and keep them there?

Some of the statistics are, unfortunately, depressingly familiar. According to *Science* magazine (28 June 1991, page 1781), there are 303 faculty in the "top ten" mathematics departments (identified as Berkeley, Caltech, Chicago, Columbia, Harvard, MIT, Michigan, Princeton, Stanford, and Yale), and the women can be counted on one hand. One is Joan Birman, who is actually tenured at Barnard College, a women's college of Columbia University. Another is Sun-Yung Alice Chang, who was offered a tenured professorship at Berkeley, but is currently at UCLA. The third is Berit Stensones, who has been appointed to an associate professorship with tenure at Michigan. And the fourth is Marina Ratner, who is tenured at Berkeley; for a history of her original appointment, see the *AWM Newsletter* from 1974 and 1975. The situation among non-tenured faculty is equally dismal: one woman out of eighty-six.

According to the October 1990 issue of *Notices*, there were 991 doctorates awarded in mathematics by institutions in the U.S. and Canada in 1989-1990, 18% of which were awarded to women. From that crop of doctorates, the thirty-nine "Group I" institutions employed 101 men, but just twelve women. Such statistics are often explained away by saying that there are no qualified women "out there." This is difficult to believe when one looks at the percentage of women receiving doctorates in mathematics, which has been plus or minus 20% for nearly 10 years now (with many of them coming from the "top ten"). And in recent years, many women have received postdoctoral fellowships in mathematics and have been invited speakers at national and international research conferences.

Once I had a conversation with a male mathematician who said he would never hire a woman mathematician because she would probably sue if she were not granted tenure. I know of no woman mathematician who has ever advocated that a woman be appointed to a position for which she was not qualified or that, once appointed, she be judged on any basis different from that of a male member of the department. Indeed, I was once asked by a man at one of the "top ten" institutions what I would do if faced with the following situation he encountered in his own department. A man and a woman were being considered for promotion to full professor. The woman's research was inferior to that of the man, but some members of the department felt that if one were promoted, the other should be also, for personal reasons. My answer was absolutely not! The woman's research should be judged on the same basis as any man's in the department. I suspected that my answer was a disappointment to the man who asked me; I think he had expected me to say that the woman should be promoted despite inferior research.

On a different occasion, when I was talking to a mathematician at another of the "top ten," I asked why there were no women on the faculty. His answer was that if the department could find anyone as good as "X," a woman at a less prestigious university, that his department would hire her. "What about hiring X?" I asked. No response—end of conversation. An answer I have heard many times from men at research universities is that women have children and cease to do research, but there are so many counterexamples that the argument is fallacious. And anyway, how many men, with or without children, have short "research lives"?

There has been a great deal of discussion in recent years about attracting more students—and, in particular, more women—into graduate school in mathematics. Programs and funding are not enough. There must be women on the faculties, and the women students must see their work evaluated on the same basis as that of their male colleagues. When it comes to mathematics, male and female students should be treated the same. But when it comes to certain kinds of social factors, it is, unfortunately from my viewpoint, sometimes necessary to treat women differently. During my years teaching undergraduates, I told my female students that I would not write a letter of recommendation for them for entry to graduate school unless they promised to complete the work for the doctorate. I do not tell my male students this, and some of them did not complete the work for the doctorate. One of my Wellesley students now jokingly tells me that the reason she has a Ph.D. is that I had refused to write a recommendation for a National Science Foundation (NSF) fellowship unless she promised she would complete the work. She is now married, has children, and does research.

It has been well documented that many capable girls and women have reacted to the myth that females cannot do mathematics by avoiding mathematics courses and steering clear of careers in mathematics and science. If schools, colleges, and universities have failed here, women and some men have worked to eradicate this injustice and have established organizations and programs for this purpose. There is space here to mention only a few.

I believe that by now all mathematicians know of the existence of the Association for Women in Mathematics (AWM) founded in 1971 as an independent organization and with offices at Wellesley College since 1973. A history of AWM, written by former AWM President Lenore Blum, appears in this issue of *Notices*.

Two years after AWM was founded, due to the efforts of Cathleen S. Morawetz, aided by Isadore M. Singer, the AMS created the Committee on Women in Mathematics, with Morawetz as its first chair. Under her direction, a Directory of Women in Mathematics was published in order to show the mathematical community that there were women who were qualified to be faculty members at research institutions, to be speakers at mathematics meetings and research conferences, and to be appointed members of important national committees. During my tenure as the third chair of the Committee, a second Directory of Women was published, and I. N. Herstein, a member of the Committee, wrote an article in *Notices*, "Graduate Schools of Origin of Female Ph.D.s" (April 1976, page 166). His idea was that, if women preparing for graduate school in mathematics were aware of the departments which had in the past been hospitable to women, they might want to consider those schools. At that time, the Committee also submitted several proposals to the NSF for funding for programs that would benefit women mathematicians, but, unfortunately, none of them was funded. (I am happy to say that in recent years the NSF has begun to fund programs almost identical to the ones the Committee recommended.)

The Committee was later expanded to the AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Committee on Women in the Mathematical Sciences and is currently chaired by Susan Geller of Texas A&M University. Geller reports that the Committee has developed a questionnaire to be distributed at Ph.D.-granting institutions in an attempt to determine why students in the mathematical sciences leave graduate school. The questionnaire has already been tested at six cooperating institutions, and as soon as funding is available, the study will include all the Ph.D.-granting institutions. The Committee has also been collecting statistics on the relative acceptance rates of male and female authors in various journals. (Journal editors interested in this study should contact Geller.)

In 1975, the MAA established the Women and Mathematics Program (WAM), the first program in the country designed to encourage female students to continue to study mathematics and to seek careers in fields requiring the use of mathematical tools. WAM participants are women from business and industry whose career choices involved a strong background in mathematics and science. They serve as mentors, role models, career counselors, and classroom visitors to elementary, middle, and high school students in sixteen regions throughout the United States. Many of these WAM participants also arrange plant tours for groups of students. The current director of WAM, Alice Kelly of Santa Clara University, says, "We work with both male and female students in our classroom visits, career counseling, and tours, thus exposing young males to the woman of today."

Many colleges and universities have instituted programs to encourage girls in elementary school and to show them how exciting mathematics can be as well as instituting programs for high school women students. An excellent reference which has descriptions of many of these programs is the proceedings of the National Conference on Women in Mathematics and the Sciences, held in 1989 and organized by Sandra Z. Keith of St. Cloud University.

In 1987, the MAA established a second committee on women in mathematics, known as the Committee on the Participation of Women, chaired by Patricia Clark Kenschaft of Montclair State University. Among the Committee's recent endeavors is the MAA publication "Winning Women into Mathematics," which includes a list of fifty-five cultural reasons why women are underrepresented in mathematics. During the national meetings in the past couple of years, the Committee has presented skits using mathematicians as actors to dramatize "micro-inequities" that have actually happened within the mathematical community. Kenschaft describes micro-inequities as "small slights that are often humorous in themselves but chip away at women like water dropping on a rock."

Charlene Morrow and her husband James are Directors of SummerMath at Mount Holyoke College. Describing the program, she writes: "SummerMath, now in its tenth year, was designed to address the underrepresentation of women in mathematics-based fields. It is an intensive, six-week program for high school age females that provides new perspectives and new experiences in mathematics, computing, and science. We emphasize greater conceptual understanding, affirmation of young women as capable members of a learning community, and the importance of constructing one's own understanding of complex ideas ... . The atmosphere of the program is one of challenge with support: the challenge of rigorous study and hard problems with the support of a community of teachers, residential staff, and peers .... Students learn to take charge of their mathematical education, gain a mathematical voice, and experience increased success in mathematics classes upon returning to school."

The Sonia Kovalevsky High School Mathematics Days began in 1985. They were initiated by Pamela Coxson and Mary Beth Ruskai, who at the time held Office of Naval Research science fellowships at the Mary Bunting Institute of Radcliffe College. They suggested that the twenty-fifth anniversary of the Institute and the fifteenth anniversary of AWM be celebrated together, and the Sonia Kovalevsky Symposium was the result. As part of the Symposium, Coxson organized a Sonia Kovalevsky High School Day for high school women and their teachers in the Boston area. The Days have continued on a national scale with some funding from AWM and the remainder from local businesses and industries.

According to Donna Beers of Simmons College, the Sonia Kovalevsky Days held at her institution "celebrate the beauty and uses of mathematics. The goal of these programs has been to show students women professionals working in attractive and challenging fields in which their mathematical preparation has proven indispensable. Above all, organizers aim to encourage young women to persevere in their study of mathematics throughout all four years of high school and beyond. The basic ingredients of these programs have included: hands-on workshops on cutting edge applications of mathematics, e.g. percolation theory, genetics, cryptology, chaos theory, and fractal geometry; career panel discussions led by women professionals, e.g. accountants, actuaries, aerospace engineers, statisticians, computer software engineers; and a lunch-time keynote speaker, often a woman scientist or mathematician who shares her mathematical biography, stressing the hard work required as well as the satisfaction and confidence that developing one's mathematical potential can bring. Student and teacher evaluations of the Sonia Kovalevsky High School Mathematics Days have been uniformly positive, urging that more be held more often, even at the middle school level in order to have a wider impact on young women students early on."

As mentioned above, the NSF now funds programs similar to those first suggested in the early 1970s by the Committee on Women in Mathematics; for example, the Visiting Professorships for Women and the travel grants for women to attend professional meetings and conferences. The NSF also funds many other programs for women, such as research planning grants, Career Advancement Awards for experienced women scientists, and Faculty Awards for Women for those who are tenured but not yet full professors. The latter two programs aim to recognize the nation's most outstanding women scientists and engineers in academic careers of research and teaching and to retain these women in academia.

Another NSF program, Research Experiences for Undergraduates (REU), has proved to be of great value to women undergraduates. For example, the nomination papers for the AWM Schafer Prize, which recognizes outstanding undergraduate women mathematics majors, show that many of the nominees spent summers in REU programs, and some became coauthors of research papers. This past summer, the NSF funded a six-week Summer Mathematics Institute at Mills College in Oakland, California for twenty-four women students, who worked intensively on advanced topics in a seminar setting. The aim of the Institute was to encourage these talented students to go to graduate school in mathematics. For a more complete description of opportunities at NSF, consult the brochure "Opportunities in the Mathematical Sciences," available from the NSF.

At present, fewer than one-fifth of the nation's mathematicians and scientists are women, and the prediction is that between 1991 and 2000 more than half of those entering the workforce will be women. We need to develop more ways of attracting and retaining women in mathematics. Women should be held to the same mathematical standards as men and should be judged on the same basis as men. *Everybody Counts* urges us to increase the pool of students who are successful in mathematics. Let's take that challenge seriously.

Julia Robinson

"Julia Robinson and I were graduate students together at Berkeley. During World War II we also did a lot of heavy computing in a large group organized by Jerzy Neyman. After the war we were glad to return to our studies and research, I to astronomy and Julie to mathematics, but there was still overlapping in statistics.

