Preparing for Science and Engineering Careers: Field Level Profiles

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PREPARING FOR SCIENCE AND ENGINEERING CAREERS:
FIELD-LEVEL PROFILES

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PREPARING FOR SCIENCE AND ENGINEERING CAREERS:
FIELD-LEVEL PROFILES

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PREPARING FOR SCIENCE AND ENGINEERING CAREERS

FIELD-LEVEL PROFILES

INTRODUCTION AND HIGHLIGHTS

This Staff Paper is an addendum to Demographic Trends and the Scientific and Engineering Work Force, an OTA Technical Memorandum published in December 1985. The paper was produced in response to a request by the Committee on Science and Technology of the House of Representatives, to examine differences in the supply and demand of personnel across individual fields of science and engineering, and the sensitivity of these fields to demographic trends.

The document consists of a dozen profiles presented in five broad field categories: the physical sciences (physics and astronomy, chemistry, earth and environmental sciences); mathematical and computer sciences; the life sciences (biological, health/medical, agricultural); social and behavioral sciences (psychology, economics); and engineering (chemical, electrical). All profiles include trend data on enrollments, degrees conferred, and employment by sector and primary work activity. Detailed information is also given on preparation for careers in science and engineering of three groups of people: women, minorities, and foreign nationals. The time period covered by most of the descriptive statistics is 1960-86.

The paper illustrates differences in the education and entry-level employment of degreed science and engineering talent, especially characteristics that are obscured by aggregated data analysis. A brief narrative introduces each broad field section and a series of graphs and charts accompanies each profile. [n addition, a note on data precedes the profiles; this note provides an overview of data sources and explains important idiosyncrasies of their reporting.

Each field profile has been written as a self-contained section. **As** the individual field or discipline is a smaller, more uniform population than the science and engineering work force as a whole, each field tends to have a characteristic pattern of education and employment. Analysis at the level of the field can improve understanding of how different market forces, demographic factors, and public policies interact to affect the supply of and demand for scientists and engineers. The following are highlights of a disaggregate analysis. Such analysis augments generalizations about the science and engineering work force as a whole.

1. The smaller and more specialized the scientific field being studied, the less predictable are changes in the factors that affect demand, such as scientific and technological **advances,** shifts in Federal funding priorities, and industrial research and development **(R&D)** spending, Small changes in the total supply of scientists and engineers can mask significant adjustment within and among fields. The total number of Ph.D.s awarded in science and engineering rose by 7 percent between 1980 and 1985. During this period, physics Ph.D. awards rose 10 percent and mathematics Ph.D.s declined almost as much. Both were overshadowed, however, by an increase in computer science Ph.D.s of 35 percent. The relationship between fields, especially mathematics and computer science, is critical for interpreting these degree trends.

