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Women Mathematicians and the World War II Transition

Men, Women, and the Mathematics Ph.D. prior to 1940

Until very recently, women have been largely absent from accounts of the social and cultural history of mathematics. Prior to 1870, women participated in mathematics, as in the other sciences, as teachers and amateurs but only rarely as professionals.[1] Among the earliest women to achieve recognition for mathematical achievements—Hypatia of Alexandria, Maria Agnesi, Emilie du Chatelet, Sophie Germain, Mary Somerville, and Lady Ada Lovelace—only Hypatia (355?–415) was widely recognized as a bona fide member of the mathematical community of her day; the others were relatively well-to-do European women of the eighteenth and nineteenth centuries who pursued mathematical interests at their leisure (Deakin 1994; Dzielska 1995; Osen 1974; Grinstein and Campbell 1987; Morrow and Perl 1998).

In the mid- to late nineteenth century, however, institutions of higher education began to open their doors to women—in Europe, and, on a grand scale, in the United States—and women began to lay claim to a place in the professions. The doctor of philosophy (Ph.D.) degree was established in Germany in the late eighteenth century, to recognize advanced study and original scholarship in a given discipline. German universities became centers of advanced study and research that were emulated in the United States and around the world. Sonya Kovalevskaya was the first woman to receive a Ph.D. in mathematics, awarded to her *in absentia* by the University of Göttingen in Germany in 1874; she was the first modern woman to pursue mathematics as a profession.[2] Many other women followed as the Ph.D. increasingly came to be

acknowledged as the professional certification for research and teaching in advanced mathematics.

But German universities conferred degrees on women only reluctantly; it was in America that women finally broke down the educational barriers and began to earn doctorates in steadily growing numbers. While there had been colleges and universities in the American colonies from the seventeenth century onward—largely devoted to the preparation of young men for careers in the ministry and in law—the development of higher education in the United States was essentially a nineteenth-century phenomenon (Newcomer 1959: 5–34). The rapid industrialization and urbanization of the new nation provided the impetus for this development (Horowitz 1987: 4–7). At midcentury, older institutions such as Harvard and Yale began to refashion themselves as research institutions on the German model (Simpson 1983: 17–21); the Morrill Land-Grant Act of 1862 led to the founding of state colleges and universities in the public interest; and private colleges and universities of every type and description sprouted up across the land in the service of varied educational, vocational, and professional objectives (Rainsford 1972; Wallenstein 1997).

With the proliferation of colleges and universities in nineteenth-century America, higher education became increasingly available to women. Oberlin College in Ohio, founded in 1833, was open to men and women of all races from its inception and awarded the first bachelor's degrees to women in the United States in 1841 (Newcomer 1959: 5; Solomon 1985: 21–22). Women's colleges were established all over the country, particularly in the aftermath of the Civil War; Mount Holyoke, Vassar, Wellesley, Smith, and Bryn Mawr rapidly grew into colleges with outstanding national reputations (Solomon 1985: 47–49). Offered as a compromise between coeducation and sex segregation, the so-called coordinate colleges were usually private women's colleges affiliated with existing public and private men's schools; Barnard, associated with Columbia and founded in 1889, and Radcliffe, associated with Harvard and founded in 1894, are the best-known examples (Newcomer 1959: 40–45; Solomon 1985: 47, 55–56). The state colleges and universities established with Morrill Land-Grant funds were generally coeducational in the North but single-sex in the South (Newcomer 1959; Solomon 1985; Wallenstein 1997).

During the academic year 1861–62, Yale University awarded the first American Ph.D. degrees, and the first such degree in mathematics. In the decades that followed, many other universities developed graduate departments in mathematics and began awarding the Ph.D., most notably Johns Hopkins and Clark Universities and the University of Chicago (Richardson 1989: 365–366; Parshall and Rowe 1994). As research-oriented departments of mathematics emerged in the United States, a genuine *community* of mathematicians began to coalesce. The New York Mathematical Society, founded in 1888, was rechristened six years later as the American Mathematical Society (AMS) to acknowledge its national scope. The AMS, dedicated to the concerns of the growing mathematical research community, sponsored numerous meetings and conferences and published two journals of its own: the *Bulletin* and the *Transactions of the American Mathematical Society* (Parshall and Rowe 1994).