"Julie was by then married to Raphael Robinson, who had an appointment in mathematics; a University rule made it quite difficult for the mathematics department to employ both of them. Professor Neyman felt that Julie should be employed and encouraged to do research. He argued that statistics, although technically in mathematics, had a lot of autonomy in budget and appointments, including a 'line item' for a research assistant. Although I already held this position, he arranged that I would be moved to another research position to accommodate Julie's appointment. Fine, except that personnel suddenly interfered, contending that the position, now that it had changed, should be under personnel—in essence, out of research. Julie was asked to submit a 'job description' of what she did each day, so she did: Monday—tried to prove theorem, Tuesday—tried to prove theorem, Wednesday—tried to prove theorem, Thursday—tried to prove theorem, Friday—theorem false. Personnel withdrew. The position remained in the graduate studies division, and Julie got appointed."

—by Elizabeth Scott, from a tribute, "Julia Bowman Robinson, 1919–1985," *Notices*, November 1985.

WOMEN IN MATHEMATICS

A Brief History of the Association for Women in Mathematics: The Presidents' Perspectives

Lenore Blum

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Preface

The Association for Women in Mathematics (AWM)[1] held its Twentieth Anniversary Celebration at the Joint Mathematics Meetings in San Francisco, January 16-19, 1991. The festivities included: a Symposium entitled The Future of Women in Mathematics, highlighting ten young women mathematicians (within ten years of Ph.D.) who talked about their current research; a Graduate Student Workshop featuring ten women graduate students who presented their dissertation results; a Workshop Luncheon where dozens more students and AWM members met to discuss "Is there life after graduate school?"; the twelfth annual Noether Lecture (by Alexandra Bellow); the presentation of the first annual Louise Hay Award for contributions to mathematics education (to Shirley M. Frye); and the AWM Anniversary Banquet followed by an Open Party complete with disc jockey and everyone's favorite dancing music.[2]

It was truly a joyous occasion. For those of us who were around during the early years of the AWM, yet still imagine ourselves somewhat youthful, at least in outlook and perspective, any initial disbelief about the prospect of celebrating our twentieth quickly gave way to feelings of deep emotion and pride—pride on having clearly made it in our own way, indeed on our own terms. The numbers of women at the meeting, from old-timers to young faculty and graduate students, and even undergraduates, were staggering. As one woman put it, one did not have to look far to see female faces amongst the sea of faces in every session of the Meetings. Having been on the committees that picked the young women for the Symposium and Graduate Workshop, as well as the Alice T. Schafer Prize committee that awarded the first prizes last summer to two outstanding women undergraduates (Linda Green and Elizabeth Wilmer), I can testify to the elation we felt on seeing the large pool of extremely talented young women mathematicians. Clearly, these awards and invitations are viewed with great respect in the mathematics community, for we witnessed department heads and thesis advisors vying with each other to position their candidates well. Our only dismay was that we could not award all those deserving.

The following article on the history of the AWM is based on an after-dinner talk I gave at the Anniversary Banquet. Shortly after having agreed to give such a talk, it dawned on me that, unlike mathematics—which to some extent one can create in one's head—for history, one needs to have the facts. And, although for a certain period of my life I was intimately associated with the AWM, I certainly did not have total recall nor even near complete knowledge of all that had happened during the past two decades.

So I decided to enlist the help of all AWM Presidents. I wrote each of the other Presidents (Mary Gray, Alice Schafer, Judy Roitman, Bhama Srinivasan, Linda Rothschild, Linda Keen, Rhonda Hughes, Jill Mesirov, Carol Wood) asking "... if you could provide me a brief review of what happened during your term, perhaps discuss its special character ... and also comment on questions such as: How you feel AWM has made a difference, areas where we need work, ideas and hopes for the future .... (Any humorous/insightful anecdotes would be welcome.) I would then try to compile and interweave these stories [in my presentation] ... ."

The history I compiled is in large part a history as seen through the Presidents' eyes, a uniquely personal vision, culled from the many letters and email responses I received. It also comes from the *AWM Newsletters*, *Notices*, my personal files, and correspondence with Judy Green about the origins of the AWM. Her article with Jeanne LaDuke on "Women in American Mathematics: A Century of Contributions" (*WM*) in *A Century of Mathematics in America* (ed. P. Duren, AMS, 1989) as well as the

[1]The AWM was established in 1971 to serve and encourage women to study and have active careers in the mathematical sciences. Membership, now numbering over 4000, includes both women and men from the United States and around the world, representing all parts of the mathematical community. For more information about the AWM, its programs and activities write: AWM, Box 178, Wellesley College, Wellesley, MA 02181.

[2]Symposium speakers were: Carolyn Dean, Bernadette Perrin-Riou, Mei-Chi Shaw, Jiang-Hua Lu, Ruth J. Williams, Laurette Tuckerman, Lynne M. Butler, Joan Feigenbaum, Elise Cawley and Jill Pipher. Graduate student speakers were: Andrea Bertozzi, Jill Dietz, Ellen Gethner, Miilja-Riita Hakosalo, Deanna Hausperger, Kitty Holland, Diana Major, Susan Schwartz, Melanie Stein and Julia Yang. Debbie Lockhart and Hugo Rossi led the Luncheon discussion.

book *More Mathematical People* (*MP*) by Donald Albers, Gerald Alexanderson and Constance Reid (Harcourt, Brace, Jovanovich, 1990) were also helpful. I have also incorporated some of my own memories and experiences, not just as AWM President, but as a woman mathematician "growing up" during that time. "Brief" in the title is meant as a disclaimer acknowledging my many omissions.

In planning the talk, I decided to quote people directly rather than paraphrase or synthesize. This turned out to be an extremely fortuitous decision for a number of reasons, including the fact that it helped provide the eloquence and humor, in addition to substance, necessary for an ideal after-dinner talk. But even more, by reading the quotes directly, I along with the audience could thoroughly enjoy what everyone had to say. In uncharacteristic fashion, I could even ham it up a bit and add some dramatic effects of my own. Some of the humor was so infectious—we were in stitches—that a couple of times I had a hard time completing a sentence I was reading.

The audience was terrific. It comprised old friends and new. The students and postdocs were there as were very many AWM members whose involvement and support over the years have been so vital to our continuing successes. All AWM Presidents except Judy Roitman (whose semester had begun) and Linda Keen (who was in Helsinki) were present as were Bettye Ann Case (longtime AWM meetings coordinator) and Anne Leggett (longtime *AWM Newsletter* editor), who both earlier in the day had received AWM citations at the Business meeting. There was Marie-Françoise Roy of the European Women in Mathematics, Hope Daly and her Joint Meetings arrangement staff who have worked so closely with us over the years, Debbie Lockhart our program officer at the National Science Foundation (NSF), Mike Dooley of the Exxon Education Foundation, and AWM Executive Director Patricia Cross—the person behind-the-scenes orchestrating this happy event.

Jill Mesirov had suggested that I recognize everyone who had been involved in founding the AWM at the beginning, asking them to rise, and then as I went through the talk, those who joined AWM in five year intervals (Eileen Poiani had done something similar at the MAA's seventy-fifth), and this turned out to be great fun. I think by the end everyone had a chance to stand.

Since I had never given an after-dinner talk before, I was really somewhat apprehensive beforehand. I suspect others felt the same apprehension, for the only public announcement I could find of my talk was in the Banquet menu. At dinner, Mike Dooley who was sitting next to me offered little reassurance when he warned that such talks should never last more than fifteen minutes. So I knew I probably did okay when afterwards Mike said I really could have gone on for another fifteen. I glanced at my watch and much to my surprise I had talked for over forty-five minutes! And then Hope Daly came by to say how she had relived every minute of all the past meetings with me. But most of all, I felt the seal of approval when Judy Green, our consummate historian, came over beaming, gave me a hug and said "You did real good!"

Here is my attempt to recapture the magical spirit of that evening . . . .

PART 1

How it was . . .

I would like to begin my talk by recreating some of the atmosphere twenty years ago. So I must start with a warning: the next few minutes [i.e. this section] may be a bit depressing, perhaps even somewhat hard to take. But bear with me, I promise it really will get better.

First, for my journey back in time, I went to the library and checked out *Notices* for 1971. The Joint Mathematics Meetings that year were held in Atlantic City; the program in the January issue was quite revealing. Of the more than fifteen invited hour speakers—AMS, MAA and ASL combined—none was female (i.e. 0%); of the more than 300 AMS ten minute talks, about fifteen were given by women (5%). I became curious and looked at the Personal Items section. This contains short descriptions of individuals' professional activities and achievements as well as job promotions and appointments. Only five of the approximately 145 blurbs seemed to mention women (less than 4%). Of the thirty-one promotions listed, three were female (10%); at the instructorship level, women seemed to do relatively better, getting three of the nine appointments (33%). Here I used the well-known mathematical technique (which has served us so well over the years) of counting and dividing to calculate the telling percentages. And sure enough, as I went down the list—as the positions became less prestigious—the percentage of women increased. As if to confirm this trend even more dramatically, I noticed further on that, of the four deaths reported in that issue, two were women (50%)!

In the February 1971 issue I found a letter from Elizabeth Berman, pointing out some "advice" on how to find employment, recently published by the Mathematical Sciences Employment Register: "Women find the competitive situation in the government somewhat more advantageous to them, since it is relatively hard to secure a well-qualified mathematician for many higher level government jobs. In many such cases women are welcomed if their qualifications are better than those of the available men." Need I say more?

A gloomy picture of the status of women in academia was painted by Ruth Silverman in a letter that appeared in the June *Notices* that year. I quote excerpts:

"Editor, *Notices*:

"As a result of surveys on many campuses it becomes apparent that there is a pattern of discrimination against women in all fields . . .

"1) Women are predominantly at the bottom of the pyramid, irrespective of qualifications . . . and suffer a substantial salary inequity. 2) Many academic departments have no full-time female faculty at all. In many . . . the percentage of female faculty is far below the percentage of females among qualified applicants. 3) In many departments women with Ph.D.s hold positions below the rank of Assistant Professor and are kept at these low ranks without promotion or significant salary increase. 4) Women tend to be hired on a marginal, temporary, or one-year basis .... Often women teaching part-time have the same teaching load as men teaching full-time. 5) There are departments which make it a policy not to appoint women who are married to members of the faculty ..."

Silverman goes on to recommend that "in the forthcoming annual [AMS] salary survey data be collected ... comparing salary levels by sex." This practice was initiated by the AMS some years later.

Now, if you were a female graduate student at the time, there were certain departments where you probably were not. For example, Princeton did not start admitting women to their graduate program in mathematics until the fall of 1968. Marjorie Stein (Princeton Ph.D., 1972) was the first woman to complete her degree requirements there, although a Japanese woman had been admitted some years earlier by mistake. Apparently the admissions committee, unfamiliar with Japanese first names, did not recognize hers as female.

But wherever you were, you may very well have been told the following "joke" by the head of your department or your thesis advisor: "There have only been two women mathematicians in the history of mathematics. One wasn't a woman and one wasn't a mathematician."

Thus it may not be so surprising that in those years we were often accused of not having a sense of humor. (Ms. magazine addressed that issue with a famous pop art cover depicting the wry feminist humor typical of the '70s: A young man earnestly asks his woman friend "Do you know the women's movement has no sense of humor?" to which she answers straight faced "No ... But hum a few bars and I'll fake it!")