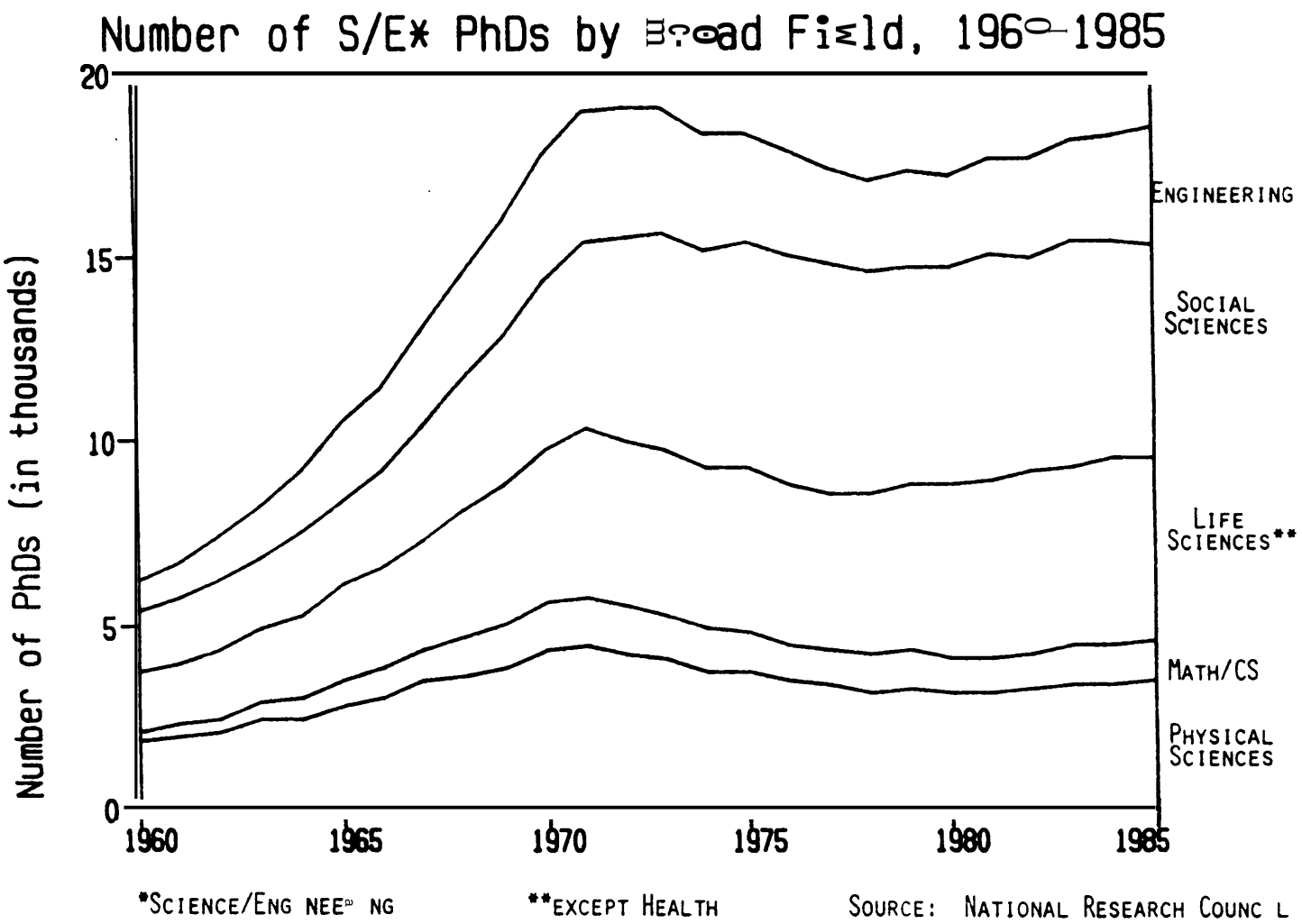
2. Demographic trends play very little, if any, role in the supply of scientists or engineers in individual fields or in one field relative to another. Some demand factors affect all science and engineering, such as the general health of the U.S. industrial economy and the level of Federal R&D funding. Although the national economy may be healthy and the overall demand for scientists and engineers strong, a downturn in the oil industry will quench the demand for petroleum engineers. Similarly, a shift in emphasis within Federal R&D funding, even though overall R&D funding remains stable, can significantly change the demand in particular fields while not changing the total demand for scientists.

3. Graduate enrollments and degree awards are highly responsive to small shifts in Federal education and research support. In academic sciences such as mathematics, the life sciences, and astronomy, Federal Government support dominates. In industry-oriented fields, students respond quickly to changes in the job market. For example, unprecedented growth in the U.S. computer and semiconductor industries in the late 1970s generated a large demand for electrical engineers and computer specialists, which was answered quickly with an equally unprecedented boom in undergraduate electrical engineering enrollments.

