DOCUMENT RESUME

ED 446 559 HE 033 399

AUTHOR	Ivie, Rachel; Stowe, Katie
TITLE	Women in Physics, 2000. AIP Report.
INSTITUTION	American Inst. of Physics, College Park, MD. Education and Employment Statistics Div.
REPORT NO	AIP-R-430
PUB DATE	2000-06-00
NOTE	18p.
AVAILABLE FROM	American Institute of Physics, One Physics Ellipse, College Park, MD 20740-3843. Tel: 301-209-3070. E-mail: stats@aip.org. For full text: http://www.aip.org/statistics.
PUB TYPE	Numerical/Quantitative Data (110) -- Reports - Descriptive (141)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Females; Higher Education; *Physics; Tables (Data); Teacher Salaries; *Women Faculty; *Womens Education

ABSTRACT

This report describes how the representation of women in physics has changed, presenting data comparing the representation of women in physics to the representation of women in other fields and in academics overall. Highlights include: an increasingly large number of girls have some exposure to physics by taking it in high school; women's participation in physics decreases with each step in the academic ladder; although women now earn more than half of all bachelor's degrees, physics is not attracting women as quickly as other fields; compared to other fields, women are underrepresented in physics at both the bachelor's and Ph.D. levels; the proportion of women teaching physics decreases as academic rank and departmental level increases; salary differences between male and female members of the American Institute of Physics' member societies are virtually nonexistent; and observers have various explanations for women's poor representation in physics, but many explanations do not hold up in light of available data, and it is possible that many women still experience subtle discrimination leading them away from physics, choosing careers that are less clearly linked to physics. (Contains 20 references.) (SM)

AMERICAN INSTITUTE OF PHYSICS

One Physics Ellipse
College Park, MD 20740-3843

EDUCATION AND EMPLOYMENT STATISTICS DIVISION
Tel. 301-209-3070

E-mail: stats@aip.org
http://www.aip.org/statistics

By Rachel Ivie
Katie Stowe

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AIP REPORT

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Highlights

- An increasingly large number of girls have some exposure to physics by taking it in high school. By 1997, almost one-half of high school physics students were girls **(Figure 1)**. About 400,000 girls take high school physics each year.
- Women's participation in physics decreases with each step up the academic ladder. For example, more than two-fifths of high school physics students in 1993 were girls, but women earned less than one-fifth of bachelor's degrees in physics five years later **(Figures 1 and 3)**.
- Although women now earn more than one half of all bachelor's degrees in the U.S., physics is not attracting women as quickly as other fields, including life sciences, chemistry, and engineering **(Figures 4 and 5)**. Compared to other fields, women are sorely underrepresented in physics at both the bachelor's and PhD levels **(Figures 4, 5, 6, 7, and Table 1)**.
- Twenty U.S. physics departments (excluding women's colleges) had more than 40% female bachelor's degree recipients during the five academic years 1994-98. This report lists these departments as well as women's colleges that grant bachelor's degrees in physics **(Tables 2 and 3)**.
- The proportion of women teaching physics decreases as academic rank and level of the department increases **(Table 4)**. However, the percentage of women faculty members at each rank is at least as high as the percentage of women earning PhDs at various points in the past. The report also lists PhD physics departments that had four or more women on faculty **(Table 5)**.
- Salary differences between male and female members of AIP's Member Societies are nonexistent, except among two groups **(Figures 12 and 13)**.
- Observers have offered various explanations for women's poor representation in physics. Many of the explanations do not hold up in light of available data. It is possible that women still experience subtle discrimination leading them away from physics and that women choose careers that are less clearly linked to physics.

In many respects, women were the driving force in higher education during the last quarter of the 20th century. Women earned 43% of all bachelor's degrees in 1970, but earned 56% of all bachelor's degrees in 1997 (National Center for Education Statistics, 1972 and 2000). The increase in the percentage of women receiving PhDs was even more dramatic. In 1970, women earned just 13% of all PhDs, but by 1997, 41% of all PhDs went to women (National Research Council, 1971, and National Opinion Research Center, 1999).

In physics, women also show greater representation at all levels, from high school physics to college and university faculty. During the 1990s, the numbers of women taking high school physics, earning physics degrees, and serving on physics faculties steadily increased. By the end of the decade, at least twenty physics departments that were not at women's colleges were producing outstanding percentages of women with bachelor's degrees in physics. There are other indicators of the progress of women in physics as well. For example, salaries for male and female members of AIP's Member Societies were relatively equal, except among two groups.

In spite of these signs of progress, women were still sorely underrepresented in physics at the end of the century. For example, in 1998, women earned less than one-fifth of bachelor's degrees in physics and only one-eighth of PhDs in physics. In addition, physics lagged far behind other fields in terms of the representation of women.

Yet, prospects for women in science overall in the 21st century are better now than they were even as recently as 1990. In 1998, Congress formed the Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (CAWMSET) "to research and recommend ways to improve the recruitment, retention, and representation of women, minorities, and persons with disabilities in science, engineering and technology education and employment" (www.nsf.gov/od/cawmset). In addition, other academic institutions may follow the example of MIT, which recently took steps to redress the discrimination experienced by its women faculty members in science (http://web.mit.edu/fnl/women/Fnlwomen.htm).

