

II. DEMOGRAPHICS OF THE PROFESSION

THE INFLUENCE OF GENDER ON ADVANCEMENT IN ASTRONOMY, PHYSICS AND MATHEMATICS

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ABSTRACT

Although legislation forbidding discrimination in academia was passed twenty years ago, women do not yet enjoy the benefits and privileges of academic life to the same extent as that experienced by their male colleagues. As we travel the highway through the academic hierarchy from education to employment to the rungs of the promotion and tenure ladder to salaries, we find an increasingly greater lag in opportunities for women. We look at the achievements and gains women have made. By comparing their progress with that of men, we are able to identify areas to which attention could be directed as efforts are made to overcome the attendant inequities. A few suggestions are proposed.

1. INTRODUCTION

Women who work as astronomers, physicists or mathematical scientists are well aware of the fact that compared to their (mostly male) colleagues, they, as women, are few in number. They are less aware perhaps of why this might be so although they do remember their student days where there, too, they tended to be outnumbered, but not outperformed, by their male classmates. In this work, we focus on the academic scene. We review the roads traveled over past years to the present day. We investigate hiring patterns, rates of promotion and tenure, and salaries. Since promotion and tenure, and salaries are tied to performance, we also consider how women's work is evaluated compared to men's work. First, however, we review educational attainments since by definition such training determines employment prospects. As we embark on this study, it is important to bear in mind that it was not until 1972 that laws forbidding discrimination were passed (Title IX of the Education Amendments, the Amendment of Title VII of the 1964 Civil Rights Acts, the Equal Pay Act and Executive Order 11246).

Much of the data and source information covering progress in the past presented herein are drawn from the studies of Hornig and Tidball,^{1,2} Dix,³ Debold,⁴ Hornig,⁵ Zuckerman,⁶ Scott,^{7,8} Ahern and Scott,⁹ Vetter^{10,11} and Sandler.¹² To these we add data extracted from the Digest of Education Statistics,¹³ the National Science Foundation^{14,15} (NSF) and the American Association of University Professors¹⁶ (AAUP; Annually). A detailed review of the past, present, and future, in the mathematical sciences can be found in Billard¹⁷ and an overview of all fields is presented in Billard.¹⁸ In some sense the present paper is a review of these studies as they pertain to astronomy, physics and the mathematical sciences though there are additional data provided.

Data for physics often include astronomy. Sometimes no separate data were available for astronomy and/or physics, in which case data for the physical sciences (excluding mathematics) are used as a surrogate. However, where known, figures are such that

women do better in the physical sciences as a whole than they do in astronomy and physics. This is due to the higher numbers in chemistry which tend to dominate the physical science picture. Also, the reader should be aware that what exactly constitutes physical science can vary (*e.g.*, does it, or does it not, include the earth sciences)? No attempt will be made to differentiate the differing descriptors here; the reader should refer to the source material for the precise descriptions. Finally, although the source data tended to be somewhat disparate and seemingly incompatible at times, they are presented here in as consistent a form as possible. Where “different” numbers existed for ostensibly the “same” classification, the differences were generally comparable to rounding errors. However, none of these perturbations was of any significant magnitude in that the overall trends and conclusions remain unaffected.

2. EDUCATION

The proportion of doctorate degrees awarded to women up to the 1930s (and including the 1930s for mathematics) remained reasonably constant but then decreased substantially until the 1960s. It was not until the late 1970s that these proportions returned to their 1920s levels (see Table 1). These proportions continued to climb until the early 1980s but have tended to maintain a steady rate throughout the 1980s with a slight jump in 1989 (see Tables 2 and 3). However, in the mathematical and physical sciences, this change in proportion is largely due to a *decrease* in the numbers of men graduating with doctoral degrees.¹⁹ The fluctuations in the percentages for astronomy are more an artifact of the small numbers involved (see Table 3).

Table 1.
Percent of Doctorates to Women, 1920–89

	Astronomy/Physics	Physical Sciences	Mathematical Sciences
1920–29	5.9	6.8	14.5
1930–39	3.8	5.5	14.8
1940–49	4.2	4.3	10.7
1950–59	2.0	3.5	5.0
1960–69	2.2	4.3	5.7
1970–79	4.2	7.7	10.5
1980–89	9.4	14.7	16.0

Source: Digest of Education Statistics,¹³ Hornig and Tidball,¹ NSF,¹⁵ Rossi and Calderwood.²⁰

Explanations similar to those for the doctoral degree pertain for changes and trends in the proportions of women receiving the bachelor and master degree.²¹ As before, there was a slight increase in numbers for both men and women receiving the bachelor degree in physics.²² Overall, between the bachelor and the doctoral degrees there is an attrition (for women) of about 25% in astronomy and physics, and 55% in the mathematical sciences.⁵

Percentages of freshmen indicating their probable major in the physical and mathematical sciences are shown in Table 4. Since 1971, the proportions for men and women in the mathematical sciences are roughly the same and this is reflected in the actual

