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Women Mathematics Ph.D.'s of the 1940s and 1950s

Finding the Women

During the years 1940 through 1959, approximately two hundred Ph.D.'s in mathematics were awarded to women by colleges and universities in the United States, as enumerated in table 1.2 of chapter 1. Because of inevitable inaccuracies in reporting and collection of data, the precise numbers are somewhat uncertain. Rounding the statistics to the nearest ten, roughly ninety women and 750 men were awarded the Ph.D. degree in mathematics by American institutions during the 1940s, while 110 women and 2,220 men received the degree in the 1950s.

During the second half of the forties and the decade of the fifties, the sheer number of Ph.D.'s in mathematics awarded in the United States increased so dramatically that it is virtually impossible to obtain a complete list of the awardees. Because they constitute a relatively small subset of the total, however, the task of compiling a fairly complete list of the women is a much more manageable one.

My search for the women began with the *Bulletin of the American Mathematical Society* for the years 1941 through 1960. In each May issue during this period, the AMS printed a complete (or nearly so) list of the previous year's Ph.D. recipients in the mathematical sciences, including pure and applied mathematics, mathematical statistics, mathematical physics, and history of mathematics. It was the practice of the AMS, at least until the late 1950s, to print the full names of women and only the initials of men. It was thereby possible to locate, on the basis of names readily identifiable by gender, well over 150 of the female Ph.D.'s.

To locate the rest, I consulted several other sources. In the late 1970s, Amy King and Rosemary McCroskey (1976–1977) compiled a list of all the women mathematicians they could locate in the United States and Canada. While their list is incomplete and contains a number of errors, it provides a starting point for further searches. One of the most vexing problems in trying to identify the women mathematicians of this generation is that women's surnames usually changed on marriage; the King-McCroskey list was particularly helpful in tracking down name changes. Still other women mathematicians were identified by their appearance in standard reference works, particularly *American Men of Science (AMoS)*—later renamed *American Men and Women of Science (AMWoS)*—and *Dissertation Abstracts.*

Once I had compiled a basic list from these sources, I sought direct verification of the names by directly contacting the women themselves—or, failing that, the graduate departments or alumni associations of their graduate institutions. As a result of these exhaustive searches, I was able to compile a more definitive list of 188 women, eighty-three from the 1940s and 105 from the 1950s, who received Ph.D.'s in mathematics from American institutions during the years 1940 to 1959.

While basic biographical information on many of these women can be found in library sources (*AMWoS,* once again, serving as a good starting point), it was my aim to try to speak to as many of them as possible to come to a fuller understanding of their lifelong relationship with mathematics. With this goal, I began searching for their names in the membership directories of the major mathematical and statistical societies. I was able to identify, locate, and contact those women who had remained active mathematically to the extent that they still maintained membership in one or more professional associations or maintained contact with a network of colleagues and friends in academia.

In the end, I conducted in-depth, in-person interviews with thirty-six of the original two hundred women. Appendix A provides a discussion of how the interviewing was carried out. The interview group, while decidedly not a *random* sampling of the women Ph.D.'s of the period, is a *representative* sampling of the professionally active women mathematicians of this generation. Seventeen of them received doctorates in the 1940s, nineteen in the 1950s. Together, they constitute nearly 20 percent

of the women who received Ph.D.'s in the mathematical sciences during the two decades.

A Distinguished Cohort of Mathematical Women

The women who earned their Ph.D.'s in mathematics during the forties and fifties include some of the most distinguished mathematicians and mathematics educators of this century. Julia Robinson, Cathleen Morawetz, and Mary Ellen Rudin are probably the best-known women mathematicians of this generation.[1] The logician Julia Bowman Robinson (Ph.D., California/Berkeley, 1948; 1919–1985) did pioneering research leading to the solution of Hilbert's Tenth Problem, a long-standing open problem in the logical foundations of arithmetic. In recognition of her research achievement, she was elected to the mathematics section of the National Academy of Sciences in 1976, the first woman to be so honored. In 1982, she was elected the first woman president of the American Mathematical Society, and in 1983, she was awarded a MacArthur Foundation Fellowship.

Cathleen Morawetz (Ph.D., NYU, 1951), who has had a long and productive career in applied mathematics at NYU and has served as director of the Courant Institute of Mathematical Sciences there, was the first woman elected to the applied mathematics section of the National Academy of Sciences in 1990. She was elected president of the AMS in 1995, the second woman to hold that office, and in 1998 she was awarded the National Medal of Science. Mary Ellen Rudin (Ph.D., Texas, 1949) has done creative work in the field of set-theoretic topology over a span of fifty years; the subject of several popular interviews, she has been an especially energetic and visible figure in the American mathematical community.

Many of the other women Ph.D.'s of the forties and fifties have made research contributions that have equaled and even surpassed these three. Among those who have made particularly substantial contributions are Dorothy Maharam Stone (Ph.D., Bryn Mawr, 1940) and Alexandra Bellow (Ph.D., Yale, 1959) in measure theory and ergodic theory; Domina Eberle Spencer (Ph.D., MIT, 1942) in mathematics applied to physics and engineering; Josephine M. Mitchell (Ph.D., Bryn Mawr, 1942) in classical

and complex analysis; Jane Cronin Scanlon (Ph.D., Michigan, 1949) in functional analysis, differential equations, and mathematical biology; Esther Seiden (Ph.D., California/Berkeley, 1949) in mathematical statistics; Wanda Szmielew (Ph.D., California/Berkeley, 1950; 1918–1976) and Marian Boykan Pour-El (Ph.D., Harvard/Radcliffe, 1958) in logic; Mary Bishop Weiss (Ph.D., Chicago, 1957; 1930-1966) in harmonic analysis; Vera Pless (Ph.D., Northwestern, 1957) in coding theory and combinatorics; and Tilla (Klotz Milnor) Weinstein (Ph.D., NYU, 1959) in complex analysis and geometry.