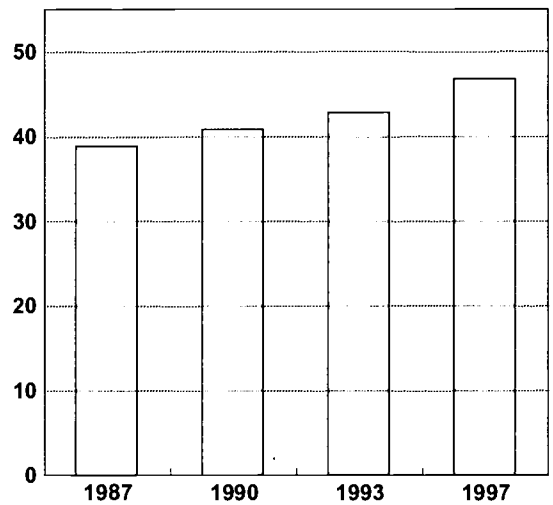
This report describes how the representation of women in physics has changed over time. It also presents data comparing the representation of women in physics to the representation of women in other fields and in academics overall. The Statistical Research Center of the American Institute of Physics collected most of the data for women in physics and previously published these data in a collection of topical reports. See the original reports for descriptions of the data collection methods.

STUDENTS

The percentages of women studying physics and earning physics degrees have increased dramatically, but the participation of women in physics decreases with each step up the academic ladder. Although more than two-fifths of high school physics students in 1993 were girls, women earned less than one-fifth of bachelor's degrees in physics five years later (1998). Nevertheless, an increasingly large number of women are at least being exposed to physics by taking it in high school.

High School Physics. The percentage of high school physics students who are girls has increased dramatically over the previous decade, reaching 47% in 1997 **(Figure 1)**. This percentage increase occurred at a time when the number of high school physics students increased as well. In fact, about 400,000 girls take physics in high school each year (Neuschatz and McFarling, 1999). Very few of them end up majoring in physics. But a significant number of young women who eventually choose a variety of majors and career paths now have at least some exposure to physics in high school. In spite of

Figure 1. Girls as a Percentage of Total Enrollment in High School Physics Over Time



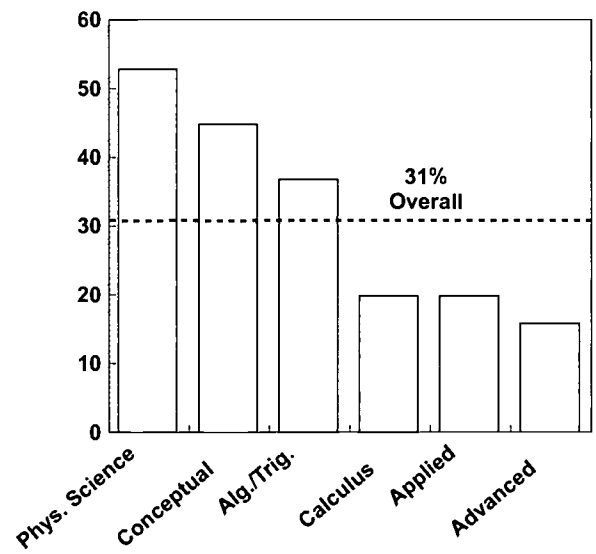
Source: Neuschatz & McFarling, *High School Physics for a New Millennium*, AIP.

this promising increase in the number of girls taking high school physics, the proportion of girls is lower in advanced placement physics courses (Neuschatz and Alpert, 1996).

Two-Year Colleges. In 1996, more than half of two-year college students were female, but only 31% of physics students in two-year colleges were female. As in high schools, the percentage of female students varies with type of course, with courses requiring less math having a larger percentage of female students (**Figure 2**; Neuschatz, Blake, Friesner, and McFarling, 1998). The courses that are most likely to lead to a physics major are the ones with the fewest women. So, it is perhaps no surprise that the percentage of physics bachelor's degrees awarded to women is quite low.

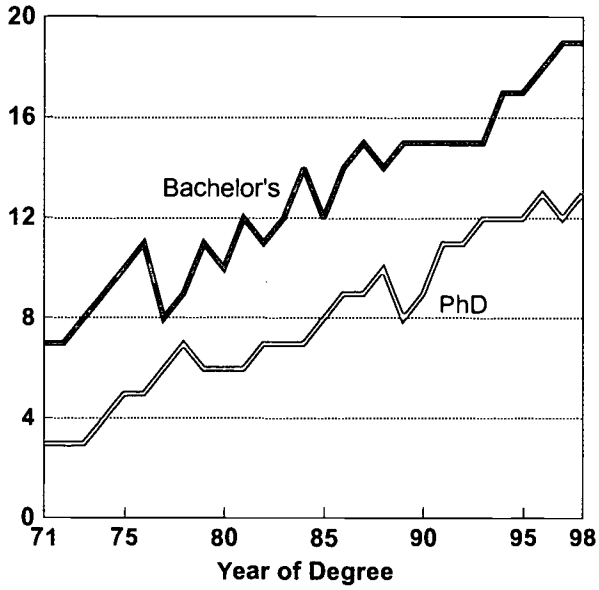
Four-Year Colleges and Universities. In the past twenty-five years, the percentage of physics bachelor's degrees awarded to women has more than doubled, and the percentage of physics PhDs

Figure 2. Percent of Two Year College Physics Students Who Are Women, Overall and by Course, 1996



Source: Neuschatz et al., *Physics in the Two Year Colleges*, AIP.