It must be said however that, sometimes at least, this mathematical in-joke was told well-meaningly (if not misguidedly)—as it were, a friendly gesture to break the ice. Certainly, that's how I had interpreted it several years earlier at a party given by my department chairman when I was a graduate student at MIT. And it clearly was a manifestation of the time, of the awkwardness everyone felt with the few women around. (It did not occur to me until some years later that it was also a callous dismissal of two of the most important mathematicians in recent history.) The effect was nevertheless to help alienate us from our history, to reinforce self-doubts, and keep us mostly unaware of the strong women contemporaries who could very well have served as important role models and mentors had we known their existence early on: Mina Rees, Julia Robinson, Mary Ellen Rudin, Cathleen Morawetz, Olga Taussky-Todd, Jane Cronin Scanlon, and Marian Pour-El are a few such examples of mathematicians at that time who come to mind.

I do not want to give the impression that all professors and thesis advisors were hopeless. Some of us were fortunate to have supportive advisors during those important years. Lipman Bers is a stunning example of a professor who did much to encourage young women in mathematics. As he put it (in *MP*), "It never occurred to me that women can be intellectually inferior to men." Among his many female Ph.D. students are Lesley Sibner, Linda Keen, and Tilla Milnor.

What we did ... (In the beginning)

Atlantic City

I think it is fair to say that the AWM had its birth at the Joint Mathematics Meetings in Atlantic City in 1971. As Judy Green remembers (and Chandler Davis, early AWM friend, concurs):

"The formal idea of women getting together and forming a caucus was first made publicly at a MAG [Mathematics Action Group] meeting in 1971 ... in Atlantic City. Joanne Darken, then an instructor at Temple University and now at the Community College of Philadelphia, stood up at the meeting and suggested that the women present remain and form a caucus. I have been able to document six women who remained: me (I was a graduate student at Maryland at the time), Joanne Darken, Mary Gray (she was already at American University), Diane Laison (then an instructor at Temple), Gloria Olive (a Senior Lecturer at the University of Otago, New Zealand who was visiting the U.S. at the time) and Annie Selden. [Harriet Lord (then a graduate student at Temple, now at Cal State Polytech at Pomona) was at the MAG meeting but unable to stay for the women's caucus.]

"It's not absolutely clear what happened next, except that I've personally always thought that Mary was responsible for getting the whole thing organized .... "

What I remember hearing about Mary Gray and the Atlantic City Meetings, indeed what perked my curiosity, was an entirely different event, one that was also to alter dramatically the character of the mathematics community. In those years the AMS was governed by what could only be called an "old boys network," closed to all but those in the inner circle. Mary challenged that by sitting in on the Council meeting in Atlantic City. When she was told she had to leave, she refused saying she would wait until the police came. (Mary relates the story somewhat differently: When she was told she had to leave, she responded she could find no rules in the by-laws restricting attendance at Council meetings. She was then told it was by "gentlemen's agreement." Naturally Mary replied "Well, obviously I'm no gentleman.") After that time, Council meetings were open to observers and the process of democratization of the Society had begun.

Boston

Meantime, in the Boston area, women mathematicians had already been meeting. As Linda Rothschild writes:

"My involvement with AWM began in the late '60s, before it formally existed. In 1969, Alice Schafer, then at Wellesley, and I (a graduate student at MIT) organized a group of women mathematicians and students to meet every few weeks to discuss common problems and goals. Bhama Srinivasan joined when she started teaching at Clark in 1970. [According to Alice Schafer, the original group also included Bernice Auslander, Kay Whitehead, Caroline Series (then a graduate student at Harvard), Eleanor Palais and, Linda Almgren Kime. Kime lived in Cambridge and that made an easy place for the group to meet.] When AWM was officially launched, our little group became the Boston area mafia of AWM. Through Alice's boundless efforts, an office was established for AWM at Wellesley, and it has been anchored there ever since . . . ."

Berkeley and me

In the beginning, I was quite ambivalent about the emerging women's movement in mathematics. As I replied to Linda Rothschild, "Thanks for the information. I was glad to have more details about the early days [of the AWM] in Boston. Things seem to have started up after I left (in '68) and it's not clear that I would have been involved . . . I was pretty 'unconscious' about such things at that time. It didn't hit me until I got to Berkeley."

The good thing about being "pretty 'unconscious' about such things" in those days was it left you free to do your mathematics. The bad thing of course was that either you internalized every negative message from society, subtle or overt, or else naively dismissed them as not meant for you. While I did not completely escape the former mode, I fit more naturally into the latter—which served me well up to a point, the point being that I also made important decisions naively.

A naive decision was for me to go to Berkeley.

After receiving my degree, I had an excellent job offer (assistant professorship) on the East Coast (Yale), my husband on the West Coast (Berkeley). We also had various joint offers, moderately good for each of us. We were up against the famous 2–body problem, classic for women mathematicians as I was to learn later (from *AWM Newsletters*[3]). But at the time, we knew of no one who might offer some wise, even sympathetic advice. I ended up accepting a lectureship at Berkeley[4] being quite assured (by the department chairman and vice-chairman) that the position was competitive in practice (if not in title) with my other offers, and that things would work out. Of course they did not.

The spring of 1971 was a particularly bleak time for me professionally. But, then again, I was in Berkeley. It was the era of People's Park, Cambodia, and Vietnam. I would have had to have been totally unconscious not to be affected by the political events around me. But also, in truth, I found it quite exciting, reminding me of a much earlier period in my life. In the Math Department, Moe Hirsch, John Rhodes, and Steve Smale had organized a Colloquium series on "Social Problems Connected with Mathematics." When Steve asked me to chair a colloquium on "Women in Mathematics," I quickly agreed.

Since I didn't know much about women in mathematics, I found three women who did: Ravenna Helson, a research psychologist who had done a study on women mathematicians and the creative personality; Sheila Johannsen, a historian knowledgable about the history of women in mathematics; and Betty Scott, chair of the Statistics Department at Berkeley, who had just co-authored a report of the Academic Senate on the status of women on the Berkeley campus.

The colloquium panel was a great success. The lecture hall was packed. And it was quite an eye-opener for me. For one, it had never occurred to me that there might be common personality traits amongst women mathematicians, except perhaps that we were each unique.[5] It had never occurred to me how statistics could be a powerful political tool. I found Betty Scott's study a masterpiece, fleshing out cold data with poignant case studies. And then there was data that spoke clearly for itself, for example, her data on faculty positions in the Berkeley Math Department (ladder positions):

academic year	*% women*
1928/29	20
1938/39	11
1948/49	7
1958/59	3
1968/69	0

But also, it was the first time I had heard about Hypatia (born in Alexandria, c. 370 A.D., wrote and lectured on Diophantine arithmetic, butchered to death at the age of 45 by religious fanatics), Maria Agnesi, Sophie Germain, and more. Sonya Kovalevsky's motto, "Say what you know, do what you must, come what may," which many of us immediately adopted as our own, told me that this was a woman who could not be cursorily dismissed.[6]

After that event, I became known as *the* expert on women in mathematics, on the West Coast at least. More importantly, I started to meet regularly with some of the women math graduate students: Laif Swanson, Joan Plastiras, and Judy Roitman. And, to use Linda Rothschild's expression, this

[3]See for example, Rebekka Struik's article, "The Two City Problem," (*AWM Newsletter*, September 1974) or Marian Pour-El's article in *Mathematics Tomorrow* (edited by L.A. Steen, Springer-Verlag, 1981).

[4]Here I was in illustrious company. Before me there was Julia Robinson who, from time to time, was a lecturer at Berkeley until she was elected to the National Academy of Sciences in 1975 (and then immediately promoted to full professor). With me as lecturer was Karen Uhlenbeck. After that, there was a long line of prominent women mathematicians (and AWM members) including Chuu-Lian Terng, AWM President Jill Mesirov and Ruth Charney, member of the AWM Executive Committee.

[5]Although, when I thought back, the three women in my class in graduate school all had been born in New York City, all were Jewish (at least in part), all studied at women's schools, married in college, had babies while in graduate school, and all studied logic.

[6]There is an interesting story here which I heard then for the first time. In 1888, Kovalevsky submitted her paper, "On the Rotation of a Solid Body about a Fixed Point" to the French Academy of Sciences to compete for the Prix Bordin. Papers had to be submitted anonymously with signatures coded by the author. That motto was Kovalevsky's code. Her anonymous paper was deemed so exceptional that the prize money was increased from 3000 to 5000 francs.

little group was to become the Berkeley "mafia" of the AWM.

The First Decade (1971-1981) Building the foundations, a time of many firsts

Mary Gray (1971–1973): The mother of us all

Without a doubt, Mary Gray is the founder of the AWM and the "mother of us all." As Carol Wood (who became AWM President in January 1991) put it: "My overwhelming sense ... is that AWM would not have existed when it did, if at all, without the energy and vision of Mary Gray. That is probably too obvious to say, and of course there are others who shaped, changed, nurtured, etc. in critical ways ... But I was always struck by Mary's vision, and I think that our birthday party is an excellent opportunity to honor Mary ..."

Mary Gray

I first remember seeing a small announcement for the new organization, the Association of Women in Mathematics, placed by Mary in *Notices*, February 1971. The first issue of the *AWM Newsletter* (clearly written by Mary) appeared that May listing Mary Gray as chairman. By the second issue, "of" was changed to "for", but I don't recall when "chairman" was replaced by "President."

The *Newsletter* has since become the very embodiment of the AWM. From the start, it was our forum for discussing the role of women in mathematics, for exposing discrimination, for exchanging strategies, encouraging political action and, affirmative action, for informing, supporting, honoring, and of course, for job listings (which first appeared in the February 1972 issue). It has been our key linkage with each other, with credit due largely to Mary and subsequent editors, Judy Roitman and Anne Leggett.

Mary set down goals and agenda for the early AWM. In an article ("Uppity Women Unite!") in the January 1972 *MAG Newsletter* she wrote: "We have some plans to improve the status of women in mathematics ... There are two categories of problems, those involving the general female population and those involving professional women mathematicians. We must go back to the elementary schools—rewrite textbooks, use films, etc., and retrain the teachers and counselors. The goal is to show girls and boys that girls *can and should* learn mathematics ... As a small first step, careful attention must be given by the mathematical community to the mathematical training of elementary schoolteachers, to see that they learn to like mathematics as well as learning mathematics ..."

Mary goes on: "What do women want? Let me be specific as far as women mathematicians are concerned: 1) Equal consideration for admission to graduate school and support while there, 2) ... for faculty appointments at all levels ..., 3) Equal pay for equal work, 4) Equal consideration in assignment of duties, for promotion and for tenure, 5) ... for administrative appointments at all levels in universities, industry and government, [and] 6) ... for government grants, positions on review and advisory panels and positions in professional organizations. Because of past injustices, special efforts will have to be made for some time to find women to consider. AWM is ready to help. Now is the time for discrimination to end."

What seems quite amazing now is that these were considered radical demands!

