

PREFACE

A BRIEF HISTORY OF WOMEN AND THE PH.D.

Depending on your field, you may be among a very small minority of the doctoral students in your science or engineering department. But just over 100 years ago, you would not have been formally admitted at all to the doctoral programs at any university in the United States. The reasons given for not accepting women ranged from those based on bad social science to silly medical science. University administrators—and society at large—espoused the view that such education would be wasted on women since they would soon be married and busy raising children. Some “scientists” of that time even believed that studying drew away blood necessary for menstruation and pregnancy, thus hampering a woman’s procreation abilities (Caplan, 1994). But even after such ridiculous arguments had been debunked, universities could still offer one final—and unarguable—excuse: there was no precedent for accepting women.

Although women at that time weren’t being formally accepted into graduate school, many did find ways to get in, usually as “special” or nondegree students. For example, in 1870 Ellen Swallow Richards applied to the Massachusetts Institute of Technology for a graduate degree in chemistry, but was instead admitted as a “special student” who was seeking a second bachelor’s degree (her first one was from Vassar). It was argued that the Chemistry Department didn’t want its first graduate degree to be awarded to a woman (Rossiter, 1982). The difficult part, it seemed, was actually being awarded a degree for the work done. One of the most infamous examples of this discrimination is the case of mathematician Christine Ladd-Franklin, who completed her dissertation in 1882 at Johns Hopkins University but was not awarded her degree until 44 years later (Rossiter, 1982).

It wasn’t until 1890 that women could officially enter graduate school in the United States, and then only a handful of universities allowed them. Over the following decades, more universities opened their doors to women doctoral students, but many barriers still remained, especially in the historically male rampart of sci-

ence and engineering. This tradition of exclusion of women in these fields becomes easier to understand, however, when one examines the history of the disciplines.

Even with over a century of U.S. graduate experience under our belts, women's involvement in the academy is still relatively new, and our official acceptance into science and engineering programs infantile. In the Middle Ages, European universities were created largely to teach theology, medicine, and law—professions that were not open to women. There were a few remarkable exceptions (such as Laura Bassi, who received her doctorate in 1733 and was a physics professor at the University of Bologna), and of course, the countless—and not so famous—numbers of women throughout the ages who studied and practiced science and engineering in whatever way they could. For the most part, however, women just weren't welcome in these professions (Ambrose et al., 1997).

Science's parameters—established by Descartes and Francis Bacon—have been blamed by some scholars for alienating women. Descartes pronounced that objectivity in science required a separation of logic from emotion (the “mind–body problem”). Bacon “declared that the purpose of science was for man to conquer and control nature for his [own] benefit” (Ambrose et al., 1997). Some writers hold that these tenets—and the scientific culture built upon them—have served to exclude women from the official scientific community in the past.

Engineering was even more exclusionary, due to its inception from a military model. In the 1400s, the word “engineering” (from the Latin word for “to contrive”) was used to describe the design of devices for warfare. Thus, an engineer was a man who employed skills to build machines of war. Even when engineering took on the qualifier “civil” to denote its nonmilitary applications, it remained a man's domain.

Although formal science and engineering education has long been the realm of men, even nonmilitary male students weren't able to formally study engineering in the United States until 1824 when the Rensselaer School (now Rensselaer Polytechnic Institute) was established (Grayson, 1977). The first doctorate ever earned in the United States wasn't awarded until 1861, when Yale granted one to a man in science.

This brings us back to the late nineteenth century, when women started to sneak in the back door of graduate programs and slowly but surely began to break down the barriers that had kept them out.

This is just a brief look at how women fit into the bigger picture of the doctorate in science and engineering. This background, however, gives us a basis on which to examine the current situation for women seeking their doctorates in those fields.