Figure 3. Percent of Physics Bachelor's and PhDs Earned by Women, 1971 to 1998

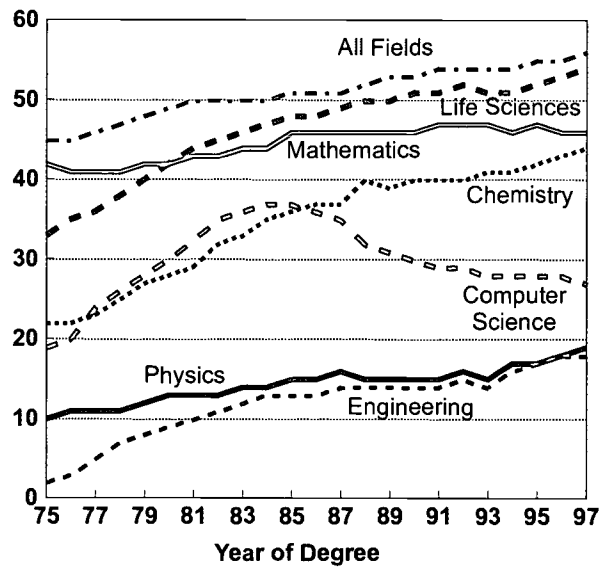


Source: Mulvey & Nicholson, *Enrollments and Degrees Report*, AIP.

awarded to women has increased more than fourfold **(Figure 3)**. Although this sounds remarkable, the percentages of physics degrees awarded to women are still very low. In 1998, just 19% of physics bachelor's degrees, 20% of physics master's degrees, and 13% of physics PhDs were awarded to women (Mulvey and Nicholson, 2000).

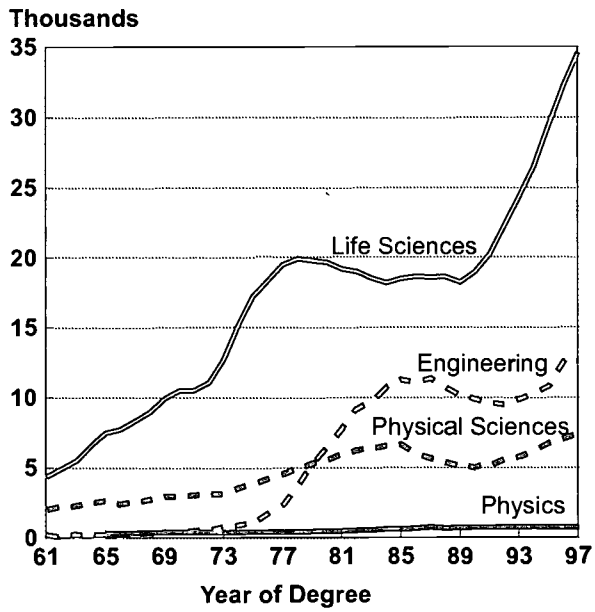
Although women now earn more than half of all bachelor's degrees, physics is not attracting women as quickly as other fields. For example, the percentages of women earning bachelor's degrees in life sciences, chemistry, and engineering have increased at a much more rapid rate than the percentage of women earning bachelor's degrees in physics **(Figure 4)**. Engineering previously lagged behind physics in percentage of degrees awarded to women, but now has approximately the same percentage of female graduates as physics. In terms of number of graduates, the field of life sciences has shown remarkable growth in the number of female bachelor's degree recipients. In 1989, 18,000

Figure 4. Percent of Bachelor's Degrees Earned by Women in Selected Fields, 1975 to 1997



Sources: National Center for Education Statistics, and Mulvey & Nicholson, *Enrollments and Degrees Report*, AIP.

Figure 5. Number of Bachelor's Degrees Earned by Women in Selected Fields, 1961 to 1997



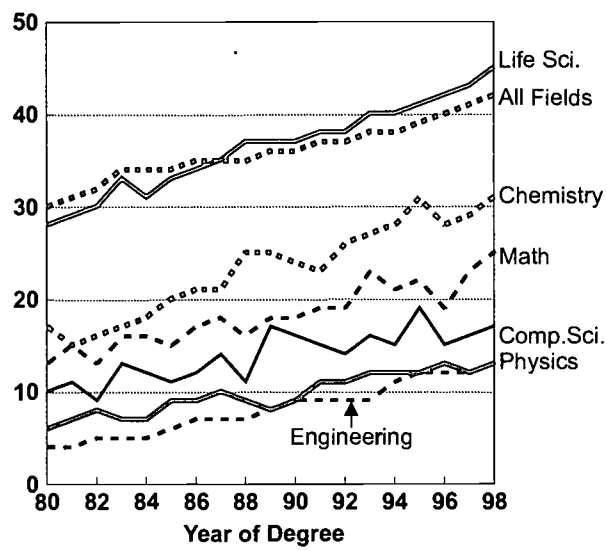
Sources: National Center for Education Statistics, and Tolliver, *Earned Degrees Conferred.*
Compiled by: AIP Statistical Research Center.

women earned bachelor's degrees in life sciences. By 1997, 34,000 women earned bachelor's degrees in this field **(Figure 5)**.