Mary Gray informed us (sometimes in far greater detail than many of us cared to know) of legislation on discrimination and affirmative action and urged us to become involved. She was not afraid to say things straight, to take on the establishment single-handedly. Challenging the system, she successfully ran in 1976 as a petition candidate for Vice-President of the AMS. As Bhama Srinivasan said when we met in Berkeley last fall, "Mary had the courage, and willingness, to take the initial steps and the initial hostility ... [charting a course] which eventually wiped out the 'old boys network.' "

Not all women mathematicians were enthusiastic about the AWM in the beginning. For example, as Cathleen Morawetz (in *MP*) puts it, "I did not want the Association for Women in Mathematics to speak for all women mathematicians. I joined them later, but at that time they were terrible attackers ... "

Nevertheless, she played an important role herself in changing the consciousness about women in mathematics. "I was on a committee for disadvantaged groups in the Math Society, and I thought there should be a separate committee for women. I was terribly afraid when I went before the Board of Trustees—or it may have been the Council. Anyway, when it came my turn to speak, I said 'There's a problem with women. You may not have noticed that there are not many women mathematicians.' "

Cathleen continues, "At that point Saunders Mac Lane said, 'Well, mathematics is a very difficult subject.' I was not up to coping with that, but Iz Singer picked up the ball. The committee [on women] was formed and I was made chairman ... "

In 1973, the Committee on Women published the first Directory of Women Mathematicians.

Alice Schafer (1973–1975): AWM Incorporated

In terms of its organizational structure, I picture AWM as an evolving continuum (built with boundless energy and grass roots networking). There is considerable overlap between one presidency and the next. Indeed, the boundaries between terms often seem quite hazy with each subsequent President building on what came before—as well as each preceding President continuing to stay actively involved. Nobody seems to take a back seat and nobody seems to retire.

This dynamic was already in evidence in the first transition from Mary Gray to Alice Schafer: "When I took over the presidency, Mary sent me a box with all sorts of papers, checks, etc ... When I asked [her] what I could do, she suggested getting AWM incorporated." Alice then goes on to relate her struggles setting up an official structure for the fledgling organization.

"That was done through a lawyer in Boston, who I had been told would charge very little, so I was amazed when he charged $500, which was really big money for AWM, and so, in the *Newsletter*, I asked for a contribution of a dollar from each member. Some gave and AWM did finally pay the bill. When it came to obtaining tax exemption status from the IRS, the lawyer said he would do it and I said first I would try. He said I could not do it, but [nevertheless] I did ..."

In the early days, money was indeed a problem. And so Alice continues: "Do you recall that one time the March *Newsletter* was printed in such small print in order to save money that many people could not read it? I think that was during my presidency. However, I do not recall that anyone sent in a contribution because of it [to help us out], but I may be wrong."

For those of you who were not around during those years, and for those of us who may have forgotten, Alice goes on to paint a colorful, and almost slapstick, picture of what we were up against and how she handled it: "One of the ... funny things that happened, that I recall, during my presidency is that when the meeting was in San Francisco [January 1974] AWM was still being harassed by the male mathematicians. Lee Lorch, friend of AWM, came to tell me that some of the men were going to attend the AWM meeting, which I was chairing of course, and were going to break it up. He thought I ought to be warned. I was glad of the warning and told him that teaching in high school for three years (before I had enough money to start graduate school) ought to prepare me for that! Actually, what is interesting, historically, is that meeting was the first time AWM had ever sponsored mathematical talks; before that it had all been consciousness raising. I had invited Cathleen Morawetz and Louise Hay to give short talks on mathematics ... and had scheduled them ahead of the consciousness raising part, and of course, their talks were good. The men, who were for the most part sitting in the last two rows in the audience, never said anything. I never knew who they were and it didn't matter ..."

Seated left to right: Alice Schafer, Carol Wood, Jill Mesirov, Rhonda Hughes. Standing left to right: Ruth Charney, Bettye Anne Case, Eleanor G. D. Jones, Susan Geller, Jenny Baglivo.

During this period, in addition to building its own internal structure, the AWM was also beginning to establish itself as a legitimate professional society, to be reckoned with amongst its peers, i.e. other mathematical organizations. To the consternation of the men who were "sitting in the last two rows" (whose shenanigans were once again foiled by Alice),[7] by the end of Alice's term AWM was about to be admitted as an affiliate member of the Conference Board of Mathematical Societies (CBMS), the umbrella society of mathematical organizations. By the time I became President, all I had to do was put on the finishing touches, and there we were, on the same Council (and on the same CBMS letterhead) with such organizations as the AMS, ASL, IMS, MAA, NCTM, SIAM, ASA, ACM, and ORSA, among others. An amazing feat for an association that was only four years old!

[7]As I recall, shortly after the AWM applied for affiliate membership in the CBMS, a mysterious math society, apparently originating in the mid-west, decided it also was worthy of CBMS membership. Its application caused something of a commotion, prompting the CBMS to reevaluate its membership criteria. This delayed AWM's entrance for about a year, but in the end, AWM was able to meet the stiffer requirements.

In its first venture into internationalism, AWM sponsored a panel at the International Congress of Mathematicians (ICM) in Vancouver, the summer of 1974, to compare the situation for women in mathematics worldwide. Speakers included: Sheila Brenner (England), Michele Vergne (France), Bhama Srinivasan (India), and Xuan Hoang (North Vietnam). Other firsts in the mathematical world during this period included Barbara Osofsky's AMS Invited Address in Dallas, January 1973—the first such address at a national meeting by a woman since Anna Pell Wheeler's Colloquium Lectures in 1927[8]—and Sloan fellowships awarded to Joan Birman and Karen Uhlenbeck in 1974.

Lenore Blum (1975–1978): Exploring new territory

In August 1975, I became President of the AWM (and served in that capacity for three years.) Since Mary had already captured the attention of the mathematics community head on, and Alice had set up the foundation for a working organization, I was mostly free to explore new territory. It seemed clear that the provincial view of mathematics—including who a mathematician was, and what a mathematician did—was a prime factor in the exclusion of women, as well as others, from the field. It also seemed clear that the provincial view was potentially limiting to the discipline itself.

So, to make this "statement," as well as to further educate myself, I decided to use the public forum which had proved so successful in Berkeley.

In those years, the academic job market for mathematicians was very tight. Many young people were in a terrible bind, given the prevailing view that the only respectable work for a mathematician was in academia. Since women mathematicians had been finding creative alternatives to academic employment for years, their experiences could be particularly useful, perhaps even change an image. I organized a panel on "Women Mathematicians in Business, Industry, and Government" for the January 1976 Joint Mathematics Meetings in San Antonio (and a similar one in Seattle, the summer of 1977). Here I met for the first time: Marjorie Stein, a mathematician working at the U.S. Postal Service (Statistical Service Requirements Division); Jessie MacWilliams, a coding theorist at Bell Labs; Mary Wheeler of Rice, also a consultant for oil companies, working on numerical solutions to P.D.E.'s; Marijean Seelbach, a topologist and functional analyst working on optimal control theory at NASA–Ames. These energetic women had clearly found unusual and challenging career paths for themselves utilizing their mathematical training and skills. It was quite inspiring.

Many of us were eager to explore further our history. I decided to organize some panels at the Joint Math Meetings on the "History of Women in Mathematics" with AWM members as speakers. What was so powerful about these sessions, even historic in itself, was that for the first time women mathematicians were talking about women mathematicians (their lives and their work) to women mathematicians. By understanding their work, possibly even identifying with their lives, the speakers were able to convey uniquely meaningful, deeply personal portraits of the women who had come before us. The sessions were charged!

In Toronto (summer 1976), Mary Gray talked about Sophie Germain and her work (a bicentennial perspective), Linda Keen about Sonya Kovalevsky (her extraordinary life and mathematical achievements), Martha Smith about Emmy Noether (her work and tremendous influence). As an added treat, Emiliana Noether came to talk about her aunt (-in-law). In St. Louis (at the infamous cold winter Meeting of 1977), Teri Perl told us about the "Lady's Almanac," a popular women's magazine published in England from 1704 to 1841, devoted in large part to mathematical questions and solutions.

But perhaps one of the most moving occasions was when Sylvia Wiegand spoke of her grandmother, mathematician Grace Chisolm Young. Because women were not admitted to graduate schools in England at the turn of the century, Grace went to Germany and became the first woman to receive a formal degree in mathematics in Göttingen—indeed the first woman Ph.D. in Germany in any field. When she returned to England, she married William Young, her former tutor. Sylvia read a poignant letter from her grandfather to her grandmother, written some years later:

> "I hope you enjoy this working for me ... I am very happy that you are getting on with the ideas. I feel partly as if I were ... setting you problems which I could not quite do myself but could enable you to ...
> "The fact is that our papers ought to be published under our joint names, but if this were done neither of us get the benefit of it. No. Mine the laurels now and the knowledge. Yours the knowledge only. Everything under my name now, and later when the loaves and fishes are no more procurable in that way, everything or much under your name.
> "This is my programme. At present you can't undertake a public career. You have your children. I can and do."[9]

An historic panel, "Black Women in Mathematics," organized by Pat Kenschaft and Etta Falconer, was held in Atlanta, January 1978. Of the twelve black women in the U.S. holding Ph.D.s in mathematics at the time (more of course held degrees in mathematics education), six were on the panel: Geraldine Darden, Elayne Idowu, Eleanor G.

[8]In the interim, women had been invited sporadically to speak at local meetings: Pauline Sperry (1933), Emmy Noether (1934), Olga Taussky-Todd (1959), Cathleen Morawetz (1969), Mary Ellen Rudin (1971), Mary Elizabeth Hamstrom (1972).

[9]See *AWM Newsletters* and also, *Math Equals* by Teri Perl, (Addison-Wesley, 1978). A number of biographies of women mathematicians by women mathematicians have appeared in the *Newsletters* over the years. As an example, in the July 1978 issue, Bhama Srinivasan writes about Ruth Moufang (1905–1977), dedicating her article to the many mathematicians who have exclaimed, "You mean Moufang is a woman?"

Jones, Evelyn Roane, Dolores Spikes and Etta Falconer.[10]

These AWM sessions at the national meetings were immensely popular. We were clearly identifying and addressing subjects of interest and issues of concern to the mathematics community-at-large (well before these issues were recognized by the establishment as legitimate, even critical). As a consequence, we began to broaden our constituency, attracting people who had perhaps felt uncomfortable with the more political tone of earlier days.

But political issues were nevertheless still very much on our minds. We provided testimony for congressional investigations, wrote university presidents and newspaper editors and letters (often signed jointly by the three Presidents Mary, Alice and me) protesting objectionable images of girls and women in textbooks, the media, and advertising. (In school math books, girls were still calculating the perfect recipe, while boys calculated the time to get to the moon. Flyers depicting a naked woman contemplating a calculator were still being distributed at the Math Book Exhibits in 1976.) In 1978, a masterful combination of teamwork and old girl networking resulted in decisions by the AMS and MAA not to hold national meetings in states that had not ratified the ERA (Equal Rights Amendment). At the International Congress in Helsinki (ICM-78), a special meeting was called by the AWM to protest the absence of women speakers. Over 500 people attended. I introduced a resolution (amended by Lee Lorch) urging this situation be rectified by the next Congress. The resolution passed by a near-unanimous vote (only three dissenters).

It was a time of heady issues, but also a time of great excitement and great fun. It was a time of newly found camaraderie, of friendships, of support and respect among women mathematicians.

I was clearly a beneficiary of this "sisterhood" during my presidency. Besides the two former Presidents to guide me, Judy Roitman was *Newsletter* Editor and Judy Green, AWM Employment Officer (a title deemed appropriate since she had taken it upon herself to analyze employment data and monitor the legitimacy of job advertisements). Both Judys were co-Vice-President.