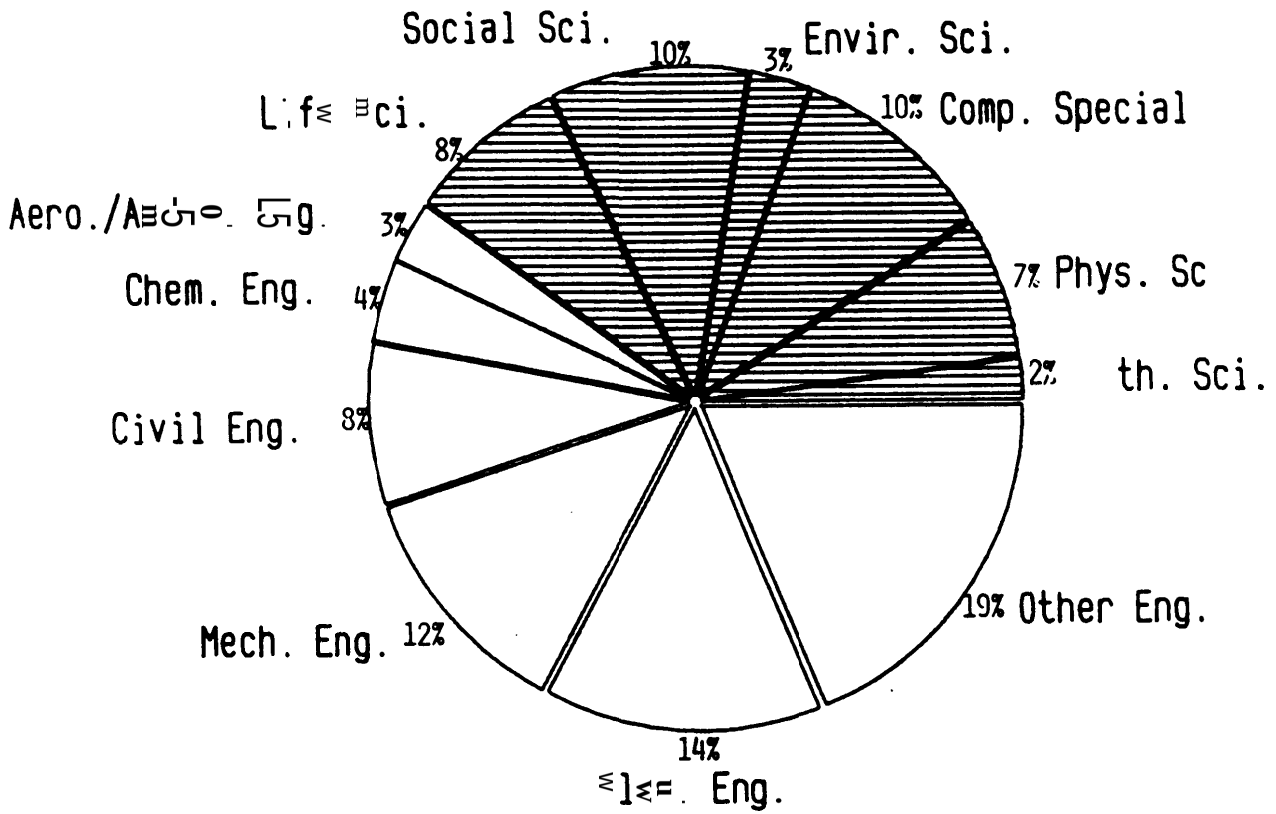
4. Breadth of employment brings stability to a field. Chemical and mechanical engineers work in many different industries and can move among them. Petroleum engineers, on the other hand, depend almost exclusively on the petroleum industry for jobs. Diversity of employment may also tend to encourage broader education and a more versatile and mobile work force. Prospects for employment, not demographics, may be the key factor in maintaining the supply of talent in afield.

5. Labor markets adjust to supply-demand gaps. The Federal role in alleviating potential shortages of technical personnel appears limited to assistance for education and retraining. Shortages and surpluses are most likely to arise at the level of the specialty or skill rather than the field, and are more likely at the level of the field than for science and engineering as a whole. While petroleum geologists are currently over-supplied, hydrologists are in demand to address rising concern over groundwater supplies and quality.

6. The labor market adjusts to supply-demand gaps in two ways: individuals already in the work force change jobs and, after a lag, the number of degrees awarded in that field changes. Students are likely to shift specialties within afield before they shift fields, and more likely to shift fields than opt out of science or engineering altogether. Students may prolong their education until a poor job market improves, or hasten entry meet changing skill requirements and job opportunities; few scientists (especially


Number of S/E* PhDs by Broad Field, 1960-1985
Number of PhDs (in thousands)
20
15
10
5
0
1960
1965
1970
1975
1980
1985
ENGINEERING
SOCIAL SCIENCES
LIFE SCIENCES**
MATH/CS
PHYSICAL SCIENCES
*SCIENCE/ENGINEERING
**EXCEPT HEALTH
SOURCE: NATIONAL RESEARCH COUNCIL