Women continue to be less well represented in physics than in most other fields at both the PhD and bachelor's levels. For the past 25 years, women have consistently earned more than 40% of the bachelor's degrees in mathematics **(Figure 4)**. Women now earn one-fourth of the PhDs in math **(Figure 6)**. Women earn more than 40% of the bachelor's degrees and 30% of the PhDs in chemistry. And in life sciences, women earn more than 50% of the bachelor's degrees and 45% of the PhDs **(Figures 4 and 6)**.

In addition to the large numbers of women earning degrees in math, chemistry, and life sciences, large numbers of women receive M.D.s, law degrees, and engineering degrees **(Table 1)**. These male-dominated fields require (to varying degrees) familiarity with technical equipment,

Figure 6. Percent of PhDs Earned by Women in Selected Fields, 1980 to 1998



Sources: National Research Council, National Opinion Research Center, and Mulvey & Nicholson, *Enrollments and Degrees Report*, AIP.

Table 1. Number of Women Receiving Degrees in Selected Fields, 1950 and 1998		
	1950	1998
Physics PhDs	6	201
Math PhDs	11	297
Chemistry PhDs	37	695
Engineering PhDs	1	769
Physical Science PhDs	58	1600
Social Science PhDs	122	3838
Life Science PhDs	113	3876
Education Doctorates	160	4120
Doctorates in All Fields	613	17856
M.D.s*	346	6450
Law Degrees*	288	17531

*These data are from 1956 and 1997. The 1997 data are the most recent data available from the Department of Education.

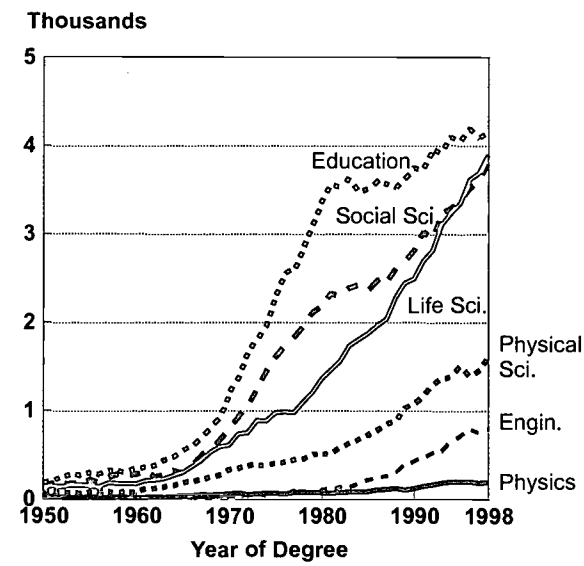
Sources: National Research Council, National Opinion Research Center, and National Center for Education Statistics.
Compiled by: AIP Statistical Research Center.

commitment to long hours, mathematical and analytical skills, just as physics does. Yet, physics picked up only a handful of women compared to these other fields.

There is no question that unprecedented social and economic changes are driving the increases in women's participation in higher education, although some fields attract larger numbers of women than other fields do. The rate of change in the numbers of women receiving PhDs in other fields is much greater than the rate of change in numbers of women receiving PhDs in physics **(Figure 7)**. Education, for example, drew in increasingly large numbers of women during the 1970s until the mid 1980s. Life sciences has been attracting women at a very high rate since the 1970s. Physics, however, has seen a very slow rate of change.

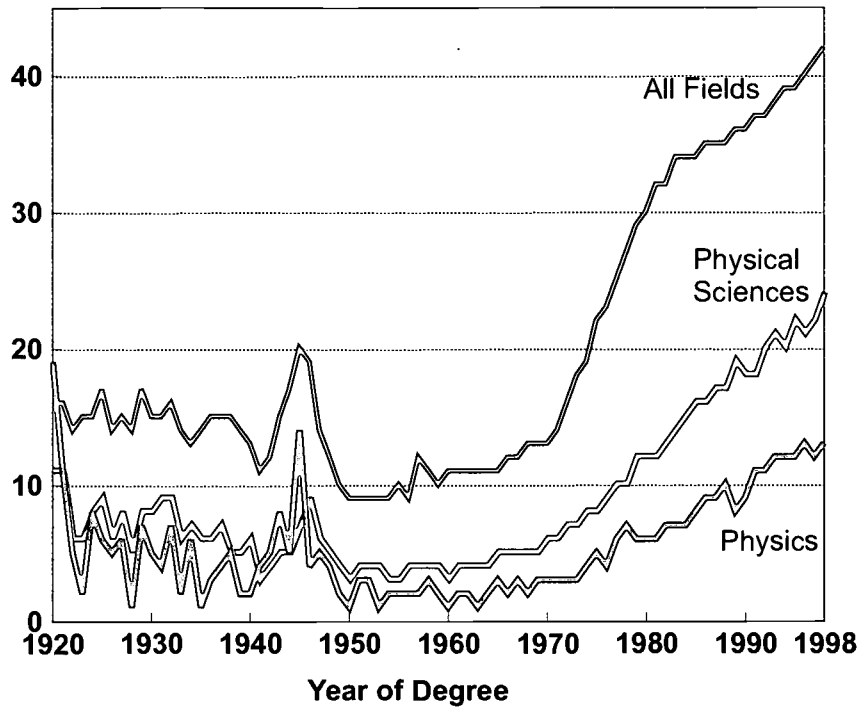
Changes in PhDs Awarded to Women During the 20th Century. We have seen that the percentages of PhDs in physics awarded to women increased during the last quarter of the 20th century. How did the percentages change before the latter part of the century, and how do these percentages compare to other fields? **Figure 8** shows the changes in the percentages of PhDs awarded to women since 1920. Notice that the percentages were generally higher before World War II than during mid-century. The exception is a spike in the percentage immediately after World War II, which was probably due to a shortage of male students during the war. This sudden, but brief, increase occurred not only in physics, but also in all fields. During the 1950s until the late 1970s, the percentages remained generally lower than they had been before the war. It was not until the late 1970s that the percentages of women receiving PhDs began to exceed the pre-war average.