Judy Roitman and I had become great friends during the early Berkeley days, and as I wrote in the November 1978 *Newsletter* welcoming her presidency, "... our friendship has grown with, indeed, has been intertwined with, our involvement in ... the AWM." She was (and is) a great—and speedy—writer, and since writing was not one of my better skills, many a President's Report was told (I can hardly say dictated) to her over the phone the night before the *Newsletter* went to press.

Judy Green often played the role of political advisor, telephone consultant, as well as AWM liaison with the Mathematics Action Group (MAG) and the National Association of Mathematicians (NAM), the association for black mathematicians. In preparing this history, I queried her: "Even though you were never President, you very well could ... have been. How come we never could get you to 'run'? You were doing a lot of the work de-facto anyway." To which she replied, "... I'm much better helping people than being in charge. I really don't like being out there in front. Judy Roitman and I were co-Vice-Presidents since neither one of us would say we'd be President-elect. At the end, she gave in before I did!" That also helps explain why my term lasted as long as it did!

Discrimination/Affirmative Action. Before going ahead, I would like to take out a few moments to address directly a few aspects of the twin issues of discrimination and affirmative action that were so central to our lives in those years.

The AWM gave women mathematicians courage to speak out publicly, even file complaints and charges about their own situation. As a consequence, our files were overflowing with correspondence from women documenting discrimination, seeking assistance and advice. Mary Gray, being the most knowledgable, handled most of these cases throughout the 1970s, but we all did some.

Affirmative action rulings often produced backlash and many abuses. For example, in order to satisfy affirmative action guidelines, many math departments resorted to "papering the files," inviting women to apply for jobs that didn't exist or had already been offered to men. A related practice is illustrated by the following letter from a woman mathematician on the East Coast to the Vice-Chairman of the Math Department on the West Coast. The names have been removed, not so much for anonymity, but rather to stress genericity:

"Dear Professor X, This is the third consecutive year that I have been invited to apply for the position of Assistant Professor in the Mathematics Department of [West Coast University]. I assume it is the third year of [WCU]'s Affirmative Action program. As I mentioned in my last response to such an invitation, I have been Associate Professor since the first year. It is hard to believe that [WCU] is serious about its Affirmative Action program if it makes no attempt to match the experience of the candidate considered with the positions available. Would you be interested in a job as Assistant Professor?

"Sincerely, Y"[11]

Indeed, while many in the mathematics community believed that there was an influx of women faculty as a result of affirmative action, the data in the early years showed quite the contrary. As an example, between 1973-1974 and 1974-1975 the percentage of women in regular math faculty positions, in most instances, actually went down; and no significant rise became evident until very much later. (See

[10]Their stories are published in the September 1978 and May-June 1980 *Newsletters*. Also see Pat Kenschaft's article, "Black Women in Mathematics in the United States," (*American Mathematical Monthly*, vol. 8, no. 6, 1981). Lee Lorch plays an important role here. Three women who studied with him at Fisk (during the period 1950-1955) went on to get Ph.D.s in mathematics: Etta Falconer, Vivienne Mayes-Malone and Gloria Hewitt.

[11]Y, a pioneer in the application of non-linear mathematics to understanding chemical and biological phenomena, is recipient of numerous honors and awards, including a Sloan, a Guggenheim and a MacArthur "genius" award.

Judy Green's article in the April 1975 *AWM Newsletter*, mine in the May-June 1976 *CBMS Newsletter*, and Mary's and Alice's in *Notices*, October 1976.)

Judy Roitman (1978–1981): A summing up

The early years of the AWM were a time of activism, of speaking out, of politics, of confrontation, of heroes and villains—when issues seemed almost black or white. Judy Roitman provides a perspective on the decade: "I can summarize my time in AWM office by saying that I was one of the last—perhaps the last—President of an amateur AWM. What do I mean by this?

Judy Roitman

"The AWM grew out of the feminist movement of the 1970s, which was marked by confrontation, attention to, and expression of, personal feelings and individual incidents, and ignorance of history. Having finally read some of this history (Margaret Rossiter's excellent book on American women scientists) I suspect that had we known how closely we were following in the footsteps of earlier feminists, and how little change their tremendous efforts made, we probably never would have bothered. So the early job of the AWM was just to look around us and report the obvious—the situation for women was terrible—and the apparently not-so-obvious—it didn't have to ... be that way. We spent a lot of time popping up at meetings (departmental, local, national) saying over and over again that women could be perfectly good, even great, mathematicians if given the opportunity ... and that there were several steps the mathematical community could take to improve things for both women and minorities. It was an easy kind of agitation—you just had to look around you and report what you saw ...

"But while this style had its successes, it was based on a sort of shooting from the hip. That is why I characterize it as being amateur ..."[12]

It was also a time of lassoing people in. In addition to national meetings of the AWM, members were organizing and meeting regionally: Sue Montgomery and Ruth Afflack in Southern California, Rebekka Struik in the Rocky Mountain region, Jessie Ann Engle, Judith Longyear and Vera Pless in the Midwest, Pat Kenschaft in New Jersey, Linda Keen in New York, to mention only a few. In the mid-1970s, AWM instituted an Open Council, encouraging the participation of members representing a wide range of self-identified constituencies and areas of interest.[13] By 1981, AWM had grown to over 1000 members (from the U.S. and fifteen other countries), its influence and political power ranging far beyond these numbers. For example, then and over the years, AWM-supported candidates in AMS elections have been quite likely to win.

The 1970s were certainly a time of increased consciousness about women in mathematics. It was also a time of many firsts. Two notable additions to those already mentioned are Julia Robinson's election to the National Academy of Sciences[14] and Dorothy Bernstein's election as President of the Mathematical Association of America (MAA), both in 1975. During Judy Roitman's term, the AWM Noether Lectures (chaired first by Karen Uhlenbeck) were inaugurated by Jessie MacWiliams at the San Antonio meeting in January 1980.[15]

But also, it was a time of solid program development and achievements. During those years, many of us were involved in designing and implementing educational programs to increase the participation of girls and women in mathematics. Other organizations—such as the Math/Science Network, headquartered in the San Francisco Bay Area, and Women and Mathematics (WAM), founded by the MAA—to which many AWM members belonged, were also very much part of this effort. Since the old system was clearly not working for us, we were motivated to explore new paradigms in teaching:

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[12]Not completely. It should be noted, for example, that the AWM by-laws were written and passed during Judy Roitman's term. Creatively, they stipulated both formal structure and procedures for AWM's governance, while at the same time leaving room for flexibility.

[13]An impressive list of such Council members, contained in the September 1978 *Newsletter*, indicates broad AWM membership interests and affiliations: pure and applied mathematics research; colleges, universities and research institutions; math education; career counseling; teacher education; four-year state colleges; two-year community colleges; high school math teachers; history; and retired women.

[14]According to (MP), "when the University [of California at Berkeley] press office received the news [of Robinson's election], someone from there called the mathematics department to find out who Julia Robinson was. 'That's Professor Robinson's wife.' 'Well,' replied the caller, 'Professor Robinson's wife has just been elected to the National Academy of Sciences.' "

[15]The Emmy Noether Lecturers have been: F. Jessie MacWilliams, Olga Taussky-Todd, Julia Robinson, Cathleen S. Morawetz, Mary Ellen Rudin, Jane Cronin Scanlon, Yvonne Choquet-Bruhat, Joan S. Birman, Karen K. Uhlenbeck, Mary F. Wheeler, Bhama Srinivasan, Alexandra Bellow.

developing hands-on activities and materials stressing problem solving skills, promoting team teaching and cooperative learning, providing role models and information to students (as well as their parents and teachers) about why mathematics was important for their future.[16] Of course, all this made sense in general. And indeed, educational programs we developed in the 1970s are now models for educational reform in the 1990s. A stellar example is Nancy Kreinberg's EQUALS teacher training program at the Lawrence Hall of Science in Berkeley. (Many articles describing successful educational programs and strategies can be found in *AWM Newsletters.*)

PART 2
The Second Decade (1981–1991): A coming of age

The second decade in the life of the AWM can be characterized variously as a period of maturing, of coming of age, of increased self-assurance, of establishing and strengthening institutional mechanisms, of gaining acceptance by the mathematics community. It was a time when AWM grew up. Indeed, these are the themes and phrases that kept recurring in my conversations and correspondence with the AWM Presidents of the 1980s.

Bhama Srinivasan (1981–1983): Noether Symposium, Speakers Bureau, Research vs. Education?

On one of those gorgeous Berkeley afternoons last fall, Bhama Srinivasan and I met at a picnic sponsored by the women graduate students in the Berkeley Math Department. Bhama had been visiting as part of the algebra year at MSRI. Being the two senior mathematicians at the picnic, it was natural to chat with the students about the usual issues that come up about women and mathematics. Much to our surprise, they knew very little about the AWM! We talked about the upcoming Twentieth Anniversary and reminisced about AWM's Tenth (also held in San Francisco at the beginning of Bhama's term). I'm not sure we made any new recruits, but the students did arrange to keep meeting weekly. And so the process renews itself.

During Bhama's presidency, AWM sponsored its first major mathematical conference, the Noether Symposium at Bryn Mawr College. Bhama credits Rhonda Hughes with the idea. The Symposium, in honor of Emmy Noether's 100th birthday, was held in March 1982, appropriately at the institution where Noether held her last position. There were nine scientific lectures as well as a panel discussion. The event "was not only scientifically successful but a specially moving occasion," Bhama remembers. Three of the women who had studied with Noether at Bryn Mawr spoke at the Symposium. They painted a picture of a mathematically charged, particularly precious time, dominated by Noether and fully integrated with women:

"Meeting Emmy Noether was one of the great things in my life," said Olga Taussky-Todd who, in 1934, had come from a research post in Göttingen to study with Noether at Bryn Mawr. "She was a teacher and she had a great urge to make people see her methods and to understand them. At Bryn Mawr it was particularly easy for me to profit ... from her school. There was her thesis student Ruth [Stauffer McKee]. There was Marie Weiss who worked on a problem explicitly suggested to her, namely units in cyclic fields, using ideas of Latimer. For this we had to thank Grace [Shover Quinn]."

Bhama Srinivsan

"We not only studied together, attended Miss Noether's and Mrs. Wheeler's lectures also," recalled Grace S. Quinn, "but we really played together, walking down Gulph Road with Miss Noether in the lead discussing mathematics intensely all the while unmindful of the traffic ..."

Ruth McKee recalled how it was to be in Noether's classes. "The strange phenomena was that from our point of view, she was one of us, almost as if she too were thinking about the theorems for the first time. There was a lot of competition and Miss Noether urged us on, challenging us to get our nails dirty, to really dig into the underlying relationships, to consider problems from all possible angles. It was this way of shifting perspective that finally hit home ... suddenly the light dawned and Miss Noether's methods were the only way to attack modern algebra ..."[17]

[16]In 1979, at the summer Meeting in Duluth, Judy Roitman organized an AWM panel "Mathematics Education: A Feminist Perspective" to discuss these new programs and strategies. Speakers included: Deborah Hughes Hallett, Diane Resek, and myself.