Several women in the group have been especially prolific in mathematics education, among them Mary P. Dolciani (Ph.D., Cornell, 1947; 1923–1985) and Margaret F. Willerding (Ph.D., St. Louis, 1947), who are well-known to generations of students at the college and precollege level for their numerous mathematics textbooks. Many others have devoted part or all of their careers to college and university administration, including two who earned doctorates at the University of Pennsylvania: Jean B. Walton (Ph.D., 1948) was dean of women, and later dean of students and coordinator of women's studies, at Pomona College; Lida K. Barrett (Ph.D., 1954) served as department head, associate provost, and dean at three different universities and in 1989 became the second woman elected president of the MAA.[2]

Quite a few women in the doctoral classes of the forties and fifties have had distinguished careers in the federal government. Notable among these are Leila D. Bram (Ph.D., Pennsylvania, 1951; died 1979), for many years the director of the mathematics program at the Office of Naval Research; Elizabeth H. Cuthill (Ph.D., Minnesota, 1951), who spent her forty-year career at the David W. Taylor Naval Research and Development Center at Annapolis; Ruth M. Davis (Ph.D., Maryland, 1955), who served as Assistant Secretary of Energy in the Carter administration; and Joan R. Rosenblatt (Ph.D., North Carolina, 1956), who had a distinguished career at the National Bureau of Standards (NBS)—later the National Institute for Standards and Technology (NIST)—from which she retired as director of the computing and applied mathematics laboratory in 1996.

At least twenty-three Roman Catholic nuns earned Ph.D.'s in mathematics from 1940 to 1959. Many of these women undertook graduate study comparatively late in life, after they had been teaching at the college

level for a number of years. Few of them did much research beyond the Ph.D. However, two of the nuns who earned doctorates at the University of Michigan during the 1940s have achieved some notoriety recently for their research. Sister Mary Claudia Zeller (Ph.D., Michigan, 1944; 1910–1991?) wrote her dissertation on the history of trigonometry. The historian of mathematics Ezra Brown has made use of her work in his study of the medieval mathematician Regiomontanus (Brown 1990). Sister Mary Celine Fasenmyer (Ph.D., Michigan, 1946; 1906–1996) completed her Ph.D. in the field of special functions under the direction of Earl Rainville. She published two papers based on her dissertation and had a long teaching career at Mercyhurst College in Erie, Pennsylvania. Rainville (1960) showcased her doctoral work in a widely read textbook, and she has recently been rediscovered by a new generation of researchers in the area of special functions and combinatorics (Zeilberger 1982; Hutchinson 1994; Warnick 1994).

In a generation of women mathematicians that features a substantial number of firsts, we find the first two African American women to earn Ph.D.'s in mathematics. Evelyn Boyd Granville (Ph.D., Yale, 1949) and Marjorie Lee Browne (Ph.D., Michigan, 1950; 1914–1979) earned their doctorates within just a few months of one another. No African American woman would earn a Ph.D. in mathematics again until the early 1960s. Marjorie Lee Browne earned her Ph.D. at the age of thirty-five and had a thirty-year teaching career at North Carolina Central University. Evelyn Granville pursued her undergraduate and graduate studies in mathematics without a break, earning her Ph.D. at the age of twenty-five; she went on to a career in industry and academia spanning nearly fifty years.[3]

Leading Producers of Women Ph.D.'s: Continuity and Change

Which U.S. institutions graduated the largest numbers of women mathematics Ph.D.'s in the postwar years? Table 2.1 lists the leading producers of women Ph.D.'s in the forties and fifties, by decade; for comparison, the table also includes the leading producers for the decade of the thirties and overall for the period 1886 to 1939. In each case, the institutions listed account for well over half the Ph.D.'s in mathematics awarded to women in the given period.

Table 2.1
Ranking of Institutions by Number of Mathematics Ph.D.'s Awarded to Women

1886–1939 (10 or more)		1930–1939 (4 or more)	
46	Chicago	24	Chicago
21	Cornell	13	Catholic
19	Bryn Mawr	8	Bryn Mawr
15	Catholic	8	Cornell
13	Yale	8	Illinois
12	Johns Hopkins	6	Radcliffe
12	Illinois	67	Six schools
138	Seven schools		
1940–1949 (4 or more)		**1950–1959 (4 or more)**	
9	Illinois	10	NYU
8	Catholic	6	Brown
8	Michigan	5	Illinois
7	Radcliffe	5	Michigan
6	Chicago	5	Minnesota
5	California/Berkeley	4	California/Berkeley
4	Cornell	4	Catholic
47	Seven schools	4	Radcliffe
		4	St. Louis
		47	Nine schools

Source: For pre-1940 data: Green and LaDuke 1987: 18 (table 3).

The table reveals some interesting historical trends. First of all, many of the older graduate departments declined in importance as producers of women Ph.D.'s in mathematics. At Johns Hopkins, Yale, Chicago, and Cornell, departments that had been granting Ph.D.'s in mathematics since the late nineteenth century, the decline may be attributed in part to the aging of the faculty and the subsequent reorganization of individual departments around a new generation of researchers. After reorganization, these departments did not resume their former status as major producers of women Ph.D.'s.