Figure 7. Number of PhDs Earned by Women in Selected Fields, 1950 to 1998



Sources: National Research Council and National Opinion Research Center.
Compiled by: AIP Statistical Research Center.

Figure 8. Percent of PhDs Awarded to Women in Selected Fields, 1920 to 1998



Sources: National Research Council and National Opinion Research Center.
Compiled by: AIP Statistical Research Center.

TOP PRODUCERS OF WOMEN WITH BACHELOR'S DEGREES IN PHYSICS

Table 2 identifies physics departments that had more than 40% women among their bachelor's graduates during the five academic years 1994-98. This is well above the five-year average of 17%. In order to be included on the list, departments also had to have at least five women graduates during these five years. The list excludes departments at women's colleges, most of whom had all female graduates. The data used to compile this list were collected from a series of AIP surveys to which over 90% of physics departments responded. In order to be considered for this list, physics departments had to consistently respond to the surveys and provide us with data about their number of women graduates. The list contains a variety of schools, both public and private. Only four of the departments on this list grant graduate degrees in physics. Remarkably, of the 34 Historically Black Colleges and Universities (HBCUs) that award bachelor's degrees in physics, eight are on this list.

We are providing this list to recognize departments that have an outstanding record in terms of graduating women with bachelor's degrees in physics. We are also interested in learning about departments that may have implemented formal or informal strategies for recruiting and retaining women in physics, either at the student or faculty level. If you know about such departments, please contact us.

Table 2. Physics Departments With More Than 40% Women Among Bachelor's Graduates, 1994-1998 (Excluding Women's Colleges)
Baylor University
Belmont University
Catholic University
Denver, University of
Dickinson College
Dillard University
Drew University
Fisk University
Fordham University
Gordon College
Grambling St. University
Hiram College
Jackson St. University
Lincoln University (PA)
Mary Washington College
Michigan at Dearborn, University of
Minnesota at Morris, University of
Southern University
Tougaloo College
Xavier University of Louisiana
Source: AIP Statistical Research Center.

WOMEN'S COLLEGES

About 2% of all colleges and universities that offer undergraduate degrees in physics are women's colleges. Five percent of the women who obtain bachelor's degrees in physics are graduates of one of these women's colleges. Thus women's colleges make a small, but significant, contribution to the total number of women receiving bachelor's degrees in physics. This is in contrast to the 34 HBCUs, which produce almost 60% of the African-Americans who receive bachelor's degrees in physics (Mulvey and Nicholson, 2000).

Table 3 is a list of women's colleges that, to our knowledge, award bachelor's degrees in physics. At most of these colleges, all of the physics bachelor's degree recipients are women.

Table 3. Women's Colleges that Grant Bachelor's Degrees in Physics, 2000
Agnes Scott College
Barnard College
Bryn Mawr College
Chatham College
Georgian Court College
Hollins University
Mary Baldwin College
Mount Holyoke College
Notre Dame of Maryland, College of
Randolph-Macon Woman's College
Saint Catherine, College of
Scripps College
Smith College
Spelman College
Sweet Briar College
Wellesley College
Source: AIP Statistical Research Center.

TEACHERS OF PHYSICS

As with students, the proportion of women teaching physics decreases at the more advanced levels. Since the late 1980s, about one-fourth of high school physics teachers have been women (Neuschatz and McFarling, 1999). In 1996, 11% of two-year college physics professors were women (Neuschatz et al., 1998). In 1998, eight percent of college and university physics professors were women (Ivie and Stowe, 1999).

Even at the college and university level, women are more likely to teach at departments that do not grant graduate degrees in physics. While 11% of physics faculty at departments that do not grant graduate degrees in physics were women, only 6% of physics faculty at departments that grant PhDs in physics were women **(Table 4)**. In addition, among the physics faculty who were newly hired for 1997-98, a larger percentage of females than males were hired on a part-time basis **(Figure 9)**.