Christine Ladd (later, Ladd-Franklin) was the first woman to be admitted to graduate study in mathematics in the United States, when she began work toward the Ph.D. at Johns Hopkins University in 1878. When she completed her dissertation in 1882, however, Johns Hopkins refused to award her the degree, on the ground that they did not confer doctorates on women; only years later did they relent, awarding her in 1926 the Ph.D. she had earned nearly half a century earlier. Winifred Edgerton was the first woman actually to receive the Ph.D. in mathematics from an American institution, when Columbia University awarded it to her in 1886 (Green and LaDuke 1987, 1989; Grinstein and Campbell 1987).

The struggles of these pioneers opened the mathematical profession to women in the United States. During the nineteenth century, a total of ten American women earned Ph.D.'s in mathematics, nine from institutions in the United States (Bryn Mawr, Columbia, Cornell, and Yale) and one in Europe (at Göttingen). All ten—together with British-born Charlotte Angas Scott, who earned a Sc.D. at the University of London in 1885 and subsequently headed the mathematics department of the newly founded Bryn Mawr College—were active members of the American mathematical community (Green and LaDuke 1987, 1989; Fenster and Parshall 1994).

From 1862 through the first two decades of the twentieth century, the number of mathematics doctorates awarded in the United States

Table 1.1
Ph.D. Degrees in Mathematics Awarded by American Colleges and Universities, 1862 to 1919

Years	Total Awarded	Men		Women	
		Number	Percent	Number	Percent
1862–1869	3	3	100	0	0
1870–1879	10	10	100	0	0
1880–1889	32	31	96.9	1	3.1
1890–1899	84	76	90.5	8	9.5
1900–1909	155	138	89.0	17	11.0
1910–1919	251	216	86.1	35	13.9
1862–1919	**535**	**474**	**88.6**	**61**	**11.4**

Source: Richardson 1989: table 1, 366 (total Ph.D.'s through 1919); Green and LaDuke 1987: table 3, 18 (Ph.D.'s to women through 1919).

increased steadily every year. From 1890 through 1919, the number of these Ph.D.'s awarded to women "doubled each decade" (Green and LaDuke 1987: 15). By 1920, the year American women won the right to vote, sixty-one women had earned the Ph.D. in mathematics from U.S. institutions; women's share of the mathematics Ph.D.'s approached 14 percent of the total. Table 1.1 gives data on the production of mathematics Ph.D.'s in the United States during the years 1862 to 1919, by gender.

Both men and women continued to earn increasing numbers of Ph.D.'s in mathematics in the United States during the 1920s and early 1930s. For both men and women, the numbers of Ph.D.'s earned in the thirties were roughly double those awarded in the twenties (Green and LaDuke 1987: 15–16). During the years 1935 to 1939, there was a drop in the overall numbers of Ph.D.'s awarded, probably due to the Depression. Table 1.2 enumerates the mathematics Ph.D.'s awarded, by gender, during the years 1920 to 1994, reported in five-year aggregates.

Taken together, tables 1.1 and 1.2 reveal some interesting trends. During the teens, twenties, and thirties, women consistently received roughly 14 percent of the Ph.D.'s awarded in mathematics in the United States in each decade. These percentages, while clearly not proportional to the distribution of women in the general population, represent a fairly stable,

Table 1.2
Mathematics Ph.D.'s Awarded in the United States, by Gender (in five-year aggregates, 1920 to 1994)

Years	Total Awarded	Men		Women	
		Number	Percent	Number	Percent
1920–1924	114	93	81.6	21	18.4
1925–1929	238	210	88.2	28	11.8
1930–1934	396	334	84.3	62	15.7
1935–1939	384	333	86.7	51	13.3
1920–1939	**1,132**	**970**	**85.7**	**162**	**14.3**
1940–1944	364	321	88.2	43	11.8
1945–1949	471	427	90.7	44	9.3
1950–1954	1,059	1,008	95.2	51	4.8
1955–1959	1,266	1,208	95.4	58	4.6
1940–1959	**3,160**	**2,964**	**93.8**	**196**	**6.2**
1960–1964	2,082	1,967	94.5	115	5.5
1965–1969	4,325	4,077	94.3	248	5.7
1970–1974	6,187	5,684	91.9	503	8.1
1975–1979	4,690	4,107	87.6	583	12.4
1960–1979	**17,284**	**15,835**	**91.6**	**1,449**	**8.4**
1980–1984	3,591	3,060	85.2	531	14.8
1985–1989	3,765	3,137	83.3	628	16.7
1990–1994	5,253	4,191	79.8	1,062	20.2
1980–1994	**12,609**	**10,388**	**82.4**	**2,221**	**17.6**
1920–1994	**34,185**	**30,157**	**88.2**	**4,028**	**11.8**