Table 2
Education Trends Since 1971—% Women
Mathematical and Physical Sciences

Year	Mathematical Sciences			Physical Sciences		
	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
1971	38.0	29.2	7.8	13.8	13.3	5.6
1972	39.0	28.7	7.9	14.9	14.0	6.7
1973	40.2	29.9	9.6	14.8	13.5	6.7
1974	40.9	31.0	9.7	16.5	14.5	7.0
1975	41.8	32.9	11.3	18.2	14.4	8.3
1976	40.7	34.0	10.9	19.5	15.5	8.7
1977	41.6	35.2	13.2	19.9	17.9	9.5
1978	41.3	34.0	14.3	21.5	17.5	9.5
1979	41.7	34.7	15.5	22.6	18.5	10.9
1980	42.3	36.1	12.8	23.9	18.6	12.8
1981	42.8	34.1	15.4	24.7	19.9	11.8
1982	43.2	33.3	13.3	26.2	21.3	13.3
1983	43.8	34.5	16.1	28.5	20.8	13.2
1984	44.3	34.7	16.5	29.4	23.7	14.0
1985	46.1	35.0	15.4	29.7	22.8	15.9
1986	46.5	35.2	16.6	29.7	24.9	16.3
1987	46.5	39.1	16.9	30.2	24.9	16.4
1988	46.3	40.1	16.2	32.2	23.9	16.8
1989	46.0	39.9	18.1	30.9	26.8	18.9

Source: Digest of Education Statistics,¹³ NSF^{14,15}

proportions graduating with the bachelor degree. In the physical sciences, the ratio of men to women has steadily decreased from about four to about two. However, there has been a greater attrition of women in the physical sciences, though it is encouraging to see this loss appears to have disappeared by the late 1980s. The larger problem here, however, seems to be attracting women into undergraduate programs in the physical sciences including astronomy and physics. Debold⁴ provides a balanced review of studies conducted to attempt to explain why women are not seeking the sciences and engineering as career choices. In particular, the belief that women are not as capable as men in these areas cannot be sustained. Indeed, where men and women have taken comparable courses, their grades are the same and have remained so over the time period 1971 to 1985 (see Table 5). On the other hand, Table 6 shows SAT-Mathematics scores by intending major and GRE-Quantitative and GRE-Analytical scores by actual undergraduate major in the physical and mathematical sciences, from which we see that men score better than women on the SAT-Mathematics and the GRE-Quantitative tests. However, this gap narrows when course taking is controlled.²³ The preparation of high school students in course-years, shown in Table 5, is higher for men than it is for women. It is this difference which essentially establishes Debold's⁴ consensus conclusion that differences in standardized test scores are largely due to course taking and not

Table 3.
Education Trends Since 1976—% Women
Astronomy and Physics

Year	Astronomy			Physics		
	B.S.	M.S.	Ph.D.(#)	B.S.	M.S.	Ph.D.
1976	10.2	9.0		10.9	9.1	
1977	13.8	17.3		10.5	9.6	
1978	20.3	12.6	5.1	11.1	9.5	4.8
1979	16.7	12.9	7.0 (8)	12.0	10.2	6.5
1980	19.7	11.4	10.7 (13)	12.8	9.9	6.3
1981	20.2	15.5	10.1 (11)	12.6	8.9	6.8
1982	18.6	13.8	15.7 (16)	13.3	12.1	7.5
1983	25.0	17.6	13.0 (15)	12.7	11.8	6.4
1984	21.1	14.9	12.2 (12)	14.3	12.6	6.8
1985	25.2	16.5	11.0 (11)	13.6	12.5	9.3
1986	15.4	13.3	8.3 (9)	14.6	14.9	9.3
1987	17.7	22.5	13.0 (13)	16.1	15.7	9.4
1988	15.1	19.3	12.3 (16)	14.9	15.1	9.7
1989	22.6	15.0	14.2 (16)	14.8	16.7	8.8

Source: NSF^{14,15}

Table 4.
Probable Major Field of Freshman

	Physical Sciences		Mathematical Sciences	
	<i>Men</i>	Women	<i>Men</i>	Women
1971	<i>3.0</i>	0.8	<i>2.6</i>	2.9
1973	<i>4.2</i>	1.1	<i>1.8</i>	1.6
1975	<i>4.0</i>	1.3	<i>1.1</i>	1.1
1978	<i>3.5</i>	1.3	<i>1.1</i>	0.6
1980	<i>3.6</i>	1.6	<i>0.7</i>	0.6
1982	<i>2.6</i>	1.0	<i>0.6</i>	0.7
1984	<i>2.5</i>	1.1	<i>0.8</i>	0.9
1988	<i>2.1</i>	0.9	<i>0.7</i>	0.6
1991	<i>2.0</i>	1.0	<i>1.0</i>	1.0

Source: Debold,⁴ NSF^{14,15}

to any inherent biological reason. That is, fewer women than men are encouraged to enter these fields and once there women experience greater rates of attrition for reasons unrelated to performance and ability.