WHAT IT'S LIKE NOW

The National Science Foundation reports that women are currently earning the majority of bachelor's and master's degrees overall, but in 1998 earned just 40% of the doctorates in science and only 13% of those in engineering (National Science Foun-

dition, 2000). More than a century after Christine Ladd-Franklin was denied a doctorate, these and other recent numbers make it clear: many women scientists and engineers face challenges throughout their careers simply because they are women. These challenges are compounded for women of color, lesbians, differently abled, and economically disadvantaged women. Most fields are male dominated at every level, and female mentors and role models are few. Doctoral work is certainly no exception, and it is only a first hurdle along the journey to a fulfilling career.

For the last 20 years, the United States has faced a critical shortage of scientists and engineers with doctoral degrees in a number of fields. Even in areas where absolute numbers are not an issue, there are real equity concerns. The number of women working and studying in the scientific and technical fields is markedly lower than the number of men. To help all individuals reach their potential and to remain competitive into the next century, it is fundamental that the United States recruit from our entire population and that we support greater numbers of women in scientific and technical Ph.D. programs.

Table 1 Number of Science and Engineering Doctorate Recipients, by Gender and Subfield, 1998

Subfield of Doctorate	Number of Doctorates		
	Total*	Men	Women
<u>PHYSICAL SCIENCES</u>	<u>6,739</u>	<u>5,104</u>	<u>1,600</u>
MATHEMATICS	1,177	872	297
Applied Mathematics	265	203	61
Algebra	75	57	18
Analysis & Functional Analysis	130	105	25
Geometry	54	39	15
Logic	16	11	5
Number Theory	46	39	7
Mathematical Statistics	204	141	62
Topology	65	52	13
Computing Theory & Practice	18	15	3
Operations Research	17	11	6
Mathematics, General	163	118	39
Mathematics, Other	124	81	43
COMPUTER SCIENCE	923	763	157
Computer Science	817	696	118
Information Sciences & Systems	106	67	39

(Continued)

Table 1 (Continued)

Subfield of Doctorate	Number of Doctorates		
	Total*	Men	Women
PHYSICS & ASTRONOMY	1,584	1,354	223
Astronomy	91	69	22
Astrophysics	117	93	24
Acoustics	18	12	6
Chemical & Atomic/Molecular	99	86	13
Elementary Particles	173	162	11
Fluids	26	26	0
Nuclear	92	81	11
Optics	104	86	18
Plasma & High-Temperature	55	53	2
Polymer	24	20	4
Solid State & Low-Temperature	313	276	37
Physics, General	190	158	29
Physics, Other	282	232	46
CHEMISTRY	2,217	1,510	695
Analytical	384	238	146
Inorganic	287	203	84
Nuclear	5	4	1
Organic	597	437	160
Medicinal/Pharmaceutical	115	68	46
Physical	278	201	77
Polymer	123	83	40
Theoretical	41	31	10
Chemistry, General	286	187	88
Chemistry, Other	101	58	43
EARTH, ATMOS., & MARINE SCI.	838	605	228
Atmospheric Physics & Chemistry	38	31	7
Atmospheric Dynamics	24	16	8
Meteorology	25	19	5
Atmos. Sci./Meteorology, General	22	13	8
Atmos. Sci./Meteorology, Other	16	14	2

Subfield of Doctorate	Number of Doctorates		
	Total*	Men	Women
Geology	171	131	40
Geochemistry	58	35	22
Geophysics & Seismology	106	85	21
Paleontology	23	16	7
Mineralogy, Petrology	14	9	5
Stratigraphy, Sedimentation	24	20	4
Geomorphology & Glacial Geology	20	12	8
Geological & Related Sci., General	13	8	5
Geological & Related Sci., Other	40	33	7
Environmental Science	73	43	30
Hydrology & Water Resources	35	27	8
Oceanography	94	64	29
Marine Sciences	18	15	3
Misc. Physical Sciences, Other	24	14	9
ENGINEERING	5,919	5,108	769
Aerospace, Aeronautic., Astronautic.	242	227	14
Agricultural	73	68	5
Bioengineering & Biomedical	207	157	50
Ceramic Sciences	24	22	2
Chemical	667	542	119
Civil	587	498	83
Communications	40	34	6
Computer	210	187	22
Electrical, Electronics	1,343	1,206	127
Engineering Mechanics	86	73	13
Engineering Physics	15	12	3
Engineering Science	50	42	8
Environmental Health Engineering	63	46	17
Industrial/Manufacturing	227	187	39
Materials Science	482	404	75
Mechanical	936	849	79
Metallurgical	59	51	7