Source: Harmon and Soldz 1978, table 26 (1920–1958); National Research Council, Survey of Earned Doctorates 1996 (1958–1994).

healthy share of the Ph.D. total over the period. In particular, by the mid-1930s, women were on the verge of attaining "critical mass": the concentration at which women begin to make the transition from token status to full membership in a professional community.[3] But at that crucial juncture, the momentum of women's gains in mathematics was slowed, first by the Depression and then by the onset of World War II.

About 1935, women's share of the Ph.D.'s in mathematics began a truly startling decline. This decline was at its steepest during the years 1945 to 1955, just as mathematics entered a period of unforeseen power,

prestige, and prosperity. From 1945 through 1974, women consistently received fewer than 10 percent of the Ph.D.'s awarded annually. In particular, women's share of the total declined through the entire period 1940 to 1959, reaching an historic low of 4.6 percent in the second half of the 1950s. It was not until the late 1970s that women once again consistently received more than 10 percent of the mathematics Ph.D.'s and not until the 1980s that the percentages returned to the levels attained in the 1930s (Green and LaDuke 1987:12).

The half-century from 1886 to 1936 was an especially bright and promising one for women in the mathematical community. What factors can account for the dramatic decline that came so abruptly afterward? I begin with a look at the American mathematical and social landscape prior to 1940, with particular emphasis on the 1930s, for it is here that the seeds of later developments were sown.

The Polarization of Teaching and Research

From the 1870s onward, as the number of Ph.D.-granting departments of mathematics increased, the American mathematical research enterprise grew in size and international reputation. The AMS, through its journals, meetings, and conferences, supported and encouraged the growth and development of research (Parshall and Rowe 1994). From the late nineteenth century through the mid-1930s, however, a substantial majority of American Ph.D. recipients did little or no research beyond the doctoral dissertation (Richardson 1989: 372–373). The primary professional activity, for nearly all the men and women who received these early American Ph.D.'s in mathematics, was teaching.

Unlike the men, however, women Ph.D.'s usually ended up teaching at women's colleges rather than coeducational colleges or universities. Despite heavy teaching loads, several of these women continued to be active in research and scholarship and assumed leadership positions in the mathematical community. Among the most distinguished of these was Anna Pell Wheeler (Ph.D., Chicago, 1910; 1883–1966), who succeeded Charlotte Angas Scott as head of the Bryn Mawr mathematics department in 1924 and directed seven doctoral dissertations there. Scott and Wheeler numbered among the handful of pre-1920 women doctoral re-

cipients who went on to hold major leadership positions in the AMS in the years prior to 1930 (Green and LaDuke 1987, 1989; Grinstein and Campbell 1982, 1987).

From its very beginnings, the American mathematical community has experienced chronic tension along a fault line that runs between teaching and research. Nowhere was this tension more clearly manifest than in the events surrounding the founding of the Mathematical Association of America (MAA) (Cairns 1938: 1–3; Ewing 1994: 3–4). In 1894, the *American Mathematical Monthly,* a journal dedicated in the main to the concerns of postsecondary mathematics teachers and students, began publication. When, under financial hardship, the *Monthly* sought funding from the AMS in 1914, the AMS politely but firmly refused. This action led to the founding of the MAA two years later. In addition to assuming responsibility for the *Monthly,* the MAA came into being to serve the professional needs of the large community of teachers and students of advanced mathematics. While the two societies had a large core of members in common, there were sufficient differences in membership patterns to suggest a genuine division in the community as a whole (Richardson 1989: 369–370).