The decline at Chicago was especially dramatic. During the years 1940 to 1946, Chicago conferred six mathematics Ph.D.'s on women; in the thirteen years following, Chicago awarded only three degrees to women

(in 1951, 1956, and 1957). As it happens, the year 1946 was a key turning point in the history of the department at Chicago. In that year, Marshall Stone came to Chicago from Harvard to head the mathematics department, and the years immediately following his arrival were marked by a nearly complete turnover in the faculty (MacLane 1989). In particular, the people who had supervised the majority of women's dissertations in mathematics in the preceding years had by that time either retired, died, or departed for other reasons. Among those who retired in 1946 was Mayme Logsdon (Ph.D., Chicago, 1921; 1881–1967), a tenured associate professor. According to Saunders MacLane, "one of her duties was that of advising and helping many women who were graduate students at Chicago" (1989: 135). After her departure, Chicago would not have a tenured woman in the mathematics department for another forty years.[4]

Stone, charged with the responsibility of creating a first-rate research department, hired a number of émigré mathematicians, along with a large cadre of young men at an early stage in their careers. The university, ideally situated in a major urban center, was poised to take full advantage of the surge of graduate students produced by the G.I. Bill. But despite the surging male enrollments, approximately 14 percent of the students enrolled in graduate mathematics courses at Chicago during the late forties and fifties were women—about the same rate at which women earned Ph.D.'s in mathematics prior to 1940 (MacLane 1989: 145–146). Yet few of these women actually completed the degree. Clearly, something in the environment for women at Chicago had changed.

The two women's colleges that had historically granted large numbers of mathematics Ph.D.'s to women exhibit diverging patterns in the forties: Bryn Mawr disappears from the leaders entirely, while Radcliffe continues to appear in the list, albeit with diminishing numbers of graduates. The graduate school at Bryn Mawr became coeducational in the 1930s and began to admit men (Rossiter 1995: 91). Moreover, the tiny Bryn Mawr mathematics department lost its energetic leader, Anna Pell Wheeler, to retirement in 1948; her last student, Dorothy Maharam Stone, received her Ph.D. in 1940 (Grinstein and Campbell 1982). The features that had made graduate study at Bryn Mawr unique since the time of its founding were rapidly disappearing, and women students at

Bryn Mawr were often advised to go elsewhere for doctoral work. By contrast, women who earned Radcliffe doctorates took their coursework and pursued research with advisers on the Harvard faculty. While many women decided against attending Radcliffe because they would be denied the Harvard Ph.D., many others were attracted to graduate study there because of the quality of the Harvard mathematics program.[5]

The Big Ten universities of the Midwest—including Illinois and Michigan and, later, Minnesota—were major educators of women mathematicians in the forties and fifties; Illinois had been among the leaders already in the thirties. The relatively late appearance of these schools among the top producers of women Ph.D.'s is, in part, a reflection of the fact that their graduate programs developed a few decades later than those at the well-known private universities. Michigan, in particular, rapidly developed an outstanding reputation for both teaching and research in the 1930s. Two of its faculty, Raymond L. Wilder and the Russian émigré G.Y. Rainich, were excellent teachers and helped to create an environment for undergraduate and graduate students that was both personally welcoming and intellectually stimulating (Kaplan 1989). Both Wilder and Rainich directed a number of dissertations by women in the forties and fifties. Both Illinois and Michigan—like their prestigious private predecessors, such as Chicago and Cornell—nevertheless show a decline in the number of Ph.D.'s awarded to women from the forties to the fifties.

The University of California at Berkeley appears in the leader list for the first time in the 1940s and remains there in the 1950s. Its presence there is due almost entirely to the influence of two men: the Polish émigrés Jerzy Neyman (1894–1981) and Alfred Tarski (1902–1983), who came to Berkeley in 1938 and 1942, respectively. The statistician Jerzy Neyman supervised the dissertations of two women, Evelyn Fix (Ph.D., Berkeley, 1948; 1904–1965) and Esther Seiden (Ph.D., Berkeley, 1949), and consulted on yet a third, that of Elizabeth Scott (1917–1988), who earned a Ph.D. in astronomy in 1949. Neyman had a reputation for being especially supportive of women colleagues, both at Berkeley and elsewhere. Both Fix and Scott remained on the statistics faculty at Berkeley for the rest of their careers. Scott, in particular, became one of Neyman's most important research collaborators and an eminent statistician in her own

right. Tarski supervised the dissertations of four women students in mathematical logic during the years 1948 to 1953; Julia Robinson was among the first of these.[6]

The Catholic University of America was founded in the 1880s for the graduate education of the Catholic priests and brothers who were to teach at Catholic men's colleges. It was only much later that the Catholic women's colleges began to send the nuns on their faculties to graduate school as well (Power 1972; Solomon 1985). As a result, America's premier Catholic graduate school emerged as a major grantor of mathematics Ph.D.'s to women in the 1930s (Green and LaDuke 1987). In the forties and fifties, however, as Ph.D.-granting departments grew in number and became more geographically widespread, Catholic University declined in importance, as many other institutions—both Roman Catholic (such as St. Louis and Notre Dame) and secular—awarded doctorates to nuns.

The emergence of NYU and Brown as the top two producers of women Ph.D.'s in mathematics during the 1950s is dramatic and striking. These two universities share the distinction of having started, during the 1940s, the first graduate programs in applied mathematics in the United States (Rees 1989). At both institutions, women were enthusiastically invited to join the growing ranks of this field. At Brown, six of the seven women who received mathematics Ph.D.'s in the years 1948 to 1958 earned them in applied mathematics.

At NYU in the late thirties and forties, Richard Courant built what came to be known first as the Institute for Mathematics and Mechanics and, eventually, the Courant Institute of Mathematical Sciences. Through a judicious recruitment of European émigrés and young American talent, Courant presided over the rapid development of pure and applied mathematics at NYU. Courant was drawn to bright, talented young women and established a reputation for encouraging them to pursue careers in mathematics.[7] All three Ph.D.'s in mathematics awarded to women at NYU during the 1940s were directed by Courant; and while only one of the ten women Ph.D.'s of the 1950s was supervised by him, his influence was felt by nearly *all* the women who studied at NYU during those years, as interviews with the women bear out. The atmosphere at NYU—particularly during the late forties and early fifties—has been described as intellectually lively, friendly, warm, and familial.