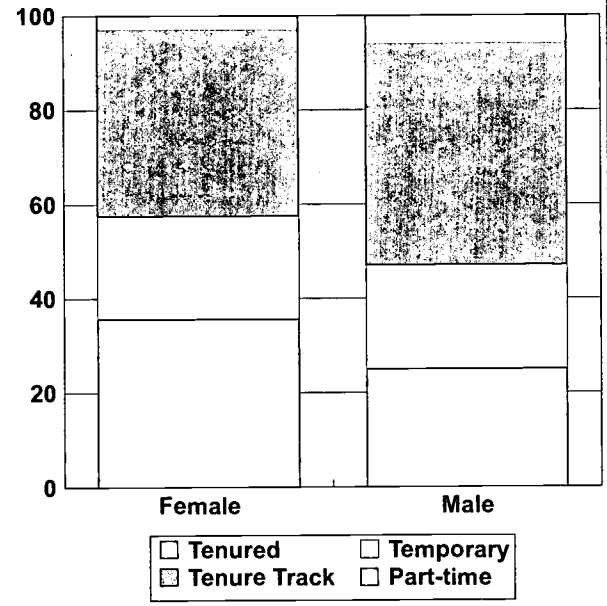
Women are also more concentrated at the lower ranks of academe. In 1998, 17% of assistant professors of physics were women, but just 3% of full professors of physics were women. However, considering the number of women receiving their PhDs in the past, women are not underrepresented on physics faculties. This conclusion is based on a 1998 survey of male and female members of AIP's Member Societies. Full professors who identified themselves as physicists received their PhDs an average of 29 years before the survey date. At that time, just 3% of PhDs in physics were awarded to women. Therefore, women's representation among full professors of physics is about what we would expect. When we look at other ranks, women's representation is better than we might expect. Associate and assistant professors who identified themselves as physicists earned their PhDs an average of 17 and 8 years before the survey date, respectively. Seventeen years before the survey date, 6% of PhDs in physics were awarded to women. Eight years before the survey date, women earned 9% of the PhDs in physics. By the time of the survey (1998), 10% of associate professors and 17% of assistant professors in physics departments were women.

Table 4. Percent of Faculty Positions in Physics That Were Held by Women, 1994 and 1998

		1994 (%)	1998 (%)
Academic Rank	Full Professor	3	3
	Associate Professor	8	10
	Assistant Professor	12	17
	Other Ranks	8	13
Type of Department	PhD-Granting	5	6
	Master's-Granting	7	9
	Bachelor's-Granting	7	11
	Total	6	8

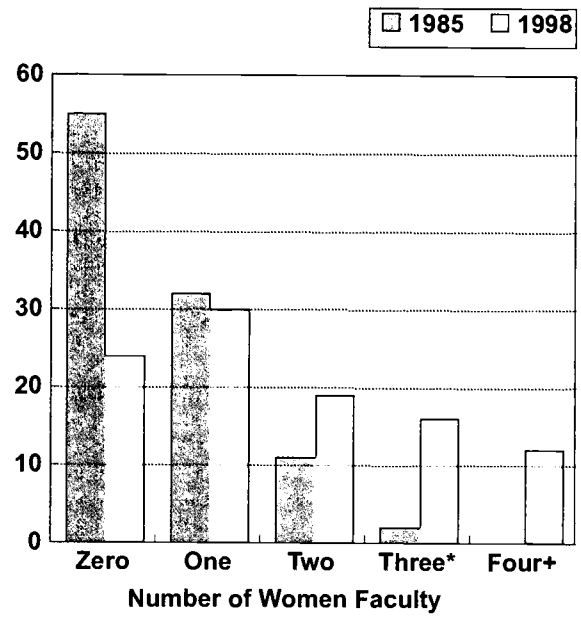
Sources: Blake, *1993-94 Academic Workforce Report*, AIP, and Ivie & Stowe, *1997-98 Academic Workforce Report*, AIP.

Figure 9. Employment Status and Gender of New Physics Faculty Hires for 1997-98



Source: Ivie and Stowe, *1997-98 Academic Workforce Report*, AIP.

Figure 10. Number of Women Faculty in PhD Physics Departments, 1985 and 1998

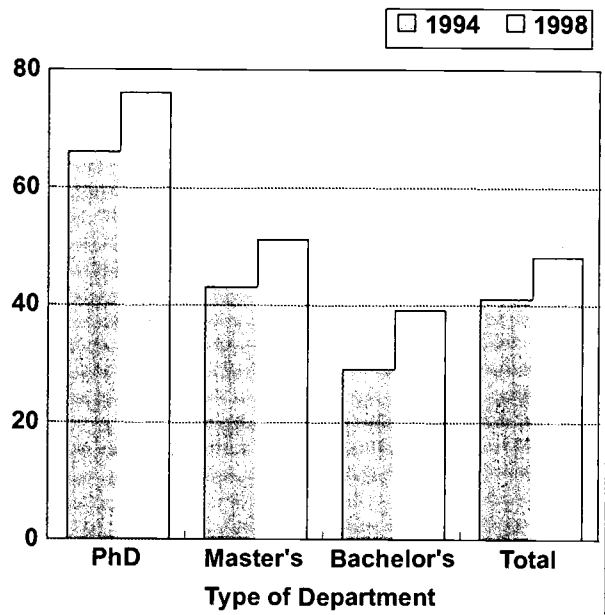


*For the 1985 data category, "Three" represents three or more.
Source: Ivie and Stowe, *1997-98 Academic Workforce Report*, AIP.