In fact, the interests and activities of the early American mathematical community were more varied and diverse than a simple bifurcation into teaching and research would suggest. Particularly during the years prior to 1930, even the most influential American mathematicians were not exclusively devoted to research or to teaching but, rather, to a synthesis of the two into *scholarship* that placed mathematics into historical, critical, and cultural contexts. Even the *Bulletin of the American Mathematical Society* was ostensibly devoted to "a historical and critical review of mathematical science."[4]

But more than any other organization, the MAA served as the natural home for the broader interests and concerns of the mathematical community. Its leadership in the years prior to World War II was firmly committed to scholarship and service to mathematics in the wider sense.[5] In an address delivered in September 1931, MAA President John Wesley Young chastised the AMS for its singleminded focus on research to the exclusion of other mathematical activities (Young 1932). "I have . . . attempted to combat the attitude," Young said, "that would make of research a fetish,

that proclaims that the only worthy function of a mathematician is research and that other activities are to be looked on with contempt." He went on to exhort the MAA membership to work in such diverse areas as "criticism, evaluation, and interpretation," "history," the writing of "advanced mathematics from the elementary point of view," "popular exposition," and administration (15).

Young's carefully chosen words reveal the gendered structure of mathematics in the early 1930s, drawing a clear distinction between the "men and women" of the MAA and the "research men" of the AMS. Among his chief priorities is that the MAA continue "to attract men and women of ability to our subject" (10). Indeed, the MAA served as professional home for many women mathematicians. Women published expository articles, posed problems, and offered their solutions in the pages of the *Monthly,* which also regularly reported news of their activities in college and university mathematics clubs. Women presented papers at MAA meetings and served in leadership positions, especially in the regional sections of the Association. The MAA was a place where women were acknowledged as mathematicians, teachers, and scholars, and treated with honor and respect.[6]

During the Depression years of the 1930s, the polarization between research and teaching/scholarship intensified. By 1930, the leadership of the American mathematical community had passed to a younger generation, whose leaders—influenced by spectacular recent developments in atomic chemistry and physics—were far more enamored of narrowly focused research than broad and humanistic scholarship (Parshall and Rowe 1994: 445–451). Stronger ties between industry and basic science, forged in the aftermath of World War I, had already begun to favor mathematical research in the 1920s. Industrial philanthropies like the Rockefeller and Carnegie Foundations supported research in mathematics and science both directly and through the National Research Council (Green and LaDuke 1987: 16; Kleinman 1995: 31–45).

While many creative young mathematicians were already present, the resurgence of American mathematical research was fueled by the infusion of mathematical immigrants from central and eastern Europe that began in the 1920s and gained momentum with Hitler's rise to power in the 1930s (Dresden 1942; Bers 1989; Reingold 1989). Many

of these immigrants had experienced the heady intellectual atmosphere of the major European research centers in Vienna, Göttingen, and elsewhere. There was an eagerness in the American mathematical research community to recreate this exciting atmosphere in the United States, and several émigré mathematicians had a hand in bringing these dreams to fruition.

Among the most significant developments of the prewar period was the founding of the Institute for Advanced Study at Princeton in 1930. The Institute, financed by corporate philanthropy, was conceived as a center for postgraduate research, with a small permanent faculty and a large cadre of temporary members holding short- and long-term appointments. The School of Mathematics was the first department created in the Institute, its original faculty a mix of Americans—James Alexander, Marston Morse, and Oswald Veblen—and refugees—Albert Einstein, John von Neumann, and Hermann Weyl.[7]

While the thirties brought renewed enthusiasm (and financial support) for research to American mathematics, the excitement was rather unevenly distributed, even among the most prestigious graduate departments. At the University of Chicago, for example, the faculty had become somewhat inbred. Numerous Chicago Ph.D.'s had simply joined the faculty on graduation, and the research emphasis of the department lay in directions that had been more fashionable several decades earlier (MacLane 1989: 138–143; Parshall and Rowe 1994: 445–446). Although many distinguished mathematicians came to the United States as refugees in the 1930s, they were not immediately made welcome. Many were unable to find employment commensurate with their talents in research due to anti-Semitism, particularly in the form of Jewish faculty quotas at several prestigious institutions (Bers 1989; Reingold 1989). Moreover, the financial constraints of the Depression often made it impossible for departments to engage in much recruitment of new faculty or to create conditions conducive to research productivity (Niven 1989).