Returning to the problem of retention of women from the undergraduate to the doctoral degree, we note Hornig and Tidball's¹ conclusion that at both the undergraduate and graduate levels, women have better scholastic records than do men, thus also

Table 5.
High School

	Physical Science		Mathematics	
	<i>Men</i>	Women	<i>Men</i>	Women
Preparation (years)				
1971	<i>1.60</i>	1.10	<i>3.50</i>	3.10
1981	<i>2.01</i>	1.59	<i>3.68</i>	3.38
1985	<i>2.08</i>	1.74	<i>3.80</i>	3.58
Grade (<i>A = 4, B = 3, ...</i>)				
1971	<i>2.40</i>	2.40	<i>2.70</i>	2.80
1981	<i>2.94</i>	2.94	<i>2.85</i>	2.83
1985	<i>2.91</i>	2.91	<i>2.85</i>	2.87

Source: Debold⁴

Table 6.
SAT and GRE Scores by Undergraduate Major

	Physical Sciences		Mathematical Sciences	
	<i>Men</i>	Women	<i>Men</i>	Women
SAT-Mathematics:				
1988	<i>583</i>	534	<i>613</i>	577
1991	<i>587</i>	541	<i>623</i>	585
GRE-Quantitative:				
1979	<i>640</i>	600	<i>682</i>	636
1987	<i>648</i>	615	<i>670</i>	635
GRE-Analytical:				
1979	<i>555</i>	564	<i>568</i>	565
1987	<i>568</i>	580	<i>590</i>	585

Source: NSF^{14,15}

removing here the oft-quoted reasons relating to abilities. Several studies prior to the 1980s showed, not surprisingly, that persistence in graduate school was directly related to level of financial aid, and that more men received support and at a higher level on average than did women; this includes the finding that more research assistantships were awarded to men and more teaching assistantships to women on average (see, *e.g.*, Harris²⁴; Haven and Horch²⁵; Solomon²⁶). Later, Berg and Ferber²⁷ found that, in the one institution they studied, there was still a greater attrition rate among women graduate students despite comparable levels of financial support. Fortunately, if the data for 1988 provided in Table 7 are indicative of prevailing patterns of support, then in the physical and mathematical sciences, the levels of financial aid have reached parity. The gap in NSF Fellowships (see Table 8) has closed considerably with the proportion

of awards in 1990 going to women in astronomy and physics being slightly higher than the proportion receiving their doctorates, and lower for the mathematical sciences.

Table 7.
Doctoral Source of Support, 1988
% Within Gender

Source	Physical Sciences		Mathematical Sciences	
	<i>Men</i>	Women	<i>Men</i>	Women
University:				
TA	<i>24.3</i>	27.1	<i>55.7</i>	57.9
RA	<i>33.4</i>	32.9	<i>10.8</i>	11.2
Fellowship	<i>3.8</i>	2.6	<i>4.7</i>	5.6
Other university	<i>0.5</i>	0.0	<i>1.1</i>	0.0
Federal support	<i>22.4</i>	23.0	<i>4.5</i>	1.9
Student loan	<i>0.8</i>	1.7	<i>1.5</i>	0.0
Family	<i>10.6</i>	7.3	<i>12.5</i>	16.8
Other	<i>4.2</i>	5.4	<i>9.1</i>	6.5
All sources	<i>100</i>	100	<i>100</i>	100

Source: NSF¹⁴

Table 8.
NSF Fellowships

	Astronomy			Physics			Mathematics		
	<i>Men</i> ⁺	Women ⁺	Women/ All*	<i>Men</i> ⁺	Women ⁺	Women/ All*	<i>Men</i> ⁺	Women ⁺	Women/ All*
1975	<i>26.1</i>	0.0	0.0	<i>26.9</i>	33.3	5.0	<i>42.7</i>	5.6	4.7
1985	<i>33.3</i>	33.3	10.0	<i>29.1</i>	19.5	8.9	<i>40.0</i>	14.0	12.5
1988	<i>25.0</i>	11.1	14.3	<i>36.0</i>	25.5	10.0	<i>44.8</i>	8.9	6.3
1990	<i>33.3</i>	20.0	20.0	<i>43.1</i>	29.6	11.9	<i>49.7</i>	14.9	11.4

⁺Number of Awards/Number of Applicants %

*Number of Awards to women/Total number awards %

Source: NSF^{14,15}

Since grades are comparable, and, once admitted, financial aid is equitable, it is clear that other factors come into play at both stages: in the admission to graduate school and in the retention/decision to stay in the discipline. Sandler,¹² Debold⁴ and Hornig⁵ provide overviews of many of the studies investigating these other, perhaps more subtle and invisible, barriers to progress, ranging from lack of eye contact to letters of recommendation. (See, AWIS,²⁸ for a chilling but compellingly illustrative discussion of letters of recommendation for the graduating doctoral student; the same principles apply for letters at all levels of the academic world.) Also, Zuckerman⁶ notes that significantly fewer women than men receive their doctorates in mathematics and

physics from the top-ranking research universities, unlike other science and engineering fields where parity has been achieved. Finally, the time elapsed from bachelor's to doctoral degree tends to be the same for men and for women.

Perhaps the biggest barrier still to be overcome is the absence of women not only on but moving up the career ladder; that is, without role models, women students cannot envision a future for themselves in these fields. Fortunately, however, some real progress in this direction is being achieved, as we shall see in the next section.

3. EMPLOYMENT

As we assess employment patterns, it is beneficial first to study patterns that have occurred in the past, so that trends and prospects for the future can be determined more accurately. In particular, we would like to see whether changes have occurred since Hornig's²⁹ assertion that in general "women are far more likely than men to be involuntarily unemployed and underemployed . . ."