In addition, the representation of women on physics faculty has been increasing, especially at departments that do not grant graduate degrees and in the lower ranks. Between 1994 and 1998, the percentage of assistant professors who were women increased from 12% to 17%. The percentage of female faculty at departments that do not grant graduate degrees increased from 7% to 11% **(Table 4)**.

The number of departments that have at least one woman faculty member has increased dramatically as well. In 1985, more than one-half of PhD physics departments had no women faculty at all. By 1998, three-fourths of PhD physics departments had at least one woman faculty member **(Figure 10)**. Statistics for departments that do not grant PhDs in physics were not available until 1994. As **Figure 11** shows, all types of departments had larger percentages of women faculty in 1998 than in 1994. By 1998, almost one-half of all physics departments had at least one woman faculty member **(Figure 11)**. This trend is good news, since many women students perceive that the presence of at least one female faculty member improves the climate for women in physics departments (Dresselhaus, Franz, and Clark, 1995).

Figure 11. Percent of Physics Departments with Women at Any Rank, 1994 and 1998



Sources: Blake, *1993-94 Academic Workforce Report*, AIP, and Ivie & Stowe, *1997-98 Academic Workforce Report*, AIP.

PhD DEPARTMENTS WITH FOUR OR MORE WOMEN FACULTY

Table 5 lists PhD physics departments that have confirmed that they have at least four women physicists on faculty. In order to be included on this list, physics departments must have responded to a 1998 Academic Workforce Survey conducted by AIP. This survey had an 85% response rate, but the list may inadvertently exclude a physics department with four or more women. The women in these departments hold various positions including tenured, tenure-track, research professors, lecturers, and visiting professors. However, post-docs are not included. The mean number of women faculty at PhD physics departments is 1.7. Therefore, this list includes departments who are well above average in terms of the representation of women.

Table 5. PhD Physics Departments with Four or More Women on Faculty, 1998

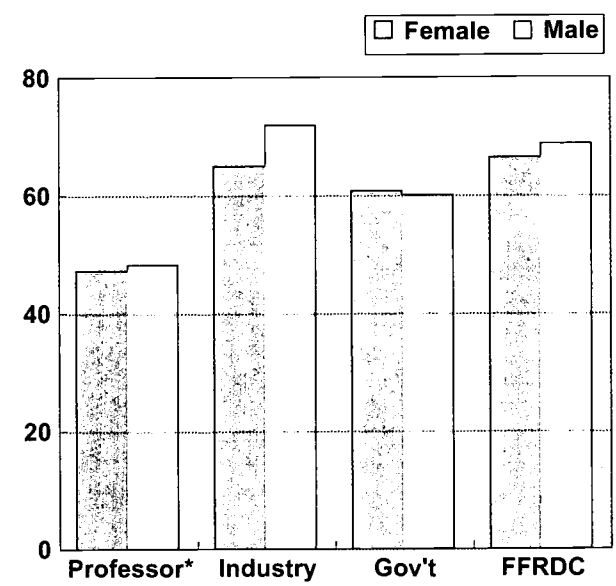
California at Davis, University of
California at Santa Barbara, University of
California Institute of Technology
Columbia University (Department of Applied Physics and Applied Mathematics)
Florida State University
Iowa, University of
Johns Hopkins University
Kansas, University of
Massachusetts at Amherst, University of
Massachusetts Institute of Technology
Michigan State University
Northwestern University
Notre Dame, University of
Oregon State University
Pennsylvania, University of
Rutgers University
Washington State University

Source: AIP Statistical Research Center.

SALARIES

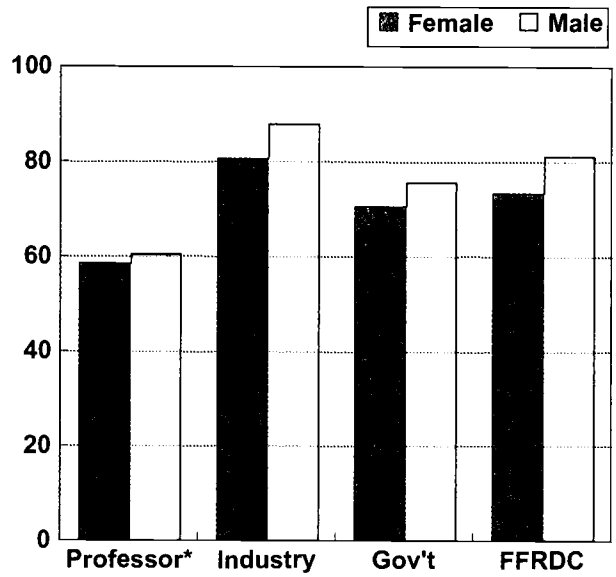
For the members of AIP's Member Societies, there are differences in salary between men and women, although most of these differences are not significant. **Figure 12** shows 1998 salary differences by employment sector for respondents who received PhDs ten or fewer years ago, and **Figure 13** shows the data for respondents who received PhDs between eleven and twenty years ago. Although most sectors show salary differences between the sexes, only two of the differences are statistically significant (α = .05, one-tailed). Among members who received their PhDs 10 or fewer years ago and who are employed in industry, women make less than men **(Figure 12)**. Among members who received PhDs between 11-20 years ago, women employed at Federally Funded Research and Development Centers (FFRDCs) make less than men employed at FFRDCs **(Figure 13)**.