At the same time, despite the heightened visibility of mathematical research in the thirties, the broadly based, humanistic scholarship of the early years did not die. While the *Bulletin of the AMS* quietly dropped its historical and critical missions in 1931, new journals devoted to historical and philosophical aspects of mathematics, such as *Scripta*

Mathematica, appeared on the scene (Merzbach 1989: 654). George Sarton, the highly influential Harvard historian of science, argued passionately in 1936 for a continuation of the thorough, careful study of the history of mathematics—by mathematicians (Sarton 1936).

But in terms of prestige and power, mathematical research was clearly in ascendancy. While the MAA and its functions, as laid out so eloquently by John Wesley Young, continued to survive and to thrive, it was clear by the late thirties that power and influence were shifting to "the research men." Although distinguished and highly productive women mathematicians came to the United States in the European migration—Emmy Noether and Olga Taussky most notable among them—the growing prestige of research made it increasingly the province of men. It is not surprising, then, that while women continued to hold national and regional leadership positions in the MAA after 1930, they were virtually absent from leadership positions in the AMS from the 1930s through the 1960s (Green and LaDuke 1989: 386, 390).

In fact, the Depression was a time of setbacks for women after the tremendous educational, social, political, and professional gains they had made through the twenties (Brown 1987; Ware 1982). Working women, both in academia and elsewhere, were particularly singled out for pay cuts, demotions, and dismissals, justified by the argument that men raising families should be accorded preference in a time of diminished resources (Rossiter 1995; Ware 1982). The cultural and economic sea change of the thirties offered but a glimpse of the greater turbulence to come.

Women and the "Mathematician's War"

Before World War II, virtually no government grants were available for mathematical research. Apart from agricultural research at universities and research conducted in federal laboratories, the government sponsored comparatively little scientific research of any kind. Indeed, the only grants available for basic science at colleges and universities were funded by private foundations. Large corporations carried out their own product-related research, but very little of this was of a mathematical nature (Kleinman 1995: 26–50).

But as war broke out and spread across Europe, the U.S. government came to recognize the importance of science and technology to national security. In June 1940, well over a year before the American entrance into World War II, President Roosevelt created the National Defense Research Council (NDRC), which was incorporated a year later into the Office of Scientific Research and Development (OSRD) under the directorship of Vannevar Bush. The OSRD funded and coordinated war-related research and development efforts through numerous university and industrial contracts (Kleinman 1995: 61–65; Zachary 1997).

Mathematicians played key roles in many of these efforts, largely under the auspices of the Applied Mathematics Panel of OSRD, directed by former Wisconsin mathematics department head Warren Weaver (Rees 1989). So great was the involvement of mathematicians in the war effort that Frank B. Jewett, chair of Bell Telephone Laboratories and an adviser to Vannevar Bush, went so far as to characterize World War II as "a mathematician's war" (Jewett 1942: 240).

What role did women play in this "mathematician's war"? Very few women mathematicians are mentioned in contemporary and retrospective accounts of war-related research and development. In fact, the contributions of just two pre-1940 Ph.D.'s recur in later accounts of mathematicians' wartime activities. Mina Rees (Ph.D., Chicago, 1931) served as technical aide to Warren Weaver on the Applied Mathematics Panel and subsequently played an important role in postwar government funding of mathematical research. Grace Murray Hopper (Ph.D., Yale, 1934) joined the Naval Reserve and began an involvement with the navy and the development of high-level computer languages that lasted for well over forty years.[8]

The role played by women mathematicians on college and university campuses was more prominent during wartime, however. As young men disappeared into the armed forces and faculty members disappeared into war work, both undergraduate and graduate enrollments on American college and university campuses were down, sometimes dramatically (Olson 1974: 46). In the wartime environment, women were especially welcome as students to offset declining enrollments. At Virginia Polytechnic Institute, a nominally coeducational but predominantly male land-grant institution, the historian Peter Wallenstein writes, "the pressure

to include women grew stronger, as students, especially men, grew scarce. . . . [T]he number of regular students dropped from 3,382 in spring 1942 . . . [to] 557 in spring 1944, to only 411 in spring 1945" (1997: 155 and 161).