Hornig's remarks were contained within the superb study by Ahern and Scott⁹ on career attainments of the approximately 50,000 recipients of doctoral degrees in the United States from 1936–78. Triads consisting of two men and one woman were formed by matching year and field of the doctorate, type of institution awarding the degree, and race. Some analyses further matched individuals by type and length of employment experiences. The triads were compiled into four cohorts, those whose degree was in the period 1940–59, 1960–69, 1970–74 and 1975–78, respectively. The entire study dealt with academic careers for all disciplines. We report here only on those conclusions pertaining to physics and the mathematical sciences.

Employment figures for the matched triads are shown in Table 9 for physics and Table 10 for mathematics. In all cohorts, fewer women than men are enjoying full-time employment. Likewise, women are more likely than men to be either employed part-time or unemployed. This is so even for the most recent graduates. Ignoring the 1940–59 cohort where the figures are possibly blurred by the fact that some of these individuals would have retired, we see that for both physics and mathematics, regardless of cohort, men are consistently more likely to be employed in full time and/or postdoctoral positions (96–98%). On the other hand, more women in mathematics are employed fully than are their sister colleagues in physics. The higher percentage of women in postdoctoral positions in the physics 1975–78 cohort is attributed to the greater difficulty women have in obtaining Assistant Professor positions.

From NSF,^{14,15} we see that ten years later, in 1987, only 1.2% (0.7% in 1989) of men but 3.0% (2.7%) of women doctoral physical scientists were unemployed, and 0.7% (0.7%) of men and 1.5% (1.0%) of women were underemployed. For the mathematical scientists, 0.9% (0.4%) of men and 1.6% (1.2%) of women were unemployed and 0.3% (0.7%) of men and 1.8% (1.0%) of women were underemployed in 1987 (1989). Thus, there was an improvement both in absolute rates by 1989 and in relative rates, though in mathematics and physics women are still 2 to 2.5 times more likely to be underemployed or unemployed than men.

To be encouraged, we note Hornig and Tidball's² report that in 1981 across all two-year and four-year colleges and universities, 15.2% of the Assistant Professors in mathematics and 6.7% in physics were women. These figures compare very favorably with the corresponding proportions of women doctorates. However, the data of

Table 9.
Percent Men and Women in Physics
Matched Triad Study

	1940–1959		1960–1969		1970–1974		1975–1978	
	<i>Men</i>	<i>Women</i>	<i>Men</i>	<i>Women</i>	<i>Men</i>	<i>Women</i>	<i>Men</i>	<i>Women</i>
Employment								
Full-time	90	74	98	73	93*	78*	78	60
Part-time	0	6	2	19	2*	12*	0	4
Postdoctoral			0	2	3*	3*	20	30
Unemployed	8	20	0	6	2*	7*	1	4
Rank								
Full Professor	62	62	32	20	2	0	0	0
Associate Professor	21	21	44	30	30	17	5	0
Assistant Professor	0	0	4	14	28	40	29	21
Instructor/Nonfaculty	0	0	0	4	0	3	0	5
Other	17	17	20	32	40	40	66	74
Tenured	90	100	85	71	52*	35*	15*	9*
Women’s salary as % of men’s	—	88	—	92	—	98	—	95

* All fields

Source: Ahern and Scott⁹

AAUP¹⁶ over all disciplines show that appointments to women are still clustered in the lower rated institutions. In contrast, Zuckerman⁶ suggests that for the sciences and engineering as a whole, women tend to be overrepresented at the top-rated institutions, but adds the important caveat that many of these appointments are in off-ladder positions. What is clear, however, is that women are being hired into academic positions, even if it is only now, fifty years later, that the proportion of faculty who are women has returned to the pre-World War II figures of 27–28%.^{30,31} More importantly, unlike the prewar women who were nearly all in nondoctoral institutions, women are moving upwards in terms of the rating and type of institution to which that appointment is made. In the next section, we look at women’s mobility up the promotion and tenure ladder.

4. PROMOTION AND TENURE

Let us first consider progress up the promotion and tenure ladder for those men and women in the matched triad study of Ahern and Scott.⁹ As we look at these results, it is important to bear in mind that the comparison is made between men and women starting out with equivalent credentials. The percentages of the men and of the women who are in each of the Full Professor, Associate Professor, Assistant Professor and Instructor/Nonfaculty ranks are shown by cohort in Table 9 for physics and Table 10 for the mathematical sciences.

It is clear that women are promoted at a slower rate than men. The one exception may be for physicists in the 1940–59 cohort, but this may be due to the fact that the

Table 10.
Percent Men and Women in Mathematics
Matched Triad Study

	1940–1959		1960–1969		1970–1974		1975–1978	
	<i>Men</i>	<i>Women</i>	<i>Men</i>	<i>Women</i>	<i>Men</i>	<i>Women</i>	<i>Men</i>	<i>Women</i>
Employment								
Full-time	91%	79%	96%	86%	93%	78%	94%	88%
Part-time	3	10	1	6	2*	12*	1	6
Postdoctoral			1	1	3*	3*	3	3
Unemployed	6	10	2	7	2*	7*	1	1
Rank								
Full Professor	90	83	52	38	2	2	0	0
Associate Professor	5	10	38	44	68	43	8	3
Assistant Professor	0	2	6	13	21	46	72	78
Instructor Nonfaculty	0	0	1	3	7	5	13	19
Other	5	5	4	3	2	4	8	2
Tenured	98	90	97	80	52*	35*	15*	9*
Women's salary as % of men's	—	99	—	89	—	93	—	98