[17]McKee went on to stress how Noether's methods were directly applicable to her own work and living. Her remarks seem particularly relevant today, as the math community seeks words and ways to communicate to policy makers,

The Symposium proceedings, *Emmy Noether in Bryn Mawr*, (edited by Bhama and Judith Sally) were published by Springer-Verlag in 1983.[18] Yet another first for the AWM!

As we drove from the picnic, Bhama and I talked more about the AWM. She reminded me of the tensions that had begun to surface during the early 1980s: Were we an organization of research mathematicians or did we represent the interests of all women in mathematics, particularly in education? Now that we were not as preoccupied with political issues as in the early years, it seemed we were having an identity crisis! Bhama recalls, "I was concerned about how to balance our various (and sometimes conflicting) constituencies and interests. So I set up a number of new committees [including the Committee on Mathematics Education, chaired first by Evelyn Silvia and now by Sally Lipsey, and the Maternity Committee, presently chaired by Anita Solow] to address these issues and involve many more women in the workings of the AWM.

Also during this period, the AWM Speakers Bureau—funded initially by grants from Polaroid, then Sloan, and directed by Judy Wason—became fully functional.[19] The Speakers Bureau provides lists of speakers and topics appropriate for high schools and colleges. This highly successful AWM activity has proved to be one of the best ways to improve the visibility of women in mathematics.

Linda Rothschild (1983–1985): A period of transition, The White House, A mathematical mentor

Linda Rothschild speaks of her presidency as "a period of transition: AWM was becoming established as a 'serious' and 'respectable' mathematics organization at that time (for better or for worse!) ... Even the White House recognized AWM as a serious organization by inviting its President to a luncheon for women's professional group leaders in honor of Women's Business Day."

Keeping with AWM tradition, Linda organized a panel (at the January 1983 Meetings in Denver) addressing issues of "Mathematics and Computers" well before this topic became fashionable in the larger mathematics community.[20] She also took care to balance research/education concerns by organizing panels on grantsmanship ("Getting them and keeping them," Albany, August 1983)[21] and, with Kay Gilliland of EQUALS, on how teachers of mathematics can encourage girls in their classes (Eugene, August 1984).

But "of the various panels I put together for the national meetings," Linda writes, "perhaps the most applauded was the one honoring Lipman Bers on his seventieth birthday [at the Louisville Meetings in January 1984] for his contribution to nurturing the success of so many female graduate students." Echoing the sentiments felt by many of us, she adds, "If only there had been ten others like him, think how many more women mathematicians there might be!"[22]

Linda described the session in the March-April 1984

Linda Rothschild

and the public, the value of mathematics: "Miss Noether's methods of working and thinking became the basis for my analytical work at the research agency of the Pennsylvanian State Legislature for almost thirty years. It is probably heresy for me to mention this in front of so many theoretical mathematicians but there is a great need in government for abstract imaginative thinkers to help solve all sorts of problems. For example: What are the basic cost factors in a given government funded program? What is the taxpayer's money really accomplishing? During my career we searched for answers to these questions in such areas as the construction of public school buildings, the operating of State mental hospitals, the faculty workload at various levels of education, highway engineering as directed toward traffic safety. We chewed over the characteristics and searched for the basic independent variables when considered from all possible points of view. Other times the problem was to find the relevant variables to determine an equitable distribution of appropriations. What was the most important factor? population density? financial need? or simple geography? . . ." (See the Symposium proceedings.)

[18]Contributors to the Noether proceedings include: Armand Borel, Walter Feit, Nathan Jacobson, Jeanne LaDuke, Marguerite Lehr, Ruth S. McKee, Uta C. Merzbach, Emiliana P. Noether, Gottfried E. Noether, Grace S. Quinn, Judith D. Sally, Richard G. Swan, Olga Taussky, Karen Uhlenbeck, Michele Vergne.

[19]Special credit for securing funds is due Eleanor Palais, longtime chair of the AWM Fund-raising Committee, and to Mary Gray and Alice Schafer.

[20]The panelists (Nancy Johnson, Louise Hay, Lucy Garnett, Marci Perlstadt and myself) talked about personal computing, running a math department with computers, evolution from mathematician to the field of computers, and computers in, and influence on, mathematical research—all quite novel topics at the time.

[21]Speakers included Judith Sunley, Alice Schafer, Rhonda Hughes, and Cora Sadosky.

[22]For remarks on previous mathematical mentors of women in the U.S., see "Women in the American Mathematical Community: The Pre-1940 Ph.D.s" by Judy Green and Jeanne LaDuke (*The Mathematical Intelligencer*, vol. 9, No. 1, 1987). Of their group of 229 pre-1940 Ph.D.s in mathematics, more than a third were advised by 8 mathematicians: Charlotte Angas Scott and Anna Pell-Wheeler (at Bryn Mawr) and 6 men—Frank Morley (at Johns Hopkins) and A.B. Coble (at Johns Hopkins and Illinois), Aubrey Landry (at Catholic University), Virgil Snyder (at Cornell) and Gilbert Ames Bliss and L.E. Dickson (both at Chicago where together they advised 30 women Ph.D.s). It is not hard to surmise that each of these men felt secure in their position in mathematics. Like Lipman Bers, all but one were at one time President of the AMS!

AWM Newsletter: "The lecture hall was filled with people who wanted to find out the secret of the 'Bers' mystique. We learned first hand that the statistics are truly remarkable. Professor Bers had had 40 Ph.D. students of whom 16 were women. The panelists, Tilla Milnor, Irwin Kra, Jane Gilman, Jozef Dodzuik and Linda Keen (moderator), all former Bers students, told fascinating stories about their experiences in graduate school ..."

What was it that made Bers such a good advisor of women students? Linda Keen provides some insights. "He gave us all, and probably the women needed it more, a confidence in our own abilities. He took it for granted that we would expect to have families and that we would continue anyway."

Linda Keen (1985–1987): Kovalevsky Symposium, Robinson Memorial, ICM-86

Linda Keen recalls highlights of her stint as AWM President. "The first highlight was the Sonya Kovalevsky celebration run by the AWM at Radcliffe together with the Mary Bunting Institute [in October 1985]. This was a two part affair. The first was a program for high school seniors, held on the campus—organized by Bernice Auslander and Pamela Coxon with help from the whole Boston group. There were talks about mathematics as well as talks about careers. The students had lunch together and had a chance to talk informally to a number of women mathematicians." This event was to become the model for the many Sonya Kovalevsky High School Days sponsored since by the AWM.[23]

From left to right: Lenore Blum, Carol Wood, Judy Green, Linda Keen.

"The second part of the affair," Linda continues, "was more 'my baby.' It was a serious mathematical conference on the theme of mathematics that had grown out of Kovalevsky's work. There were about ten speakers, more than half women." Three special sessions (organized by Jane Cronin Scanlon, Lesley Sibner, and Jean Taylor) in conjunction with the Kovalevsky Symposium were held at the AMS meeting in Amherst two days earlier. *The Legacy of Sonya Kovalevskaya*, a collection of papers[24] presented at both events and edited by Linda, was published in 1987 (AMS, *Contemporary Mathematics*, volume 64).[25]

"Then there was the Julia Robinson Memorial session sponsored jointly by the AWM, the AMS, and the MAA [New Orleans, January 1986]. It was really a super affair with great talks." Constance Reid, Julia's sister and biographer of mathematicians, spoke about Julia's life.[26] Lisl Gaal gave a brief description of Julia's thesis, and Martin Davis a retrospective of her mathematics. Lisl quoted Julia: "When I am dead I hope I shall not be remembered by anecdotes, but for my work."

Julia Robinson was a great mathematician. Her work was instrumental in the solution of Hilbert's tenth problem. She was the embodiment of firsts for contemporary women in mathematics: the first woman President of the AMS, the first woman mathematician elected to the National Academy of Sciences, the first woman mathematician to receive a MacArthur award. Julia was not an active AWM member, but supportive in private ways. As she became more involved in public life, her support increased. As Vice-President of the AMS, she intervened when the Council would not consider a motion to move a meeting from a non-ERA state because the motion was not already on the agenda. Julia pointed out this was an emergency situation. The motion passed and the meeting was moved. Linda recalls that when Julia was AMS President "she really made sure women were placed on important committees—and was very supportive to me, both as Council member and as President of the AWM." Julia Robinson was a "role model" for many of us long before we understood what that expression meant. She will continue to be a source of inspiration for a very long time.

A final highlight of Linda's term was the ICM-86 in Berkeley. "Our program at that meeting was a real success as you know," Linda writes. There were nine panelists from ten countries and five continents.[27] "The forming of

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[23]In the spring of 1987, Alice Schafer ran a SKHS Day at Simmons College, where SKHS Days have been held every year since. (Alice taught at Simmons after retiring from Wellesley—hence the connection; never one to retire, she is currently head of the Math Department at Marymount University!)

[24]Contributors to the Kovalevsky proceedings include: Patricia Bauman, Enrico Bombieri, John W. Cahn, Roger Cooke, Dennis Deturck, Jozef Dodzuik, Hans Engler, Carolyn Gordon, Ann Hibner Koblitz, Tilla Klotz Milnor, Richard Palais, Thea Pignataro, Emma Previato, Burton Randol, Michael Shub, Dennis Sullivan, Jean Taylor, Chuu-lian Terng, Alphonse T. Vasquez.

[25]In this volume, Ann Hibner Koblitz ("Changing Views of Sofia Kovalevskaia") presents an alternative, perhaps more plausible, perspective on the Prix Bordin story mentioned earlier. "Anonymity would not have been easy to achieve in the relatively small European mathematical community of the time," she contends. Furthermore, there is "overwhelming evidence that the French academicians decided to make the motion of a rigid body the topic of the 1888 Prix Bordin contest precisely because they knew that Kovalevskaia was working on the problem." Koblitz contends further that Felix Klein and Eric Bell are two of the people most responsible for the "fictionalization" of Kovalevsky as a "frivolous creature on the fringe of the mathematical world." Koblitz is particularly pointed in her criticism of Bell, claiming that "it is to him that mathematicians are largely indebted for distorted impressions of their predecessors."

[26]See "An Autobiography of Julia Robinson by Constance Reid" in *MP*.

[27]Panelists were: Josefina Alvarez (Argentina), Bodil Branner (Denmark),

the European Women in Mathematics was a long range aftereffect . . . ."

"There was also the sturm and drang about the number of women invited to the ICM." At the AWM panel, Linda read a resolution she had earlier presented to the ICM Executive Committee concerning the selection of women (and those in other groups) as Congress speakers. This resolution was endorsed by the 400 attendees at our meeting.[28] "This brought us to the attention of the international community and as you saw [at the ICM-90 in Kyoto] many are now more sensitive to the issue."

Gender, Mathematics and Science. In the mid-1980s, there was a flurry of work by a group of feminists theorists on gender and science. In commentary fairly critical of this work, Ann Hibner Koblitz succinctly summarized the main ideas behind the theory. "Put in its most general guise, the new 'gender theory' says that centuries of male domination of science have affected its content—what questions are asked and what answers are found—and that 'science' and 'objectivity' have become inextricably linked to concepts and ideologies of masculinity." She then lists eight criticisms of which I will mention only two, namely that gender theorists "seem unaware of the increasing numbers of women who have had satisfying lives as scientists" and "employ cartoon-character stereotypes of science, scientists, men, and women." (See "A Historian Looks at Gender and Science," *AWM Newsletter*, July-August 1986.)