Just as certain graduate departments were noted for the production of comparatively large numbers of women Ph.D.'s, certain advisers were noted for their encouragement and willingness to advise and support women students. At NYU, for example, two pure mathematicians, Wilhelm Magnus and Lipman Bers, came to be known as especially friendly to women; each supervised the dissertations of three women students in the 1950s and many more thereafter.[8] In general, émigré mathematicians were often particularly encouraging to women. To those I have already mentioned—Bers, Courant, Magnus, Neyman, Rainich, and Tarski—must be added the names of Reinhold Baer (at Illinois and Yale), Waldemar Trjitzinsky (at Illinois), and Antoni Zygmund (at Chicago). Many other mathematicians—even if they did not have large numbers of women students during the forties and fifties—consistently supported women's mathematical ambitions and willingly supervised women's Ph.D. theses. Among these were Paul T. Bateman (Illinois), Robert Cameron (Minnesota), E.W. Chittenden (Iowa), E.P. Lane (Chicago), C.C. MacDuffee (Wisconsin), R.L. Moore (Texas), and R.L. Wilder (Michigan).

Mathematical Specialization and Gender

Do women have particular aptitude for, or are they particularly attracted to, certain subfields of mathematical inquiry? The answer is by no means clear. In their study of the pre-1940 American women mathematics Ph.D.'s, Judy Green and Jeanne LaDuke have determined that the most popular fields of dissertation research were geometry (38 percent), analysis (30 percent), and algebra and number theory (24 percent). They attribute the preponderance of women in geometry to a handful of highly influential thesis advisers in that field who were especially receptive to women students. In general, Green and LaDuke argue against the notion of a "woman's field" within mathematics (1987: 20–21).

In recent decades, however, studies and anecdotes about women, men, and mathematics have put forward the view that women show a significant preference for discrete mathematics over analytical fields, while for men the preference is generally reversed (Hutchinson 1977; Helson 1971; Luchins and Luchins 1980). If there is any truth to the assertion that

women prefer algebraic over analytical fields, this preference was not evident in the forties and fifties. Such a preference—if it exists at all—must be a relatively recent (post-1960) phenomenon.[9]

During the period 1940 to 1959, over 40 percent of the women earned their Ph.D.'s in the fields of analysis and applied mathematics, outnumbering those working in algebra and other discrete fields by a margin of over two to one. In particular, women seemed to be particularly attracted to relatively new fields in mathematics—applied mathematics, statistics, logic, combinatorics. This observation is consistent with the model put forward by Margaret Rossiter (1978), who asserts that in "a rapidly growing field, with a shortage of highly qualified people, women [are] tolerated and even sought out." Sadly, however, Rossiter's model also suggests that women are more likely to persist in fields that are out of fashion, or in which future progress is unlikely, because they are "more willing than men to endure the hardships of a stagnant or shrinking field" (147).[10]

An Introduction to the Women Interviewees

Nearly all of the thirty-six women interviewed for this study have maintained a lifelong connection to the mathematical and academic communities and have had careers in teaching, research, government, educational administration, or some combination thereof. Appendix B lists each interviewee alphabetically, together with information on when and where the Ph.D. was earned, dissertation adviser, general field of dissertation research, marital status, career pattern, and location and length of each interview. Regrettably, the group of interviewees does not include any of the more than twenty Roman Catholic nuns who earned Ph.D.'s from 1940 to 1959; many of them are no longer living, while a number of others declined to be interviewed.

While several of the women with whom I spoke have achieved a modicum of fame and even celebrity in the mathematical community, a good many have lived productive lives in comparative obscurity. What all of these women have in common is that each had the talent, the opportunity, the perseverance, and the good fortune to complete a Ph.D. in mathematics and that each has faced the challenge of making mathematics an important, ongoing part of her life.

Just over a third of the interviewees were either immigrants or children of immigrants from eastern and central Europe. Each of these women found her personal outlook irrevocably shaped by the emigrant experience. Many of the women in this group express a sense of gratitude toward America, accompanied by a strong work ethic and an intense ambition to succeed in their adopted country. Moreover, as the psychologist Ravenna Helson has suggested in her research on women mathematicians in the late 1950s, their European backgrounds enabled them to "avoid some anti-intellectual influences of the mainstream of American culture" (1971: 218).

Well over half of the women interviewed grew up in or near large North American cities; in particular, eight of the interviewees spent the majority of their childhood years in and around New York City. Their urban upbringing exposed them to a diverse cultural, intellectual, and political life. By contrast, six of the interviewees were raised in the urban or rural South, in families that prized education, especially education for women.

As explored further in chapter 3, the future career success and satisfaction of these women seemed to depend crucially on having had a family environment in which education was valued and in which their ambitions were supported and encouraged. Several of the women described home environments where intellectual and social issues were freely discussed and intellectual curiosity was actively nurtured.

The educational backgrounds of parents varied widely. A handful of fathers held Ph.D.'s or worked in the medical or legal profession; four of the mothers held doctorates. In particular, two fathers and one mother held the Ph.D. in mathematics. Several of the women reported having particularly well-educated mothers. In a few families, higher education was a long-standing tradition for both men and women: Mary Dean Clement reports that both of her paternal grandparents had college educations; Mary Ellen Rudin and Joan Rosenblatt report that this was true of both of their grand*mothers*.

In many cases, however, the parents had little formal education and were largely self-taught. As a consequence, they had tremendous respect for education and, because they had not had much themselves, prized it for their children, both male and female. The support and encouragement

of at least one parent seems to have been of signal importance to a young woman's later development as a mathematician. In particular, a solid grounding of support from at least one adult—a parent or a teacher—at an early age helped to provide a bulwark against discouragement or discrimination farther down the road.

Many of these women identified an interest in mathematics as young girls, but this interest was often no more intense than other intellectual interests at the time. Contrary to the dictates of the myth, it was not so important that mathematical interest and talent emerged early; rather, it was much more important that *all* talents and interests be allowed to rise to the surface at an early age and that none in particular be suppressed. A few of the women showed an early interest in the sciences—particularly physics—but many others indicated that languages fascinated them even more. Not surprisingly, perhaps, many of the interviewees aspired to become teachers from an early age.