* All fields
 Source: Ahern and Scott⁹

numbers are very small, there being only fifteen Full and five Associate Professors. More typical of that cohort are the figures given for mathematics. Even so, most faculty have eventually moved up the ranks though more women than men are likely to be frozen in rank below the Full Professor level. Also, the final career prospects in this regard may well have been set for these cohort individuals by the time of the 1972 legislation. Members of the 1960–69 cohort in 1979 have had their doctorates for 10–20 years and by the prevailing standards of the 1970s both men and women (in view of the 1972 enactments) should have reasonably expected promotion to Full Professor to have occurred or very nearly so. Yet, we see that men are 1.5 times as likely as women to have attained this top rank. Also, considerably more men than women have received tenure; 85% compared to 71% in physics and 97% compared to 80% in mathematics.

The same disparities exist for the 1970–74 cohort. In physics, twice as many men have been promoted beyond the Assistant Professor rank. In mathematics, men are 1.5 times as likely to have been promoted. The higher absolute percentages for men and for women in mathematics who have been promoted are explained by the stronger tradition of graduates in physics first spending time in postdoctoral positions before proceeding to a tenure-track position. There is no improvement in the figures for the 1975–78 cohort. Equally distressing is the continued differential in the proportions receiving tenure (see Tables 9 and 10).

Ahern and Scott⁹ delved into possible explanations for this slower rate of progress for women with a more detailed analysis of faculty in the 1970–74 cohort. In particular, they found that three commonly held beliefs were dispelled by the data. First, while those whose primary responsibilities involved teaching rather than research were more

Table 11.
% Promoted to Associate Professor by 1979–1970—74 Cohort

Factor	<i>Men</i>	Women
Teaching Institution	<i>64</i>	48
Research Institution	<i>60</i>	32
Married, no children	<i>51</i>	41
Married, with children	<i>66</i>	51
Single, no children	<i>53</i>	37
Single, with children	<i>80</i>	33

Source: Ahern and Scott⁹

likely to be promoted, men still fared better than women (see Table 11). The second myth is that women lose time to childbearing. However, from Table 11 we observe that married women with children fared better than did married women without children or single women with or without children. Furthermore, the worst scenario for men, that of being married and without children, equalled the best scenario for women; that is, in all cases more of the men were promoted. Thirdly, the belief that women are less mobile also did not hold up under scrutiny. More women changed jobs than did men. Men who did move typically went to better positions while women tended to move laterally. The shattering of these latter two myths was also effectively demonstrated when Hornig and Tidball¹ concluded that there was no difference in progress between single or married women.

An analysis of the time in rank and time to tenure also shows differential progress. Using a regression approach, Ahern and Scott⁹ found that the most important predictors were a weighted measure of time (*viz.*, time since receipt of the doctorate and years full time work experience), but that this measure was always better for men than for women. In particular, they determined that the average time in rank before promotion was 10.3 years for women and 8.2 years for men. An estimate of the average time to tenure for their 1970–74 cohort was 5.9 years for men and 6.3 years for women. In a later study of the mathematical and physical sciences and engineering in 1981, Hornig and Tidball² calculated the 25th, 50th and 75th percentiles of time to tenure at 4.5 years for men (4.9 years for women), 6.3 years for men (6.9 years for women) and 8.7 years for men (10.8 years for women), respectively. In that same study, Hornig and Tidball² found that there was a large difference (larger than in the other sciences) in the 1981 tenure status of Associate Professors in physics, with approximately 85% of these men but only 60% of the women tenured.

Unfortunately, there is no corresponding study of matched individuals for the present time. However, Table 12 shows the rank and tenure status of physical and mathematical science faculty in four-year colleges and universities in 1989. Again, 1.5 times as many men as women³² are at the Full or Associate Professor rank. In the physical sciences, substantially more of the women³³ are in non-rank positions; the corresponding rates for mathematics are roughly equal for both men and women. When it comes to tenure, women in mathematics have fared better than their physical science counterparts when compared to men, though in both mathematical and physical sciences more men than women have gained tenure. This table also shows the distribution

of all faculty by gender in each of the rank and tenure levels.³⁴ Although these data are not directly comparable to those of the matched triad study, it is clear that while there has been some improvement in promotion and tenure progress over the intervening ten years, it would seem to be only marginal.