(Continued)

Table 1 (Continued)

Subfield of Doctorate	Number of Doctorates		
	Total*	Men	Women
Mining & Mineral	21	17	4
Nuclear	97	86	10
Ocean	29	29	0
Operations Research	62	47	15
Petroleum	48	42	6
Polymer/Plastics	59	44	15
Systems	68	59	9
Engineering, General	30	23	3
Engineering, Other	194	156	38
<u>LIFE SCIENCES</u>	<u>8,540</u>	<u>4,640</u>	<u>3,876</u>
BIOLOGICAL SCIENCES	5,848	3,298	2,533
Biochemistry	798	448	349
Biomedical Sciences	184	101	79
Biophysics	166	119	47
Biotechnology Research	12	8	4
Bacteriology	13	9	4
Plant Genetics	40	22	18
Plant Pathology	18	10	8
Plant Physiology	61	33	28
Botany, Other	113	58	55
Anatomy	35	27	8
Biometrics and Biostatistics	75	35	39
Cell Biology	299	145	154
Ecology	292	177	114
Developmental Biology/Embryology	127	66	61
Endocrinology	30	16	14
Entomology	138	101	37
Biological Immunology	245	130	115
Molecular Biology	741	414	324
Microbiology	384	214	169
Neuroscience	412	244	168
Nutritional Sciences	137	42	95

Subfield of Doctorate	Number of Doctorates		
	Total*	Men	Women
Parasitology	15	9	6
Toxicology	156	95	61
Human & Animal Genetics	196	105	91
Human & Animal Pathology	91	56	35
Human & Animal Pharmacology	256	133	121
Human & Animal Physiology	258	158	100
Zoology, Other	111	68	43
Biological Sciences, General	217	133	82
Biological Sciences, Other	228	122	104
HEALTH SCIENCES	1,500	488	1,006
Speech-Lang. Pathology & Audiology	95	20	74
Environmental Health	54	37	17
Health Systems/Services Admin.	63	27	36
Public Health	157	49	107
Epidemiology	166	54	112
Exercise Physiology/Sci., Kinesiology	129	80	49
Nursing	399	17	380
Pharmacy	156	79	75
Rehabilitation/Therapeutic Services	33	11	22
Veterinary Medicine	48	30	18
Health Sciences, General	17	5	12
Health Sciences, Other	183	79	104
AGRICULTURAL SCIENCES	1,192	854	337
Agricultural Economics	155	115	40
Agricultural Business & Management	2	2	0
Animal Breeding & Genetics	18	12	6
Animal Nutrition	45	32	13
Dairy Science	10	8	2
Poultry Science	11	8	3
Fisheries Science & Management	30	22	8
Animal Sciences, Other	60	44	16

(Continued)

Table 1 (Continued)

Subfield of Doctorate	Number of Doctorates		
	Total*	Men	Women
Agronomy & Crop Science	96	77	18
Plant Breeding & Genetics	69	55	14
Plant Pathology	66	42	24
Plant Sciences, Other	37	23	14
Food Engineering	13	10	3
Food Sciences, Other	153	87	66
Soil Chemistry/Microbiology	27	20	7
Soil Sciences, Other	74	53	21
Horticulture Science	60	47	13
Forest Biology	20	14	6
Forest Engineering	2	2	0
Forest Management	27	18	9
Wood Sci. & Pulp/Paper Tech.	25	21	4
Conservation/Renewable Nat. Res.	25	14	11
Forestry & Related Sci., Other	69	53	16
Wildlife/Range Management	55	41	14
Agricultural Sciences, General	8	7	1
Agricultural Sciences, Other	35	27	8

*Grand totals include 174 doctorate recipients whose gender was unknown and 20 doctorate recipients whose doctoral field was unknown.