In all of the sciences, and mathematics in particular, women were also made welcome as graduate teaching assistants, to offset staffing shortages caused by involvement of male faculty in off-campus war research. As the war progressed, the government instituted special instructional programs for military personnel that were to be carried out under contract on college and university campuses, most notably the Navy V-12 program and the Army Specialized Training Program (ASTP). At the approximately 300 colleges and universities sponsoring the V-12 and ASTP programs, the demand for teaching personnel escalated. Students and recent Ph.D. graduates in mathematics, male and female, were often called on to staff these military courses (Newsom 1943a, 1943b; Cairns, Dresden, and Kline 1943; Price 1943).[9]

The wartime enrollment decline was decisively reversed with the passage of the Servicemen's Readjustment Act of 1944, familiarly known as the G.I. Bill of Rights. Even before the war's end, veterans who had seen a tour of military duty began enrolling in college and university courses, often for the first time. The demand for teaching personnel, which had gone up slightly and selectively with the institution of the military training programs, increased substantially across the board beginning in 1944 (Olson 1974). From 1942 to 1946, the number of women teaching mathematics at U.S. colleges and universities more than doubled, while the number of women on faculties across all the science disciplines more than tripled. Indeed, as historian Margaret Rossiter asserts, "the movement of women scientists onto college and university faculties during the war was so widespread that it constituted their principal contribution to the war effort" (1995: 10–11).

In short, while the crisis of World War II brought increased opportunities for women to study and teach advanced mathematics on college and university campuses, it also tended to heighten the polarization of teaching and research in mathematics that had begun in the 1930s. While "research men" had helped to win the war, women took up the task of educating the troops.

Mathematics, Education, and National Security in the Postwar Years

Because the Allies' victory in World War II was seen as having resulted significantly from their scientific and technological superiority, political sentiment ran strongly in favor of continued governmental and military support of basic research. The postwar years saw the establishment in 1946 of the Office of Naval Research (ONR) and the Atomic Energy Commission (AEC), and finally, in 1950, the National Science Foundation (NSF). Because so many mathematicians had been involved in war work, new government funding agencies were extremely generous to projects in all areas of mathematics, pure and applied. This most basic, least empirical, and "purest" of the sciences was now seen as crucial to the security and power of the nation (Richardson 1943; Brink 1944; Rees 1989; Kleinman 1995; Zachary 1997).

After the austerity of the Depression and World War II, American mathematics was poised on the brink of a period of growth and efflorescence. All that was needed to fuel the expansion was a massive influx of young recruits to the field. That influx was provided, at least initially, by the G.I. Bill, which enabled millions of American service personnel—some of them women, but the overwhelming majority of them men—to undertake undergraduate and graduate study in colleges and universities all across the United States. Many of these men would not have attended college at all without the financial assistance of the G.I. Bill, and many of them, on graduation from college, found academic life to their liking and continued on for advanced degrees (Olson 1974; Hartmann 1982).

The glut of incoming students created a dramatic shortage of teachers; graduate students and even knowledgeable undergraduates were pressed into classroom service.[10] In the early years after the war, with graduate enrollments still comparatively low, women were generally made to feel welcome as graduate students in mathematics; their services as teachers were particularly in demand. At the same time, many major public and private universities coped with the enrollment boom by restricting undergraduate admissions of women. Even some women's colleges made provisions to accommodate returning G.I.'s on their campuses.[11]

By the late 1940s, increasing numbers of men were starting work toward the Ph.D. in mathematics. Women, who had been welcomed as

graduate students throughout the war and amidst the chaos of the early postwar years, suddenly found themselves in competition with substantial numbers of men for faculty attention and departmental resources. As the environment for graduate students became more competitive, so, too, did the environment for faculty, both on university campuses and in the mathematical community as a whole. With the increased availability of research funds from the federal government, and graduate teaching assistants to do lower-division teaching, graduate departments of mathematics had the financial means to lower the teaching loads of their faculty involved in research. At the same time, newly-established federal grants provided summer salaries and release time from teaching. With increased means came increased expectations of faculty research productivity; ambitious younger faculty could choose, from a large pool of talent, those doctoral students most likely to assist them in carrying out their research plans.