Half of the women interviewed earned their undergraduate degrees at coeducational institutions—liberal arts colleges, large state universities, and privately or publicly funded urban universities—in the United States. Five of the women earned their first university degrees abroad. Just over a third of the women interviewed completed their undergraduate study at single-sex institutions: eight at private women's colleges, three at coordinate colleges, and two at teachers colleges (which were effectively, if not explicitly, single-sex institutions at the undergraduate level). A substantial majority of the women lived at home, for financial reasons, for all or part of their college years.

Most of the women identified mathematics as their major early in their undergraduate studies. For those whose major was undecided at an early stage, nearly all had included mathematics among the possibilities, with the exception of Tilla Weinstein, who began as a major in English and philosophy and began to consider mathematics as an option halfway through her college education.

Nearly all of them identified an inspiring teacher, or teachers, at the high school or college level who particularly sparked their interest in mathematics. In many cases, college teachers encouraged these women to continue to graduate school, often recommending the same graduate school they had attended. For example, all three of the women interviewed who

earned doctorates at the University of Chicago in the forties were encouraged to do so by Chicago-trained faculty at their undergraduate colleges. But in several other cases, the decision to attend a particular graduate school was made out of financial necessity or geographic convenience.

Many of the women experienced significant delays between receipt of the undergraduate degree and receipt of the doctorate; the mean elapsed time between receipt of the undergraduate degree and awarding of the doctorate is nearly eight years. Many women who attended college during the Depression simply did not have the financial means to continue directly to graduate school. Moreover, some women who took high school teaching jobs right out of college decided after a few years that they would rather teach more advanced mathematics to older and more mature students and thus went on to graduate study in mathematics after a hiatus of several years.

For the European emigrant women, delays between undergraduate and graduate study were often caused by the extreme adversity of moving from country to country. Quite a few of the interviewees, particularly those who earned Ph.D.'s in the 1950s, married before or during graduate school. For these women, family responsibilities, or the precedence granted to a husband's education or career, sometimes caused delays in their own educational progress. Moreover, a few of the women held full- or part-time jobs in graduate school, which sometimes delayed their progress to the doctorate.

The process of selecting an adviser and a field of dissertation research was not much different than it is now. Typically, a beginning graduate student would enroll in a course and become interested in the subject matter and the teacher at the same time; working with a particular adviser in a particular field would then be a natural outgrowth of having taken the course. Then as now, it was sometimes difficult to change advisers once a relationship had been established. A reluctance to change advisers could have serious consequences down the road for women who found themselves trapped in a comparatively unfashionable or unproductive line of research; in particular, this seems to have been a problem for the students of E.P. Lane at Chicago.

At many different universities, a high degree of cameraderie existed among the graduate students and, often, between the graduate students

and faculty. At the same time, however, some obvious social distinctions were made between male and female graduate students. For example, at the University of Chicago during the war, women graduate students were responsible for preparing, serving, and cleaning up after the weekly colloquium tea, while men were generally exempted from any such responsibilities—a division of labor under which many of the women students chafed.

During the growth and expansion of the mid- to late forties, there was a mood of excitement on campus, and both women and men "caught the bug" of mathematical research during these years. For example, Jane Cronin Scanlon, Margaret Marchand, and Barbara Beechler paint especially vibrant pictures of the intellectual excitement at their respective campuses—Michigan, Minnesota, and Iowa—during the years immediately following the war. By contrast, Augusta Schurrer, who worked on her Ph.D. at Wisconsin from 1945 to 1952, noticed that the graduate school environment gradually became much more competitive and far less welcoming to women as increasing numbers of men arrived for graduate study.

Marital Status and Children

In their interesting and provocative study, *Women of Academe,* Nadya Aisenberg and Mona Harrington (1988) assert that American women have been presented with two mutually conflicting models of how to achieve personal and professional fulfillment, which they refer to as *the marriage plot* and *the quest plot.* Particularly in the 1950s, the marriage plot was the cultural norm for American women, who were expected to stay at home raising children and maintaining a supportive home for their husbands; the quest plot was the norm for men, who journeyed out into the wider world and engaged in public life.

The women mathematics Ph.D.'s of the forties and fifties were strongly affected by the conflict between the marriage plot and the quest plot. Fully three-quarters of the interviewees—twenty-seven of the thirty-six—have been married at one time or another during their lives. Moreover, most of these women embarked on their married and professional lives nearly simultaneously: only four of those who married did so more than five years after completing the Ph.D.

Among those women who received Ph.D.'s in mathematics prior to 1940, sixty-three percent never married (Green and LaDuke 1987: 21). Thus, the generation of women who earned Ph.D.'s in mathematics in the forties and fifties is really the first in which substantial numbers set out to challenge the cultural norms and interweave elements of the marriage and quest plots into the fabric of their lives. It is no simple matter to gauge their success. Of the twenty-seven interviewees who married, five were divorced at the time of the interview; three had divorced and remarried; and one had been divorced, remarried, and subsequently widowed.

Eighteen of the interviewees—two-thirds of those who married—have had one child or more. In keeping with the mores of the times, responsibility for children fell disproportionately on the women. Almost all of the women with children reported that they engaged the services of nannies, housekeepers, or babysitters at least some of the time and that such hired help was frequently hard to find. Mary Ellen Rudin reports that, at times, the expenses of child care amounted to more than what she was paid as a part-time teacher at the University of Wisconsin.

Fully half of the women interviewed were married for a significant period of time to another mathematician or to an academic in another field. In many of these couplings, a shared love of mathematics provided a strong social, intellectual, and emotional bond. But in nearly every academic marriage, the man's career development was given priority, and in some cases the woman was handicapped in her ability to finish the Ph.D. or secure a professional position commensurate with her abilities. Antinepotism rules remained in force at many American colleges and universities through the late 1960s and greatly limited the career opportunities of many of the women in this group.[11] In addition, some of the interviewees reported difficulties associated with continuing work or study while pregnant, particularly in the 1950s; it was considered inappropriate and even obscene for an obviously pregnant woman to hold forth in front of a classroom, especially before a class of men.