NOTE: Field groupings may differ from those in reports published by federal sponsors of the Survey of Earned Doctorates.

Excerpted from Doctorate Recipients from United States Universities: Summary Report 1998 (see Sanderson et al. in Bibliography).

See <http://www.nsf.gov/sbe/srs/srs00410/tables/tab1.xls> for data on other disciplines.

Source: NSF/NIH/NEH/USED/USDA, Survey of Earned Doctorates

Why aren't more women earning their Ph.D.s in science or engineering? Why aren't women with degrees remaining in academic careers? The answers are complex but have a great deal to do with the nature of doctoral education, the atmosphere, and largely unconscious attitudes and cultural biases in many graduate programs in the sciences and engineering. In our culture, we presume that math ability is male-gendered and innate. In other cultures, everyone is assumed to be able to learn math, so it is taught to everyone. This disparity in presumed ability to do math can become a source of low self-esteem in women raised in the Ameri-

can culture. Even if they are “good in math,” they may see all men (and women from other cultures) as better in the subject than they because they lack the self-confidence that comes from being nurtured in math education. In countries where high school courses in math and science are required, women do better in science (Schiebinger, 1999).

Doctoral work, particularly in science and engineering, uniquely challenges women and, in many cases, promotes the success of men. A number of people in higher education still cling to the outdated model that only white men have the ability to be successful scientists and engineers, that women are best suited to careers in the humanities and social sciences, and that women just aren’t tough enough to succeed in technical fields.

For women to survive in graduate school—and to emerge ready for careers in the academy, industry, or the public sector—they must overcome stereotypes and hidden barriers. Women need to learn how to maneuver in a predominantly male graduate school environment, how to think like academics, and how to be politically astute.

This book is designed to unravel some of the mystery around graduate school programs in science and engineering and to provide strategies for succeeding. Each chapter covers a different aspect of graduate school, from identifying funding sources to writing the dissertation to looking for a job. The guide focuses on the emotional and social challenges women may face, and it offers practical suggestions and advice for surviving and thriving in graduate school, not because all

WHAT IT TAKES

“When I think about what it takes for women to be successful as scientists, four categories come to mind into which most successful women scientists fall: some are oblivious to negative feedback; some are stubborn and the more they hear ‘you can’t do this,’ the harder they try; others are very creative and take unusual paths in both their careers and personal lives; and a few are simply incredibly brilliant. Most women fall into the first three categories, and there is room for all types of personalities. I consider myself part of the ‘stubborn’ category. I’ve always found science fun and stimulating. For me it is important to remember the wonderful aspects of it even when I experience unpleasantness.”

Debbie C. Crans
Associate Professor of Organic Chemistry
Colorado State University
(Ph.D., Organic Chemistry, Harvard University)

From *Journeys of Women in Science and Engineering: No Universal Constants*

women will face any or every problem, but because those who do are most in need of advice. The guide covers the practical side of graduate school including course work, choosing an advisor, and funding concerns. It also discusses common problems and concerns many female graduate students report. The bibliography contains our sources and other helpful publications.

Interspersed throughout are personal stories and advice from current female graduate students based on their experiences in graduate school and from women engineers and scientists from across the United States. All of the stories included in the guide are from real people in actual situations, but in most cases the names and departments have been changed to keep their identity confidential.

We hope you will use our guide as a resource when considering graduate school or as a handbook to help you thrive. And never forget: the path is worth it. Women who work in these careers enjoy relatively high standing and salaries, job security, and mobility. But most importantly, they work at what they love and have a chance to make a difference.