Table 12.
Rank and Tenure Status, 1989, %

	Physical Sciences				Mathematical Sciences			
	Within Gender		All Faculty		Within Gender		All Faculty	
	<i>Men</i>	Women	<i>Men</i>	Women	<i>Men</i>	Women	<i>Men</i>	Women
Rank:								
Full								
Professor	<i>47.3</i>	22.1	<i>43.2</i>	1.9	<i>52.8</i>	25.9	<i>47.7</i>	2.4
Associate	<i>14.7</i>	16.8	<i>13.4</i>	1.5	<i>23.2</i>	31.7	<i>21.0</i>	3.1
Assistant	<i>10.5</i>	20.1	<i>9.6</i>	1.7	<i>16.9</i>	33.5	<i>15.2</i>	3.3
Other	<i>27.4</i>	41.0	<i>25.1</i>	3.6	<i>7.1</i>	8.9	<i>6.4</i>	0.9
Tenure Status:								
Tenured	<i>56.0</i>	34.0	<i>51.2</i>	2.9	<i>68.8</i>	55.1	<i>62.1</i>	5.4
Tenured track (untenured)	<i>8.8</i>	15.9	<i>8.0</i>	1.4	<i>14.9</i>	26.8	<i>13.5</i>	2.6
Nontenure track	<i>8.1</i>	17.3	<i>7.4</i>	1.5	<i>4.7</i>	7.1	<i>4.3</i>	0.7
Other	<i>27.1</i>	32.9	<i>24.7</i>	2.8	<i>11.5</i>	11.0	<i>10.4</i>	1.1
All ranks tenure status	<i>100</i>	100	<i>91.3</i>	8.7	<i>100</i>	100	<i>90.2</i>	9.8

Source: NSF¹⁵

5. SALARIES

Since salaries are tied in part to ranks it is not surprising that, as ranks for women lag behind those for men, so do salaries. However, while we have seen some forward progress, albeit small in promotion, any change in salaries has been backwards in that the disparities have tended to widen rather than narrow. (This phenomenon has occurred in all the sciences and engineering fields with the notable exception of the life sciences.¹⁰) Table 13 shows women’s average salaries as a percentage of men’s average salaries over the period 1973 to 1987 for doctoral graduates in the physical and mathematical sciences. Vetter¹¹ further shows that the gap widens with years experience, and that after about 25 years work experience, women’s salaries flatten out while men’s salaries continue to increase. Except for the 1940–59 cohort in mathematics, these same conclusions are drawn from the study of matched individuals (see Table 9 and 10). What is perhaps more distressing about these results is that even for individuals in the 1975–78 cohort, who at the time of that study had worked only 1–4 years, women’s salaries had already fallen behind those of men, with a 2% deficit in mathematics and 5% in physics.

Table 13.
Doctoral Women's Salary as % of Men's Salary

Year	Physical Sciences	Mathematics
1973	81.4	87.8
1977	70.1	84.3
1981	78.8	83.6
1985	81.2	83.0
1987	80.0	83.4

Source: Vetter,¹⁰ NSF¹³

If we consider salaries by rank, as given in AAUP¹⁶ (1975–91) and Digest of Education Statistics,¹³ for doctoral research universities, we obtain the deficits in women's average salaries as a percentage of men's average salaries, for the period 1974 to 1991 (see Table 14). Again, the overall conclusion is that comparative salaries have not improved. The deficit has held reasonably constant at 10% for those in the Full Professor rank, but has increased slightly to 6% at the Associate Professor level and has almost doubled from 5.4% to 9–10% at the Assistant Professor level. The higher percentage deficit over all faculty is a reflection of the fact that proportionately more women are at the lower ranks and hence receive lower salaries.

Table 14.
Percent Deficit in Women's Average Salaries

Rank	1974–5	1976–7	1980–1	1985–6	1987–8	1990–1
Full Professor	10.2	10.3	9.4	10.9	10.6	10.1
Associate Prof.	4.7	4.9	5.7	6.3	6.4	6.0
Assistant Prof.	5.4	5.8	6.3	9.1	10.0	9.3
Instructor	4.8	6.3	6.5	9.4	11.1	10.8
Lecturer				13.4	13.5	14.9
All Ranks	22.3	23.2	23.5	24.7	24.8	

Source: AAUP¹⁶ (1975, 1977, 1981, 1986, 1988, 1991); Digest of Education Statistics¹³

That this salary lag persists is particularly surprising and discouraging, in the light of the fact that considerable attention has been paid to developing methods to correct such deficits, as well as to exploring what factors should be included in any such analysis. The AAUP developed a Faculty Salary Evaluation Kit⁸ (or Kit) which has been widely disseminated. See, also, Scott^{7,35} and Gray and Scott³⁶ which provide background as well as advice on the Kit's use. A summary of these can be found in Billard,¹⁷ while Billard *et al.*³⁷ provides a statistical procedure for implementing the class action recommendations³⁶ to correct any inequities identified by use of the Kit. Briefly, the Kit utilizes multiple regression techniques, while Billard *et al.*³⁷ develops regression equations for both men and women and then rotates the equation for women so as to coincide with that for men.

6. EVALUATION AND PERFORMANCE

Promotion and tenure and, to a lesser extent, salaries are tied to measures of performance and evaluation. In a study of thirty-one variables (such as publications, doctoral students, year and type of degree, ...) influencing salary, Scott⁷ found significant differences between men and women's salaries despite the fact that, on each of six different measures of ability, women performed to a higher level than did men, regardless of field. The same conclusions would apply to promotion and tenure. Thus, differences could only be explained by gender, and in particular to gender related perceptions of quality and performance. Measures of research productivity run the gamut of numbers and quality of publications, grants, graduate students supervised, service on prestigious boards, invitations to speak at professional meetings (local, national, international), election to society offices, etc. Since in a doctoral granting institution, the ability to provide cutting edge material to graduate students is an important component of teaching, these research measures also constitute a partial measure of instructional productivity.