A letter from Mary Beth Ruskai in the May-June 1986 *Newsletter* expressed concerns felt by many of us "that a few very vocal and visible sociologists are succeeding in promulgating opinions that are detrimental to the advancement of women in science."

Ruskai discusses a rash of articles in the popular press where arguments presented by gender theorists invoke a number of stereotypical misconceptions. For example, she points out that "instead of being concerned that women with an aptitude for computing, science, and mathematics were going into other fields" some advocates of the theory see this as a virtue—women are not interested in science because it does not deal with subtleties. Ruskai is critical of the dichotomous distinction between "artistic" and "technical," the cures for math/physics anxiety devoid of proper math preparation, the recurrent idea "that women are more intuitive than men, where intuition and logic are perceived as opposites." She calls for AWM to take a stand.

Ruskai's letter generated more response than anything else that had ever appeared in the *AWM Newsletter*—a number of responses are contained in the November-December 1986 issue. Here, for example, Marriane Nichols expresses an alternate point of view. Namely, she argues, if we understand "the biases that do exist in math and science today," then we can "see how they limit what we can know and understand. From there one perhaps can begin to expand and enrich these fields."[29]

Rhonda Hughes (1987–1989):
Acceptance by the Establishment, AMS Centennial, Travel Grants, Schafer Prize

"By the time I became AWM President," writes Rhonda Hughes, "the organization had clearly gained the acceptance of the mathematics establishment (whether we wanted it or not). I could tell, because all sorts of people began to talk to me who had never done so before. (This sort of thing should not, however, go to one's head. As soon as my term ended, some of these same people started calling me 'Jill'. . .)."

While very much a participant in establishment activities, AWM was still mindful of its unique perspective and role in the mathematics community during Rhonda's term. The AWM "Response to the David Report" (San Antonio, January 1987) focused on initiatives for women and minorities.[30] Panelist Fern Hunt emphasized the need to increase the diversity of people doing mathematical research, not only from a political or social point of view, but to promote the "diversity of ideas—one of the prerequisites for progress in mathematics." So to the famous (or infamous) line from the film *Casablanca*, "Round up the usual suspects!" she would add, "And round up the unusual ones too!" Louise Raphael discussed NSF initiatives for women and minorities and also shared a key factor which helped her reenter mathematical research. "Namely, it is essential to find collaborators who share the same mathematical interest." Other panelists were John Polking and Barry Simon; Lida Barrett moderated.

AWM's presence was very much in evidence at the AMS Centennial Celebration, held in Providence in August 1988.[31] The AWM panel, "Centennial Reflections on Women in American Mathematics," focused on a century of contributions and experiences of women mathematicians. Judy Green and Jeanne LaDuke discussed their findings on the substantial presence of female Ph.D.s in American mathematics before World War II—and the dramatic decline after the war—as well as more recent history. Mabel Barnes, Olga Taussky-Todd, and Vivienne Mayes-Malone reflected on their own experiences, giving us a rare and personal accounting of this history as well as a unique glimpse into their own lives:

Marie Françoise Coste-Roy (France), Consuelo Flores (Nicaragua), Gudrun Kalmbach (Germany), Maria Jose Pacifico (Brazil), Jennifer Seberry (Australia), Caroline Series (England), and Josephine Guidy-Wandja (Ivory Coast). Although the panel was large, we had no representation from a large part of the world—indeed from Eastern Europe through Asia. This was partially rectified at the ICM-90 in Kyoto where panelists included: Rajinda Hans-Gill (India), Hu He-sheng (China), Maria T. Lozano (Spain), Aiko Negishi (Japan), Kati Tenenblat (Brazil), Gillian Thornsby (New Zealand), and Asia Weiss (Canada).

[28]As a personal protest, Marina Ratner had taken the more extreme position of publicly boycotting the Congress. (See "Women in Mathematics: An International Perspective, Eight Years Later," LB, *The Mathematical Intelligencer*, vol. 9, no. 2, 1987.)

[29]For a thoughtful and well articulated account of this viewpoint by one of its key theorists, see *Reflections on Gender and Science* by Evelyn Fox Keller (Yale, 1985). In this book, Keller calls for a science "in which difference, rather than division, constitutes the fundamental principle for ordering the world . . ."

[30]See *AWM Newsletter*, May-June 1987.

[31]At the formal ceremonies, Rhonda presented the AMS with congratulatory wishes from the AWM and in appreciation was presented a silver bowl from the AMS (which now ritually gets passed down from one AWM President to the next at inauguration time).

Mabel Barnes (Emerita Professor at Occidental College and mother of algebraist Lynne Barnes Small) told of her experiences in the early 1930s at the newly established Institute for Advanced Study: "Even in remote Nebraska I heard about a place called the Institute for Advanced Study opening up in Princeton. I applied for admission and was accepted ... Soon after I arrived, the Director of the School of Mathematics took me aside and warned me that Princeton was not accustomed to women in its halls of learning and I should make myself as inconspicuous as possible. However, otherwise I found a very friendly atmosphere and spent a valuable and enjoyable year there. Had I not gone East, I would not have met Olga Taussky as early as I fortunately did."

Olga Taussky-Todd cited the time in 1958 when she was invited to give a one-hour lecture at an AMS meeting, the first woman since Emmy Noether in 1934. "At such an occasion the chairman usually says a few kind words by way of introduction. I trained myself to say 'thank you for your kind words.' " she recalled. "However, he only mentioned my name and Caltech and I almost thanked him for his 'kind words.' " The fact that she studied and worked in several countries allowed Olga to observe a number of facts about "the behavior" and "treatment" of women over the years. "Now we live with Women's Lib and it has not only changed the opportunities for women, but also their behavior towards each other. Women are now 'friends' of women colleagues ... "

Vivienne Malone-Mayes, the only black math professor at Baylor, spoke of being a black woman graduate student at the University of Texas at Austin in the late 1950s. This was a time when blacks could not be T.A.s nor join their classmates for discussion at segregated cafes. "I can personally vouch that my personal isolation ... was absolute and complete ... At times I felt that I might as well have been taking a correspondence course," Vivienne recalled. "The history of black women in mathematics (based upon the parameter of Ph.D.s) ... is only recent history in comparison with the centennial of years since the first white female Ph.D." she pointed out. The first white woman to be awarded a Ph.D. in mathematics in the U.S. was Winifred Edgerton Merrill (Columbia University, 1886). The first black women to be awarded math Ph.D.s were Marjorie Lee Browne (at Michigan under G.Y. Rainich) and Evelyn Boyd Granville (at Yale under Einar Hille), both in 1949. "It should be noted," Vivienne added, "that many of the dissertation advisors received criticism for sponsoring these black female doctoral candidates. Their courage must be acknowledged as an important factor in the careers of these mathematicians ..."[32]

Reflecting on her presidency, Rhonda points to growing pains as well as significant achievements. "In my time, we still seemed plagued by the research-education tension in our membership. This appears to be less of a problem now, with the wide range of programs and activities we've taken on." On the positive side she concludes, "I am most pleased with the establishment of the Travel Grant program, and the Schafer Prize. Seeing all those bright undergraduate women receiving awards in Columbus [Joint Meetings, August 1990] symbolized for me the whole point of AWM. And once they become mathematicians, the Travel Grant program might further help their professional development."

Louise Hay Award. It seems most fitting here to make special mention of the Hay award, established by the AWM to recognize contributions to mathematics education, but especially to talk about Louise, who was very much part of the foundation and fabric of the AWM. Indeed, she was slated to have become AWM President in 1991.

Louise Hay died on October 28, 1989 at the age of 54. She had been a faculty member and Head of the Mathematics Department at the University of Illinois at Chicago for many years and had a profound effect on women students there like Rhonda Hughes. At the AWM meeting in Louisville, January 1990, Rhonda delivered a deeply moving testimonial. As Rhonda spoke, I thought of the time I first met Louise. It was the year I started to work on my thesis and Louise was visiting MIT on an NSF postdoctoral fellowship. I remember being startled to see a woman's name on a math faculty door, but even more startled to see Louise. Since I had never seen a woman mathematician before, I had imagined her to fit the common stereotype of the time—and certainly that was not what I saw! As Rhonda, I too was impressed by "her unusual combination of youth, vivacity, and mathematical reputation." She was a living role model.

Louise Hay

[32]See *WM* and the November-December 1988 *AWM Newsletter* for more on these fascinating stories and an account of the centennial history.

Louise was intimately connected with the origins and growth of the AWM, particularly in the Chicago area. In "Fond Remembrances of Louise Hay" (*AWM Newsletter*, January-February 1990), Rhonda recalls Louise's support and encouragement from the beginning: "Inspired by AWM's founding, Nancy Johnson (Louise's Ph.D. student) and I organized the women graduate students and faculty in the department for the general purpose of raising our own consciousness, and that of the men around us. We had a huge crowd at our first meeting (those were heady days!), and one woman who had been on the faculty for many years expressed the hope that we wouldn't make waves. 'And what's wrong with making waves?' Louise retorted ... "

Over the years, Louise supported all facets of AWM activities. "I last saw Louise in Atlanta in January 1988, when I invited her to speak in the AWM panel discussion 'Is the Climate for Women in Mathematics Changing?' " Rhonda remembers. "She always seemed to say things you wouldn't hear others say. I can't imagine anyone but Louise paraphrasing Virginia Woolf, 'Women will not achieve equality until they have earned the right to be hacks ... not everyone is a genius.' "[33]

Jill Mesirov (1989–1991):
Looking outward, the Twentieth Anniversary

In her President's Report in the *AWM Newsletter* (January-February 1991), Jill Mesirov presents an impressive list of AWM activities during the past two years: panels, Sonya Kovalevsky High School Days, graduate student outreach, Schafer Prize and Hay Award, Resource Center development, Twentieth Anniversary celebration, Noether Lectures, outreach to other societies, Speakers Bureau, Travel Grant program. This multifaceted array of activities represents a truly remarkable testimony to Jill's presidency as well as to the cumulative work and accomplishments of the AWM during the past twenty years. We seem to have resolved our identity crisis by doing it all!

"I think of the past two years as a time when the AWM began to look outward to the rest of the mathematical sciences community," Jill writes in one of our many email conversations. "Our major success in this was the beginning of an ongoing presence at SIAM [Society for Industrial and Applied Mathematics] National Meetings ... My goal in these efforts was to broaden our representation, influence, and activities beyond the AMS and MAA. And I think this is happening."

"I also think of the last two years as a kind of 'coming of age' " she continues. "We have really expanded the scope of our activities ... I think that our relationship with NSF has become quite strong and vital over the past couple of years. They really view us as giving lots of value for the money they invest in our programs and are very keen these days to fund programs to encourage women and minorities in the sciences.[34] Exxon has also been an important partner for us, giving us yearly grants towards our operating expenses as well as to support the complete revision of the Resource Center.[35] Tricia [Cross, AWM Executive Director] has really been vital in building up this relationship."

But, as is characteristic of all superachievers, Jill sees projects yet undone, some very close to home. "One area that I wasn't able to make progress on (directly or indirectly)," she points out "is the two career family and children issue. One can't do everything I guess. It's funny because in many ways this is something that is really important to me because it really has an impact on my life everyday."