Among the interviewees in the present study, nine remained unmarried throughout their lives; yet another decided to stay single after a brief, early marriage ended in divorce. Among the unmarried, few expressed regret or bitterness; for some it was clearly a choice. It is interesting to

note that seven of the women who never married received their Ph.D.'s prior to 1949; their undergraduate education had mostly taken place in the 1930s. They came of age at a time when professional women were largely *expected* to remain unmarried; marriage, therefore, may have seemed less compulsory to them. Their female teachers—and primary role models—had for the most part been single women.[12]

Married or not, all of the women interviewed were affected by the cultural norm of the marriage plot. Almost without exception, they reported that as children they *expected* to marry and have families when they grew up. A few of the women who formed professional ambitions at a young age defiantly resolved that they would *never* marry, but these resolutions were sometimes broken later on. Both Janie Bell and Dorothy Maharam Stone made such resolutions during their teenage years, yet each married a fellow mathematician shortly after completing the Ph.D.

Academic Career Paths

Of the thirty-six women interviewed, twenty-eight were eventually tenured professors at one or more colleges or universities in the United States. Of these twenty-eight, six achieved tenure at women's colleges (Schafer, Anderson, Asprey, Bates, Freitag, and Beechler). One (Marchand) was tenured at a small coeducational liberal arts college, Adrian College in Michigan. Five ultimately received tenure at comprehensive state universities (Willerding, Granville, Steinberg, Schurrer, and Williams). Remarkably, the remaining sixteen were ultimately tenured at research universities.[13]

While the majority of the interviewees ultimately held tenured positions at colleges and universities, it was unusual for a woman to start out on the tenure track and remain on it continuously throughout her career. In fact, only nine of the twenty-eight women in the ultimately tenured group held tenure-track positions continuously from the Ph.D. onward. Of these nine, seven worked for one institution for essentially their entire career (Anderson, Asprey, Bates, Wurster, Larney, Schurrer, and Freitag). Several of the other nineteen women held temporary faculty positions, or experienced periods of unemployment, during the first several years after receiving the doctorate, most commonly because they were starting a

family or deferring to the career of a spouse. A few of these women spent extended periods during the early years of their careers in nonacademic employment (Eberlein and Pless).

What was the academic job search like for new Ph.D.'s in mathematics in the forties and fifties? Nowadays, college and university mathematics departments advertise their open faculty positions in the journals of the professional organizations for mathematics—such as AMS, MAA, and the Society for Industrial and Applied Mathematics (SIAM, founded 1952)—and job candidates make direct application for these positions. But in the 1940s, new Ph.D.'s generally landed their first jobs almost exclusively through an informal system that I refer to as *the old-boy/old-girl network*. Typically, a student's adviser would put the word out to colleagues and friends at other institutions that he had a student who was completing a Ph.D. and about ready to take a teaching job. At the same time, department heads seeking new faculty members would contact graduate departments where they had contacts or connections in search of fresh Ph.D.'s. Through these informal conversations, new Ph.D.'s were matched with job openings with remarkable efficiency.

One of the predictable results of the old-boy/old-girl system was that women Ph.D.'s ended up in the mathematics departments of women's colleges, many of which were headed by women Ph.D.'s of the pre-1940 generation. At the women's colleges, teaching loads were often very high and research opportunities were limited. At the same time, the mathematics departments at coeducational colleges and universities, headed and for the most part staffed by men, generally recruited men. If a woman wanted to continue in research, she had to take active control of her job search, often moving through a succession of positions until she found one in which her research efforts were supported and rewarded.[14]

Four of the women interviewed *never* held a regular tenure-track job until they were abruptly appointed to tenured positions when they were already relatively far along in their research careers. From 1955 until 1967, Jean Rubin held temporary faculty jobs, first at the University of Oregon and later at Michigan State. In 1967, however, both she and her husband, also a mathematician, were offered tenured faculty slots at Purdue. Only then did Michigan State come through with a counteroffer of tenure, but the Rubins chose to move to Indiana nevertheless. Lida

Barrett, who married a fellow mathematician in graduate school, was repeatedly denied graduate support and regular faculty positions because of antinepotism rules while her husband was alive. But on his death in 1969, she was immediately offered a tenured professorship at the University of Tennessee. After ten years of temporary faculty status at the University of Wisconsin, Mary Ellen Rudin was appointed a full professor with tenure in 1970. Vera Pless received her first regular faculty appointment in 1975, when the University of Illinois at Chicago hired her as a tenured professor of mathematics and computer science.

Sudden promotions and tenurings of women became increasingly common in the early 1970s, particularly in the aftermath of Title IX, as colleges and universities were scrambling to find highly qualified women to promote or appoint to tenured positions.[15] Title IX of the Educational Amendments Act of 1972 is the piece of federal legislation that effectively "banned sex discrimination in any program of an institution [of higher education] receiving federal funding, including sports, textbooks, and the curriculum" (Rossiter 1995: 382). It was the culmination of more than ten years' organized effort on behalf of women in academia and government seeking equal pay, equal treatment, and equal status.

Discrimination and Opportunity

Without exception, the interviewees all experienced significant obstacles to the pursuit of careers in mathematics because they were women. Particularly in the 1930s and 1940s, many institutional barriers were in place for women who wished to study mathematics. In both high school and college, for example, Grace Bates had to request permission to take advanced mathematics courses, normally available only to men. At all educational levels, women regularly encountered faculty and administrators who either blatantly or subtly conveyed the message that women couldn't or didn't do mathematics. When she entered MIT as an undergraduate at the age of sixteen in 1937, for example, Domina Spencer was denied a full-tuition scholarship on the ground that women—who would eventually marry and drop out of sight—were "a bad investment." She, like many of the other interviewees, refused to back down in the face of such overt discrimination and simply resolved to prove them wrong.