Figure 12. 1998 Adjusted Mean Salaries by Selected Employment Sectors Within 10 Years Since PhD



*9 - 10 month salaries.
Source: 1998 Society Membership Survey, AIP.

Figure 13. 1998 Adjusted Mean Salaries by Selected Employment Sectors Within 11-20 Years Since PhD



*9 - 10 month salaries.
Source: 1998 Society Membership Survey, AIP.

EXPLANATIONS

Observers of physics have speculated as to why women choose fields other than physics in specific and science in general. In this section, we will address six of these hypotheses. The first four can be dismissed based on the evidence in this report. The last two cannot be supported using the evidence in this report, but they cannot be dismissed either.

First, some have speculated that women enter physics classes with poor math backgrounds and are unable to keep up with the mathematical demands of physics. A variation of this assumption posits that women, although able, are less confident in math than men are, and choose fields that are less dependent on math. By itself, the math hypothesis seems insufficient given the large percentage of women earning bachelor's degrees in math **(Figure 4)** and the increasingly large numbers of women earning PhDs in math **(Table 1)**. Note that more women earn math PhDs than physics PhDs although math is a smaller PhD field than physics.

A second hypothesis for women's poor representation in physics is that women have less experience with hands-on learning involving technical equipment and machinery. This hypothesis assumes that from a very early age, our society gives boys more exposure to mechanical toys. As boys become older, they are encouraged more often than girls are to tinker with and repair machines and equipment. Therefore, when girls enter the physics lab, they are at a disadvantage when it comes to using the lab equipment. Again, however, we must question the sufficiency of this reasoning when we consider the large numbers of women earning degrees in engineering **(Figures 5, 7, and Table 1)**. In fact, the number of women earning bachelor's degrees in engineering in 1997 was more than three times greater than the total number of men *and* women earning bachelor's degrees in physics **(Figure 5)**.

Third, some observers have speculated that when making career choices, women more often than men consider the time that having a family will take and choose careers that do not require long hours away from the family. These observers reason that a research career in physics requires long hours in the lab, and therefore women choose other careers. The sufficiency of this hypothesis, like the first two, falls short when we look at the large numbers of women choosing medicine and law **(Table 1)** and life sciences **(Figures 5, 7, and Table 1)**.

Similarly, some observers have hypothesized that women do not have personality characteristics that are compatible with success in science. These personality characteristics include determination, competitiveness, assertiveness, and persistence. However, we must question the validity of this

claim when we consider the large numbers of women entering fields that also value these characteristics, such as medicine, math, law, and other sciences **(Figures 5, 7, and Table 1)**.

Fifth, many have noticed that women in science are often the victims of discrimination, ranging from harassment which is sexual in content (and which is probably more rare) to harassment because they are women. The latter can range from discounting women's contributions in science classes, to interrupting or ignoring women who attempt to make comments in discussions, to open hostility on the part of male students and faculty (AAUW, 1992; Dresselhaus et al., 1995). Recently, MIT documented similar discrimination for its women science faculty. MIT's report showed inequities in salary and that senior women were allocated less lab space and fewer university grants than senior men were. Senior women faculty reported that they were overlooked for influential committee assignments and that they were encouraged to do more teaching than research. Indeed, the percentage of women faculty members in the sciences at MIT had remained at about 7% since the late 1970s despite increasing numbers of women PhD scientists during this time (Lawler, 1999).

One factor that may serve to mitigate this hostile environment, especially for students, is the presence of more women faculty members. Women attempting to enter physics (especially at smaller colleges) may never encounter a female physics professor and are often lucky to have one other woman in physics classes. This quickly sends the message to women that physics is a "man's" field. Other sciences, especially life sciences, now have enough women that a critical mass has been reached, and women students are more easily attracted into these fields.

A final hypothesis for the dearth of women in physics is that women do not perceive that a physics degree will help them achieve their career goals, which may be different from the career goals of men. This hypothesis really contains two issues: (1) the necessity of teaching students how to use a physics degree to achieve their career goals (a laudable goal for recruiting and retaining both women and men), and (2) determining if the career goals of women and men are different, and if so, why. Explanations for differing career goals may well begin in early childhood socialization, in which girls are encouraged to pursue different interests than boys. These experiences continue through high school and college, where young women encounter the stereotyped expectations of their teachers, parents and peers, who (often very subtly) point out "appropriate" majors and career paths for females. The stereotypical "appropriate" majors for women do not include physical sciences.

Nevertheless, all of the above hypotheses are mere speculation. In order to understand women's poor representation in physics, we need more data about why some women stay in physics and why others leave. We hope to gather these data, perhaps through a series of interviews, in future studies.

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