A host of factors contributed to the declining share of mathematics Ph.D.'s awarded to women in the 1950s. Because of the stateside shortage of men during World War II, women were allowed and even encouraged to work in industries and professions that were traditionally closed to them. The image of Rosie the Riveter on patriotic posters of the time enhanced the notion that working women were active contributors to the national defense. But once the war had been won, it was time for women to return to their traditional roles. The prevailing cultural message to the woman of the late forties and early fifties—delivered through magazines, newspapers, radio, and eventually television—was that her proper social role was to marry, make a home, bear and raise children, and provide emotional nurturance and social support to her husband. To do so was just as patriotic as working outside the home during the war had been (Friedan 1963; Hartmann 1982).[12]

Just as young men were increasingly drawn to academic careers in mathematics, academic institutions were erecting barriers to women's professional advancement. Antinepotism rules became increasingly prevalent at American colleges and universities and came in many forms. Some prohibited members of the same family from being employed in the same institution or the same department, and still others prohibited one family member from being in the position to make personnel deci-

sions about another. What they all had in common was that, in practice, they were applied prejudicially and often peculiarly against women (Dolan and Davis 1960; Rossiter 1982, 1995). Because women mathematicians who marry frequently marry other mathematicians, antinepotism laws could be particularly crippling to the career prospects of a married woman in mathematics.[13]

The expansion in higher education that had begun in response to the G.I. Bill continued through the 1950s and into the 1960s. Once the United States had entered the cold war, the highest priority was placed on maintaining the technological and military superiority of the United States over the Soviet Union and its allies. The Soviet launching of the first space satellite, *Sputnik,* in 1957, merely intensified the preexisting emphasis on scientific research and development and, concurrently, on scientific and technical education (Clowse 1981; Rossiter 1995: 63–64).

The continued growth of higher education was ensured by the demographic pressure of the baby-boom generation—the children born between 1946 and 1964—which brought a new wave of bulging undergraduate enrollments in the sixties. As the enterprise of American higher education expanded, colleges and universities continually sought to upgrade their facilities and enhance their status. "Upgrading and enhancement" frequently meant heightened emphasis on faculty research and graduate education. In particular, state normal schools and teachers colleges were transformed into comprehensive state universities. Women's colleges felt increasing pressure to become coeducational and to increase the proportion of men on their faculties (Harcleroad and Ostar 1987: 41–64; Rossiter 1995: 206–234). The net effect of these transformations was to substantially reduce the visibility of women in academia.

The Myth of the Mathematical Life Course

The twenty-five-year period following the conclusion of World War II was, in the opinion of many observers, the golden age of American mathematical research. As the prospect of a career in mathematics became increasingly attractive and desirable in the prosperous postwar years, *the myth of the mathematical life course* (hereinafter, *the myth*) became the prevailing model of how that career should unfold. While many aspects

of the myth date back to the nineteenth century and earlier, the conditions were ripe in the postwar years of the forties and fifties for the myth of the mathematical life course to grow and flourish. The rapid expansion of higher education, the proliferation of academic job openings, the high status and substantial funding accorded to mathematical research: all of these circumstances created the conditions under which it was possible, for the first and perhaps only time in history, for substantial numbers of mathematicians—mostly men—to carry on their lives and careers in conformity with its pattern.

According to the myth, mathematical talent and creative potential emerge very early in childhood. These natural gifts are focused and directed toward mathematics from this early age. In college, that the major will be mathematics is a foregone conclusion, and the student proceeds from college to an elite graduate school without a break. In graduate school, the student comes under the tutelage of a powerful mentor, under whose direction he writes a doctoral dissertation that makes a significant contribution to his area of study. As his graduate studies draw to a close, his mentor assists him in landing a postdoctoral research position at a similarly elite doctorate-granting department of mathematics, and afterward he goes on to one or more positions at comparably distinguished universities, where his creative achievements are rewarded with tenure.

The mathematician is extraordinarily productive in research from his late teens until his early forties and during this period does his best work. There are no interruptions during these years of scholarly productivity (except possibly for a brief period of military service), and to a considerable extent, the mathematician ignores or eschews other interests during this time. It is very helpful if the mathematician has a spouse who will take care of domestic and family concerns and provide him with a peaceful home environment that supports his creative work.

In the later years, research productivity continues, albeit at a somewhat lesser rate; the mathematician continues to generate creative ideas, but the working-out of these ideas falls to his younger colleagues and (especially) graduate students, who carry out the various aspects of his research program. It is perhaps possible, later in life, for the mathematician to enjoy some hobbies and diversions, but his primary concern is and continues to be mathematics.