There is now a substantial literature covering many aspects of performance and evaluation by gender, and spanning many specific disciplines. These range from numbers of publications, invitations, grants, etc.³⁸⁻⁴³ to situational factors and discipline variations,^{31,44-48} to the reward structure—or more accurately a lack of rewards such as promotion and tenure itself, travel monies, summer research support, graduate students, appointments to prestigious universities, desirable teaching assignments, etc., for equivalent work^{39,49-54}—to Zuckerman's⁶ conclusion “that many accomplished women were ignored or actively discouraged” with any honors being late if at all (see, also, Rossiter⁵⁵), to what Theodore⁵⁶ calls the “shifting of the criteria,” a delightful phrase were it not so devastating in its impact on careers. In the present work, we confine attention to just a few of these studies. A more extensive review of these and related works can be found in Billard¹⁸ and Sandler.¹²

These results, even taking into account the many factors involved (situational, discipline, etc.), lead to the inevitable conclusion, previously enunciated by Cole³⁹ and Davis and Astin⁵⁷ among others, that still today women's work is perceived to be of lower quality and that it is rarely cited as having made major contributions (in effect substantiating the earlier Scott⁷ results). One of the early studies illustrating this effect is that of Fidell⁵¹ in which identical vita were sent to department heads in psychology. Where job offers were made, those vita carrying a man's name tended to receive more offers and at a higher (Associate Professor) level while those with a woman's name received fewer offers and at the lower (Assistant Professor) level.

Arguably one of the most important contributions to this discussion, however, is that of Paludi and Bauer.⁵⁸ In that study, 180 men and 180 women reviewers were asked to rate comparable papers one third each of which were supposedly written by a John T, a Joan T, or a J. T. McKay, respectively. The ratings ranged from the highest at one to the lowest at five. The mean average ratings scored are shown in Table 15. Thus, we see that the men rated papers believed to be written by a man (John T.) higher than those papers believed to be written by a woman. The score of 2.7 for those papers purportedly authored by J. T. McKay reflects the belief of many of the reviewers that these authors were really women. Perhaps, surprisingly, women reviewers also gave a differential rating to men and women authored papers. However, although not the

intent of their study, one could argue that these results for women reviewers support any contention that much of these gender related biases are a product of our culture with the cultural effect influencing the respective genders to differing degrees in their perceptions of work performed by men and women.

Table 15.
Mean Rating Scores

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

Source: Paludi and Bauer⁵⁸

If we compare Fidell's⁵¹ study prior to the 1972 legislative acts and that of Paludi and Bauer⁵⁸ after the 1972 legislation, we are sobered by the apparently very real lack of progress. It would therefore seem that reasons behind these phenomena, and/or techniques to change them, need to be established before substantial progress can be made. If what seem like cultural influences suggested by the Paludi and Bauer⁵⁸ study are indeed true, then some effort at least should be directed towards both men and women in order to remove such influences. Alternatively and/or concurrently, methods which bypass the inherent cultural problems can be implemented. This has effectively been done by the Modern Language Association (MLA) as far as publications are concerned. Lefkowitz⁴³ reports that in 1974 the MLA adopted a policy whereby papers being reviewed for presentation at MLA meetings would be subjected to doubleblind refereeing. In the first year of that policy, the number of accepted papers authored by women doubled; likewise, in the second year, the numbers doubled again until, by 1978, the proportion accepted was comparable to the proportion of submitted papers written by women. The MLA subsequently elected to use doubleblind refereeing for all their publication avenues.

In a different direction, Davis and Astin⁵⁷ found that for highly productive researchers in the social sciences (in which papers rather than books are the standard medium for publication), rather than numbers of papers *per se*, it was the number of invited chapters (either new material or republications of earlier well versed papers) in a book which served as the most important indicator of the established researcher's reputational standing. Of course, such invitations presuppose that quality work existed and/or a reputation was already established to elicit the invitations. Similar comments would no doubt pertain if studies were to be made relative to invited presentations, appointments to boards, election to office, etc.

For those who use citations as a measure of reputation, Ferber⁵⁹ offers both a word of caution and a measure of hope. Caution is demanded when we note Ferber's conclusion that authors tend to cite authors of the same gender, possibly because of a sharing of papers within networks where networks tend to be dominated by a single gender.⁶⁰ On the encouraging side, however, Ferber⁵⁹ found that as the proportion of women in a field increased, this disparity in citation patterns decreased.

7. CAN PARITY BE ACHIEVED?

Today, five years later, we still have to conclude with Sandler¹² that the perception that discrimination on the university campus is past is not substantiated by the facts; to the contrary, it is alive and well, although in 1992 we can declare that real progress has been made. The current gains exist primarily in women's access to graduate education and later to their proportionate appointment to Assistant Professor positions, although not yet to tenure track posts in the higher rated institutions in numbers commensurate to their doctorate awards. This is a substantial start. Unfortunately, women's progress up the promotion and tenure ladder still lags well behind the rate of movement enjoyed by their equivalent male colleagues; indeed progress here is only slight. The biggest problem lies with salaries, where no progress has been made in closing the gap; rather, the gap if anything has widened.