Nevertheless, Jill's enthusiasm is hardly dampened. "It's been a crazy two years, exhilarating, overwhelming, frustrating, rewarding. Believe it or not, I really enjoyed it!"

How things are ... (An assessment)

Did the AWM make a difference? "My God yes" responds Judy Roitman. It was not uncommon for major women mathematicians to be unemployed; young women were routinely discouraged; the few who persevered were usually treated badly; and role models were few and far between."

One need only look at the program for this Joint Meeting (See *Notices*, December 1990) to sense the very real involvement of women in the mathematical world today—a stark contrast to Atlantic City twenty years ago! As Carol Wood puts it, "women are everywhere dense." Invited speakers include: Christel Rotthaus (AMS/AWM/MAA), Rebecca Herb (AMS/MAA), Maria Klawe (AMS) and Jill Mesirov (MAA). Dusa McDuff is the first recipient of the AMS Ruth Lyttle Satter Prize, established by Joan Birman in memory of her sister to recognize an outstanding contribution to mathematics research by a woman.[36]

In the professional organizations and institutions, we are no longer on the outside but rather play key roles within the internal power structure. Witness Deborah Haimo taking over the presidency of the MAA from Lida Barrett as Marcia Sward, MAA Executive Director, looks on![37] In the AMS, women are Vice-Presidents, Trustees, Council members, and chairs of important committees; Julia Robinson was AMS President (1983-1984). Cathleen Morawetz has been Director of the Courant Institute, Judith Sunley is Director of Division of Mathematical Sciences at the NSF. Women

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[33]Louise Hay's autobiographical article, "How I became a mathematician (or how it was in the bad old days)" appeared in the September-October 1989 issue of the *AWM Newsletter*. "If there is a moral to this tale of how I became a mathematician," she concludes in the article, "it is that sources of inspiration and opportunities to change your life can come unexpectedly and should not be ignored; and that you should not neglect the dictates of your own career, taking some risks if necessary, since you never know what the future will bring."

[34]The AWM Travel Grant program is funded by NSF; our postdoc/graduate student workshop program is funded jointly by NSF and ONR.

[35]Resource materials, including a booklet *Careers that Count: Opportunities in the Mathematical Sciences* and a brochure highlighting the Noether Lecturers (both written by Allyn Jackson), are available from the AWM Resource Center at Wellesley.

[36]Dusa's moving and very personal response appears in *Notices*, March 1991. Highly recommended reading!

[37]For information on women in the MAA and much more, see "Winning Women Into Mathematics," produced by the MAA Committee on the Participation of Women and edited by Pat Kenschaft (MAA Publications, 1991).

mathematicians have been elected to the National Academy of Sciences, received MacArthur "genius" awards, Sloan Fellowships, Guggenheims, Presidential Young Investigator awards, and routinely, NSF fellowships and research grants. At ICM-90 in Kyoto last summer, six women gave 45-minute invited talks[38] and Karen Uhlenbeck gave the first of fifteen plenary addresses. Of the five U.S. delegates[39] to the International Mathematical Union General Assembly, three were women—all AWM members.

During the past twenty years, the percentage of U.S. women receiving Ph.D.s in mathematics has increased dramatically, from about 6% to over 20% per year. (See the Annual AMS-MAA Survey, *Notices*, November 1990.) But curiously, although there was a significant jump in the number of new female Ph.D.s in mathematics during the early 1970s, we find since then that the number has stayed amazingly steady (except for a peak of 102 in 1980-1981), averaging at eighty-six per year. What has happened is the number of U.S. male Ph.D.s in mathematics during this period has dropped by more than half (from 658 in 1974-1975 to 312 in 1989-1990). While a number of far-reaching conclusions and speculations may be drawn, suffice it to say that, relatively speaking, women have gained ground in this domain.

How much of the changes are due to the AWM and how much to the times in general? "This is a false question," Judy Roitman contends. "The AWM is the expression in the mathematical community of the broader feminist movement ... But without the AWM or some similar group (and I think it was an act of brilliance to form it outside of the existing mathematical organizations rather than a caucus within ...) the changes for women would have been fuzzier and less specific, driven by affirmative action necessities (which are pretty minimal) and vague changes in public perception, and not directed by our own understanding of what has to be done."

Where we're going ... (Hopes for the future)

Thus, as we celebrate and reflect on our 20th birthday, we clearly have a collective sense of optimism and well being. But lest anyone get the impression we are entering our twenty-first year in a mode of complacency, Jill Mesirov, with characteristic sense of mission and responsibility, outlines our ongoing agenda:

- We must continue to find ways to identify talented young girls and encourage their interest in mathematics.
- We must make sure that women are guided to the best graduate program for their needs and abilities. Women traditionally have been underrepresented in the top rank graduate programs; we should understand why that is true and help to correct it.
- Those of us who are professionally active in research, industry, or education have an obligation to our young women colleagues:
  - to support them at the beginning of their research or teaching careers,
  - to bring them into the appropriate network and bring their work to the attention of the rest of the community, and
  - to find creative ways in which to help them through the difficulties of two-career relationships and childrearing.

And in good tradition, Carol Wood, next AWM President, is positioned for the ongoing challenge.

Carol Wood (1991–1993):
Looking into the crystal ball

Carol writes of her vision and hopes for AWM during her upcoming term, mindful of difficult choices that will have to be made. "I see this as a time when AWM has enormous opportunities to make a difference in the lives and careers of young women, and find this both frustrating and exhilarating. Frustrating, because there are too many things we could be doing, and we risk the danger of doing few of them well if we can't make judicious and difficult choices. Exhilarating, because AWM has, I feel, been accepted as the organization to which many groups now turn for leadership in matters involving the participation in mathematics of women, and because there is an awareness that women are needed for the future health of mathematics."

With fitting metaphor, she continues, "In a way, the demands on AWM remind me most of the microcosm of a woman's life, with her multiple roles, and with all the people whose demands, needs, and expectations make it both necessary and difficult to determine what matters and what doesn't."

Nevertheless, undaunted by these multiple demands, Carol has expansive plans for the future. "Something which I would like to achieve during my presidency," she writes, "is the establishment of strong ties with existing organizations concerned with promoting and encouraging participation of women in mathematics in other parts of the world, and also to see AWM play the role of midwife in bringing such groups into being ... In some ways we would be playing a leadership role, but in many others we would be awed by the wisdom of our international counterparts."

Summing up, Rhonda Hughes voices our shared sentiments: "I think we are entering our twenty-first year more unified and stronger than ever before, with a unique opportunity to have influence on the next generation of mathematicians. What used to be our concerns alone are now the concerns of the entire community, and we can give leadership and vision to the effort to get young people interested in mathematics. After all, we have been thinking about how to do this for a long time ..."

Acknowledgments and appreciation

In this brief account, I have only been able to mention a small fraction of the people, institutions, and events that have been so vital in creating and shaping our history.

[38]Invited Speakers at ICM-90 included Lenore Blum, Shafi Goldwasser, Dusa McDuff, Colette Moeglin, Mary Rees, and Eva Tardos. In addition, Joan Birman presented the account of the work of Field's Medalist Vaughan Jones.

[39]The U.S. delegates were Alice Chang, Andy Gleason, Ron Graham, Linda Keen, and myself.

We owe our successes to the AWM officers (both official and unofficial) over the years, the AWM staff at the Wellesley office,[40] the many committee members, the speakers and panelists at AWM sessions, the Noether lecturers, the numerous contributors to the *AWM Newsletter* (which makes for such fascinating and insightful reading one is tempted to quote it all!), the organizers and participants of AWM outreach activities—particularly the Speakers Bureau and the Sonya Kovalevsky High School Days—and mostly to our enormously supportive and participatory membership.

I would like to acknowledge specially all those who were involved in planning and organizing this Anniversary Celebration.[41] Funding for the Symposium and Workshop has been provided by grants from the National Science Foundation and the Office for Naval Research.

Our sister organizations, the AMS, the MAA, and more recently SIAM, have been truly that; we greatly appreciate the support and recognition they have shown their younger sibling.

Finally, on behalf of the AWM, I would like to express our deep appreciation to Wellesley College for its support over the years, and particularly for providing space for the AWM headquarters office and Resource Center. For its ongoing funding of the Resource Center as well as general support, we are grateful to the Exxon Education Foundation.

Postscript: The "trickle up" effect

Just as I was finishing this article, a reporter from *Science* magazine phoned. He wanted to talk about the dearth of women in the top U.S. mathematics departments. I wanted to talk about the active presence of women in the American mathematics community. Implicit in our conversation was the (seemingly paradoxical) question: If women are doing so well in mathematics today, then why are they not represented in the top departments? Obviously, the answer is complex.

In the 1970s, when affirmative action came into being and government was enforcing the laws, we saw changes for women, not so much in academia, but in industry. In those years, government was putting pressure on industry to hire women. Industry in turn tried to hire women in technical fields and found there were not many. To remedy this situation, both government and industry started supporting educational programs to increase the participation of women in mathematics-based fields. These programs were remarkably successful and women started becoming more visible in technical areas, particularly in the fledgling computer industry. In the 1980s, when the political pressure let up, industry continued to hire women in technical fields. Why was this? For one, they had already had the experience of working with competent women. For another, it was in their interest: With the drop in Americans entering technical fields and the balance of technological expertise and industry shifting to other parts of the globe, increasing the numbers of women could help the U.S. maintain its technical edge.

What happened in academia? While government was enforcing affirmative action legislation in industry, it basically maintained a hands-off policy towards universities, responding to strong arguments of academic freedom and autonomy. One of the strengths of American institutions of higher education has been their long history of self-governance. So universities experienced minimal pressure from government to change. Then why did big changes take place in the mathematics societies and at many departments, but not in the top departments? During this period, the AWM and its members were certainly an omnipresent force within the math societies, both raising the consciousness of the community as well as wielding a fair amount of political influence. In the 1980s, many math departments were directly affected by the decline in Americans studying mathematics (and now in the 1990s, by the crisis in the job market for mathematicians). Thus, the problems of the larger society hit home, and these groups responded to the situation in much the way that industry had. That is, it was viewed as in everyone's best interest to increase the participation and visibility of women in mathematics. On the other hand, the top departments have been buffered by and large from the changes in society. Even in tough times, they have first pick of the top students (and in the current tough times, their students do better on the job market). These departments are not as viscerally aware of the problems affecting the rest of the community. And in the main, they have not taken a leadership role in changing the situation. This has come from elsewhere.

And changes have indeed occurred. The large numbers of active women researchers attest to that. The large numbers of women giving invited talks at national and international meetings attest to that. The large numbers of women in leadership positions in the mathematics societies attest to that. Before, when the numbers were small, the few women mathematicians available could not always satisfy all the criteria (not all professional—and not always as objective as might be claimed) for getting a position: Are they *the* top person in the particular field the department is hiring? Are they in the right professional circles? Are they at the right age or stage of their professional careers? Does their personal circumstance allow them to move? And so on. Now there is a near critical mass and an excellent pool of women mathematicians. I predict that within five years there will be vast changes in the top departments reflecting (and benefitting from) changes already in place within the wider mathematics community. One might call this the "trickle up" effect.

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[40]In particular, special acknowledgment is due Ruth Samia and Margaret Munroe, who ran the AWM office for many years.

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