Table 2 Timeline

Early 1800s	Technical institutes and land-grant colleges educate engineers and other technicians who could feed America's burgeoning economy. Higher education was becoming less elite and more practical (Boyer, 1990; Glassick et al., 1997).
1836	Georgia Female College at Macon opens and is the first institution in the United States to grant degrees to women. Required courses included astronomy, chemistry, and mineralogy (Ambrose et al., 1997).
1837	Oberlin College is the first college to admit women into its regular program (Selby, 1999).
1861	The first U.S. doctorate is awarded at Yale (in science) (Davis et al., 1996).
1870	Ellen Swallow Richards applies to MIT as a graduate student in chemistry, but is accepted instead as a "special" student pursuing a second bachelor's degree (Rossiter, 1982).
1876	Johns Hopkins University is founded, mainly to offer doctoral degrees (Boyer, 1990).
1882	Mathematician Christine Ladd (later Ladd-Franklin) submits her dissertation at Johns Hopkins University, but is refused a degree by the Board of Trustees (Rossiter, 1982).
1890–1892	Women are accepted as graduate students by Yale, the University of Pennsylvania, Columbia, Brown, Stanford, and the University of Chicago. Because of peer pressure, other universities soon followed suit and, by the early 1900s, women were accepted into most graduate schools (Rossiter, 1982).
World War I	A boom in employment occurs for women in engineering and science. Although these women had proven that they could do "men's work," returning soldiers took back their jobs and the women engineers and scientists were sent "home."
early 1920s	Harvard Medical School appoints Alice Hamilton as its first woman faculty member. Hamilton, the best qualified candidate Harvard could find in industrial medicine, was not allowed to use the faculty club or march in the commencement procession (Glazer and Slater, 1987).



Figure 2 In the 1920s, women earned 15% of all doctorates (Lomperis, 1990) and 12% of science doctorates (Vetter, 1984). (Photo credit: Courtesy of Carnegie Mellon University Archives.)

- 1926** Christine Ladd-Franklin is awarded her Ph.D. in mathematics from Johns Hopkins University—44 years after she earned it (Green and LaDuke, 1987).
- 1940** Thirteen percent of all doctorates are awarded to women (Chamberlain, 1988).
- 1944** G.I. Bill is first authorized. Almost 8 million veterans use the bill to attend college, but only 3% of the veterans enrolled in college in the 1940s were women (Hollenshead, 1998).
- 1947** President Truman creates the President’s Commission on Higher Education, which seeks to shift emphasis from educating the elite to educating the masses (Boyer, 1990).
- 1950** The National Science Foundation is created to “promote the progress of science.”
- 1950s** Fewer women receive Ph.D.s than in the 1920s (Hollenshead, 1998).
- 1960** Women earn 2.6% of engineering, physics, and mathematics doctorates and 8.8% of life sciences doctorates (Lomperis, 1990).



Figure 3 In the 1950s, fewer women received Ph.D.s than in the 1920s (Hollenshead, 1998). (Photo credit: Courtesy of Carnegie Mellon University Archives.)

(Continued)

Table 2 (Continued)

1960s	The Civil Rights Act and the Federal Women's Program outlaw discrimination in employment.
1970	Women earn 3.6% of engineering, physics, and mathematics doctorates and 13% of life sciences doctorates (Lomperis, 1990).
1980	Women earn 9% of engineering, physics, and mathematics doctorates and 25.9% of life sciences doctorates (Lomperis, 1990).
1989	Women earn 28.1% of all science and engineering doctorates (National Science Foundation, 2000).
1989	Harvard tenures its first woman chemistry professor (Cynthia Friend) and in 1992 tenures its first woman physics professor (Melissa Franklin).
1998	Women earn 34.3% of science and engineering doctorates (National Science Foundation, 2000).
1998	Microbiologist Rita Colwell is appointed the first female head of the National Science Foundation.