Some will argue that it is this continuing gap in salaries which has the greatest debilitating effect on morale. Others feel it is the differential evaluations of their work. In this regard, those studies (discussed in the last section) indicating comparable work perceived to be performed by women is evaluated as being of lower quality, imply the converse rule that women's work has to be of a higher quality than that of men to be perceived of as being equal. Thus, there is an inherent injustice present which is hard to justify or comprehend. Indeed, there are several studies that show that for women a negative relationship exists between quality of work and reputation, but this relationship is positive for men.^{39,45,52} Hence, the more accomplished a women's work might be, the less likely she was to be rewarded. These results are not inconsistent with an earlier study on salaries by Scott³⁵ which showed that it was usually the case that a woman who actually had a salary close to the average salary for males with the same years of experience, etc., was indeed experiencing considerable bias when work accomplishments are taken into account. Such women tended, by every measure except salary, to be truly outstanding. However, whether it be salary itself or work evaluations, both are clearly related and contribute to morale problems. Furthermore, both of these together with the relative lack of rewards have a considerable cumulating effect which in the long run is wasteful especially since it is avoidable.

As indicated in Section 5 above, techniques to correct salary inequities have been available for a long time. However, they are apparently not being used, or not being applied in a nongender equitable manner, or else other forces are at play. Some such forces are inevitably related to those underpinning performance evaluations. While some of these inequities can be explained by the cultural influences alluded to in the discussion of the John and Joan T. McKay papers, the Persell⁴⁵ type studies indicate there is more than this cultural influence affecting women. One possibility is the perceived threat women's presence generates to men, or, more particularly, the perceived threat of the outstanding women since below average and average women tend not to be disadvantaged to the same extent. In addition to the Persell,⁴⁵ Cole³⁹ and Chamberlain⁵² studies dealing with reputation, one is referred to those studies (not discussed in this work) on the difficulties experienced by women appointed to administrative positions (if such appointments are made, and that, of course, is itself a source of inequity; see, Sandler¹²). How these problems can be solved is well beyond the scope of this work; but solutions do need to be found, it is believed, if true parity is to be achieved.

Finally, we direct attention to the many suggestions of Debold⁴ who has developed a nice list of other approaches to be adopted, together with ideas of implementation, ranging from ways of increasing access to education such as the availability of fellowships, etc., for women, to the presence of role models. Debold's ideas are clearly essential. However, without improved progress in those areas discussed in this present work, they will not prevail. For example, while their access to education has already increased, if undergraduate and graduate women do not see women on the academic faculty, or if their work opportunities are limited, eventually such women will look elsewhere for career goals. Concurrently, if those few women faculty (who are themselves the role models for those in the classroom) are not promoted and tenured at an equitable rate, receive lower salaries, and enjoy fewer rewards than they see their male colleagues enjoying, they will inevitably as a group become the invisible women. Thus, their effectiveness even as role models is reduced, with ultimately a negative effect on recruiting efforts at the student levels.

Can parity be achieved? I firmly believe it can be. Will it be achieved soon, next year, say? Unfortunately, not. However, as campus administrators and senior faculty (especially those who will review material for promotion and tenure, appointments to positions, and make salary recommendations) become appraised of the true facts, an inherent belief in the integrity of faculty colleagues compels one to believe parity can and will be achieved. Some possible adjustments which men and women alike will need to consider have been proposed herein. Perhaps the most important factors worthy of study fall under the purview of social scientists. Meantime, there is much that we in the mathematical and physical sciences, and in astronomy and physics, in particular, can do to achieve our own goals of parity.

8. SUMMARY AND CONCLUSION

In conclusion, we have found an increasingly greater lag in opportunities for women as we travel up the highway through the academic hierarchy from education to employment to the rungs of the promotion and tenure ladder to salaries. We have looked at the achievements and gains that women have made. By comparing women's progress with that of men, we are able to identify areas to which attention could be directed as efforts are made to overcome the attendant inequities. A very few suggestions have been proposed as we considered these specific topics and more were proposed in the previous section. It is doubtful that any one of these suggestions in and of itself alone will have a major impact; nor is it likely that the implementation of every one of them (assuming all upon scrutiny and full investigation prove themselves to be appropriate, viable, or even doable proposals) would provide a complete answer. Of course, none of these ideas is new; much effort has already been expended by numerous people in the past, as witnessed by the substantial progress already made. That such progress has been made provides the encouragement that with continued efforts parity will indeed be achieved.

Acknowledgement

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- ³²That is to say, 62% to 39% in the physical sciences and 76% to 57.6% in mathematical sciences.
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- ³⁴For example, 1.9% of all physical science faculty are women Full Professors, while 43.2% are men Full Professors. Hence, in the physical sciences, 4.2% of the Full Professors, 9.8% of Associate Professors, 5.6% of Full and Associate Professors, and 15.3% of Assistant Professors are women; likewise, 5.4% of those tenured,

- 14.6% of those untenured but in a tenure track and 16.5% in a nontenure track are women. For the mathematical sciences, the corresponding figures are 5%, 12.9%, 7.6%, 17.7%; and 8.0%, 16.3% and 13.9%, respectively.
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