As has already been mentioned, these women were at various times adversely affected by antinepotism rules and discriminatory attitudes toward pregnancy. Unmarried women did not always fare better: when Margaret Willerding came to Washington University as an instructor in 1947, she was told that she would not be promoted as quickly as her male colleagues. Many other women knew that they had been passed over for promotions and raises in favor of men, but few were informed of the situation so bluntly.

Some of these women faced multiple forms of discrimination. Evelyn Granville, who as a young girl aspired to a career in teaching, spent nearly fifteen years working in government and industry, where the opportunities for an African American woman were greater than in academe. She did not return to university-level teaching until 1967. In the case of Rebekka Struik, gender discrimination merely compounded other forms of discrimination she experienced. It was her left-wing political views and activities that left her vulnerable to attack during the McCarthy years of the 1950s. By virtue of her involvement with leftist student groups, she lost a job as a computer programmer at the University of Illinois and also lost a fellowship to attend graduate school in mathematics at Northwestern University.

All of the women interviewed had to struggle against discrimination to a greater or lesser extent, but they differ widely in their attitudes toward such discrimination. Some of them feel that their gender is an asset that has, at times, provided them with certain advantages. Even before the days of Title IX and affirmative action, some individuals took a special interest in the promotion of women. Kenneth Wolfson, the forward-looking chair of the mathematics department at Rutgers University, built up a first-class research faculty in the sixties and seventies by mining untapped sources of talent, hiring Jane Cronin Scanlon and several women Ph.D.'s of her generation in the process.[16] Federal programs, particularly at the NSF, provided opportunities and resources for women to pursue graduate education and postgraduate research. Tilla Weinstein, for example, attended graduate school at NYU from 1955 to 1959 on an NSF graduate fellowship that provided living expenses for herself, her husband, and her child.

In the late 1950s and early 1960s, organizations as diverse as the National Research Council (NRC), the American Association of University

Women (AAUW), and the American Association of University Professors (AAUP) began a concerted assault on antinepotism rules at U.S. colleges and universities (Rossiter 1995). Over the course of a decade, these rules gradually disappeared. The women's movement of the mid- to late sixties—given impetus by the 1963 publication of *The Feminine Mystique* by Betty Friedan—applied the necessary social and political pressure that eventually led to government action against sex discrimination in higher education.

With the federal legislation of the 1970s, colleges, universities, and the federal government were all required to provide equal opportunity for women, and special efforts were made to recruit women to posts that had hitherto been inaccessible to them. While many of the resulting affirmative action efforts were carried out grudgingly, many more opportunities opened up for women in the 1970s and 1980s. Many of the women mathematicians in this study—just entering the peak of their professional creativity and energy—were able to take advantage of these new possibilities. They were invited to serve on national boards and hold national office in professional societies; they were promoted to tenured professorships and rewarded with long-overdue gender equity pay increases; they were invited to move into influential administrative positions.

Many of the women interviewed were sympathetic with the goals of the women's movement, although some were alienated by its methods. Some of them fully embraced the arrival of the movement and became active in efforts to enhance the status and opportunities of women in mathematics and the sciences—most notably Alice Schafer, who played a key role in the founding of the Association for Women in Mathematics (AWM). Established in 1971, the AWM has done more than any other organization to increase the visibility of women in mathematics and to advocate for women's equality in the profession. Several of the other women interviewed are or have been members; some are actively involved in the organization, others not.

Deflection—and Defection—from Academic Careers

Of the eight women who were not eventually tenured in mathematics or mathematics-related departments, four can be described as having been *deflected*—to borrow a term from Aisenberg and Harrington (1988)—

from their original plan to pursue a career in college or university teaching and/or research in mathematics. For three of the women (Bell, Calloway, and Morley), marriage to a graduate school classmate sharply curtailed their pursuit of an independent academic career. Mary Dean Clement, who never married, held a succession of unsatisfying teaching positions in the forties and early fifties and ultimately went to work at a military research facility attached to the University of Chicago, where she had earned her degree.

In addition to these four women who were deflected from the academic career track, five other interviewees can be said to have *defected* from academia. Margaret P. Martin actually held academic positions in statistics for over twenty years and was tenured in two of them. As her parents grew older, however, she chose to live closer to their home in St. Paul and left academia to work as a biostatistician for the Forest Service, where she spent the last twenty or so years of her career. Her defection came not from disappointment or disaffection but rather for personal reasons.

By contrast, Joan Rosenblatt, Betty Jane Gassner, and Susan Hahn never *sought* academic positions on completion of their doctorates. Rosenblatt, whose parents were professors at Columbia, was already quite familiar with academic life and chose instead to pursue a career with the federal government (NBS/NIST). Gassner and Hahn, who had been graduate students at NYU, chose to remain in the New York area; Gassner worked in a succession of industrial research positions, while Hahn spent over twenty-five years at IBM.

Jean Walton is unique among the women who did not end up as professors of mathematics. During the hiatus between her master's degree and work toward the doctorate, Walton served as assistant dean at her undergraduate alma mater, Swarthmore College. On completing the Ph.D. in mathematics at the University of Pennsylvania in 1948, her stated objective was to teach mathematics at a small liberal arts college. But on the strength of her prior administrative experience, she was offered—and accepted—the position of dean of women at Pomona College, where for several years she also taught classes in the mathematics department. As the years went by, she became more deeply committed to her administrative work and stopped teaching mathematics altogether, although she maintained her affiliation with the mathematical societies. Ultimately, however, she severed her connection to the mathematical community entirely.

Varieties of Mathematical Activity

With the exception of Jean Walton, all of the women interviewed identify themselves as mathematicians or as practitioners (*doers*) or teachers of mathematics. Most regard teaching and research as the activities that are most crucial to the ongoing growth and development of the field. Bearing in mind that any attempt to classify these women in terms of their primary career activity is but a rough approximation, I offer three general categories that describe the main focus of their mathematical activity and their identity as mathematicians: researcher, teacher, and scholar-teacher.