Several aspects of the myth are clearly peculiar to mathematics. Because many people have experienced school mathematics as abstract and difficult, the general public is inclined to view mathematics as the domain of geniuses who understand and enjoy the subject because they were "born that way." Since mathematical knowledge is cumulative, early difficulty with mathematics often seems to be compounded with the passage of time; so that by the sixth grade, for example, it may already be too late to repair a wounded relationship with the subject. Such experiences seem to underscore the popular perception that mathematical talent needs to be discovered and nurtured from an early age (Tobias 1993).

In many important respects, however, the myth is not specific to mathematics but describes the ideal development of any academic career. In an incisive analysis of the academic career system as it has evolved over the past two centuries, the sociologist Arlie Russell Hochschild (1975) has pointed out that many disciplines emphasize the importance of creative achievement at an early age. The emphasis on uninterrupted progress is not even unique to academic life but underlies the whole notion of how careers—especially men's careers—ought to unfold. Her characterization of the idealized American academic career path sounds strikingly similar to the timetable laid out in the myth. Moreover, she explicitly questions the appropriateness of this timetable for women:

> The academic career is founded on some peculiar assumptions about the relation between doing work and competing with others, competing with others and getting credit for work, getting credit and building a reputation, building a reputation and doing it while you're young, doing it while you're young and hoarding scarce time, hoarding scarce time and minimizing family life, minimizing family life and leaving it to your wife—the chain of experiences that seems to anchor the traditional academic career. Even if the meritocracy worked perfectly . . . I suspect there would remain in a system that defines careers this way only a handful of women at the top (49).

The emphasis on youthful achievement, common to the folklore about both mathematicians and academics, seems to be significantly a product of the modern conception of the career. "The link between age and achievement for many specialties housed in the university resembles that of athletes more than that of popes or judges," Hochschild writes. "Interestingly, achievement came later in life for men before 1775—before the massive bureaucratization of work into the career system" (61).

How many mathematicians, of either the prewar or the postwar period, have managed to live out the letter of the myth?[14] Regardless of the extent to which the myth is mirrored in the reality of actual lives, there can be little doubt of its power. The myth has been, and continues to be, aggressively perpetrated, particularly in interviews, autobiographies, biographies, memoirs, and reminiscences of mathematicians whose careers reached their full flowering during the postwar expansion.[15]

In a number of important particulars, the myth is an inappropriate one for women, and for this reason I have used the masculine pronoun throughout my description of its major features. Few women have spouses who will shield them from distractions or exempt them from the responsibilities of home and family. Those women who have such supportive spouses nevertheless must face the essential conflict between single-minded focus on work and the biological timetables of reproduction. In fact, it is only relatively recently that women have been able to combine marriage and academic career at all: before World War II, female elementary and secondary schoolteachers were routinely dismissed on marriage, and women faculty at women's colleges were expected to remain single (Ware 1982; Scharf 1980; Rossiter 1982; Solomon 1985). Historically, even unmarried or childless women have experienced barriers to their educational and career advancement that have made youthful achievement and professional continuity extremely difficult (Ahern and Scott 1981: xviii; Ruskai 1984).

The women mathematicians of the wartime and postwar generations came to maturity just as the myth was gathering strength in the American mathematical community. But their teachers and mentors included men and women of the prewar generation, who held to a broader view of the mathematical community—embracing both women and men—and a more inclusive view of mathematical activity—encompassing research, teaching, and scholarship. The women mathematics Ph.D.'s of the forties and fifties were caught between two cultures. While many attempted to conform to the myth, experiencing conflict in the attempt to do so, some found ways to adapt the myth to their own life circumstances. Others were able to pursue careers on the model of the prewar generation of women in mathematics. Most often, however, their mathematical lives were an improvisational blending of the old and the new.

What did it mean to the women of this transitional generation to be a mathematician? Were they able to develop, nurture, and sustain a sense of mathematical identity, particularly in cases of extreme dissonance between their own aspirations and the contradictions of the mathematical community and the larger culture? In the chapters that follow, I take a closer look at the group of women who received Ph.D.'s in mathematics from American colleges and universities during the years 1940 to 1959. In particular, I consider the various stages of mathematical development, as viewed through the eyes of thirty-six of these women, in an attempt to obtain some insight into the answers to these questions.