Nine of the women interviewed are readily identifiable as researchers: Maharam Stone, Spencer, Cronin Scanlon, Rudin, Morawetz, Eberlein, Rubin, Pless, and Weinstein. Yet another, Joan Rosenblatt, pursued a varied career in the federal government that included lengthy administrative stints; yet she, too, seems to identify primarily with research and scholarly activity. In addition to these ten, Lida Barrett's primary focus was in research until she became involved in academic administration in the early 1970s.

The high-status role of researcher, which was presented as normative to most doctoral students in the postwar years, was the role most at odds with the cultural expectations of women, particularly during the 1950s. It is interesting to note, therefore, that all eleven of the women who identified as researchers are or have been married for a significant part of their active professional lives and that only one of these women was childless. This raises the possibility that married women with children may in fact have been more acceptable in the male-dominated mathematical research community because they had also fulfilled their social obligations as women. It also raises interesting questions as to just how effectively unmarried or childless women were integrated into the postwar American mathematical community.

Nine of the women were associated with the more traditionally female role of teacher: Anderson, Wurster, Larney, Schurrer, Beechler, Schafer, Marchand, Granville, and Williams. Again, this classification is a fairly rough approximation; Marchand, for example, spent four of her first six postdoctoral years as a research biostatistician but from 1956 until her retirement in 1990 worked primarily as a teacher of mathematics.

Although Larney, Granville, and Wurster were involved in the writing of mathematics texts, teaching was clearly their primary focus.

For three of these women—Beechler, Schafer, and Marchand—the choice of teaching as a career clearly involved a turning *away* from research. From a very early age, Barbara Beechler was enthralled with the romance of scientific discovery, but her graduate school experiences were a source of alienation and disillusionment and soured her on the possibility of future research. Alice Schafer feels very strongly that the graduate faculty at Chicago in the forties simply did not take the research potential of women students seriously; in a sense, she feels she was limited to a teaching career from the start. Her anger over these experiences has been creatively channeled over the years into her enthusiastic mentorship of young women in mathematics and into her energetic leadership of the AWM. For Margaret Marchand, by contrast, the turn from research to teaching was a welcome return to her original ambition and so did not, apparently, engender the kind of bittersweet or angry feelings expressed by Beechler and Schafer.

Many of the women interviewed occupy a position intermediate between the categories of *researcher* and *teacher,* which I refer to as the *scholar-teacher.* For the scholar-teacher, scholarship and teaching are regarded as mutually interdependent, although teaching often takes preeminence. Asprey, Bates, Willerding, Freitag, Lax, Luchins, and Struik have all been scholar-teachers; each has pursued scholarly interests that at times proved indispensable to their teaching. For example, Winifred Asprey established close ties between Vassar College and IBM, which culminated in the establishment of a computer center at Vassar in the mid-1960s. Grace Bates, whose doctoral research was in abstract algebra, later conducted research in probability and statistics with Neyman at Berkeley. This dramatic shift of research field came as an outgrowth of her need to learn the subject in order to teach it at the undergraduate level at Mount Holyoke College. For both of these women, research and scholarship were intertwined with their teaching in a fairly seamless way.

In addition to the seven women already mentioned, the career of Margaret Martin prior to her move into the Forest Service had the quality of the scholar-teacher: the statistical research she conducted over the years arose from her role as a statistical consultant for schools of medicine and

public health, particularly in connection with her work as a teacher of statistics to medical students. Maria Steinberg's professional experience defies neat categorization but has something of the spirit of the scholar-teacher. Research and teaching tended to be sequential rather than simultaneous activities during her career. Although her involvement with research effectively ended in the 1950s, she has maintained an ongoing sense of connection to the research community through her husband, Robert Steinberg, so that the spirit of mathematical research is very much a part of her sense of herself as a mathematician.

As is noted in chapter 1, many mathematics faculty at prestigious colleges and universities in the early decades of this century viewed themselves as scholar-teachers. Thus for the women mathematicians of the postwar generation, the role of scholar-teacher may be viewed as a return to the turn-of-the-century academic ideal. It may also be viewed as a creative synthesis of the "female" role of teacher and the "male" role of research mathematician, but for many of these women it was also a not entirely satisfactory compromise between two unacceptable career alternatives.

The other six women interviewed (Clement, Bell, Calloway, Morley, Gassner, Hahn) defy neat categorizations. Clement and Morley may be regarded as deflected scholar-teachers, Calloway and Gassner as deflected researchers. Susan Hahn's career at IBM was shaped by the commercial needs of the company and took her progressively further away from her mathematical origins. Although Janie Bell cannot be said to have had a career in teaching, she has held short-term and temporary teaching positions at every level from elementary school through college and very clearly sees herself as a teacher of mathematics.

Accomplishments and Expectations

Any attempt to assess the degree of success that these women have achieved in their lives and careers must take into account the extent to which their accomplishments fulfill the expectations they had for themselves. For example, many of the women interviewed whom I have categorized as teachers have nevertheless expressed tension or dissatisfaction over the road not taken in research. Some of them genuinely wish they

had been granted the opportunity to prove themselves as researchers; others simply report feeling a tension between the research expectations others had for them and the professional activities they freely chose to pursue. Violet Larney goes so far as to raise the provocative question: are women actually *capable* of conducting research in mathematics at the same level as men?[17]

Success and satisfaction are derived from many things: a feeling that one has contributed substantially to the body of mathematical knowledge; a feeling that one has made a contribution to the welfare of students or to the mathematical and academic communities as a whole; the sense that one has made the best use possible of one's talents and energies. The chapters that follow explore in detail the lives and careers of this special group of thirty-six women in an attempt to better understand the personal and professional dimensions of success and failure, satisfaction and frustration, in their lives and careers, in and around mathematics.