U.S. Scientists/Engineers* by Field, 1986

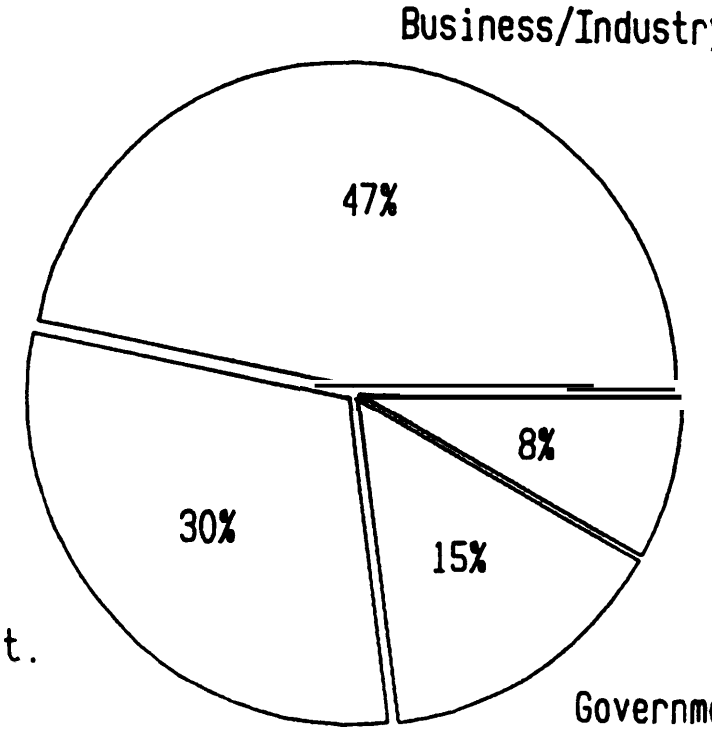


SCIENTISTS ▨
ENGINEERS □

* DEGREE

SOURCE: NATIONAL SCIENCE UNDATION

Sc by Sector of Employment, 1

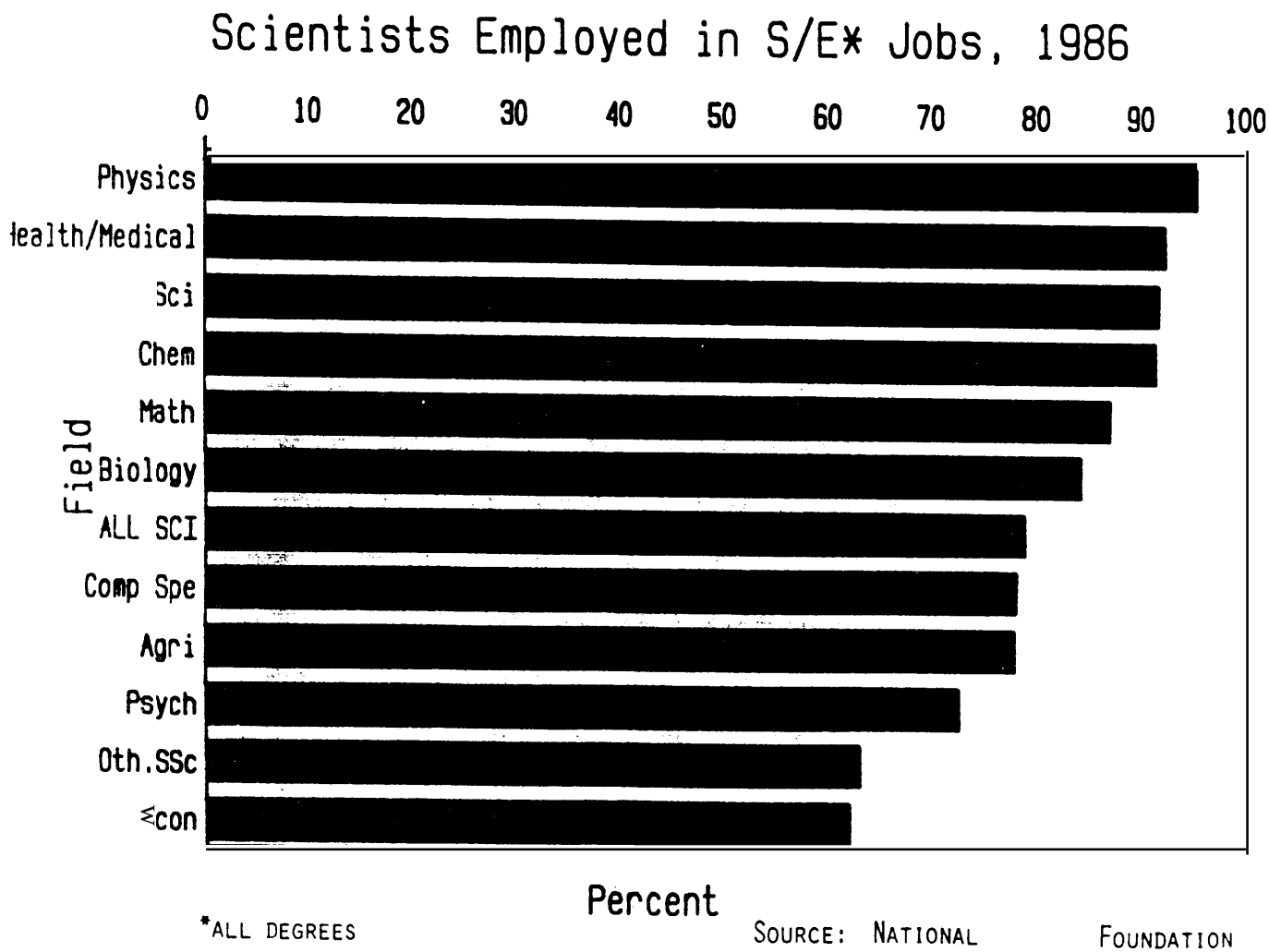


*ALL DEGREES

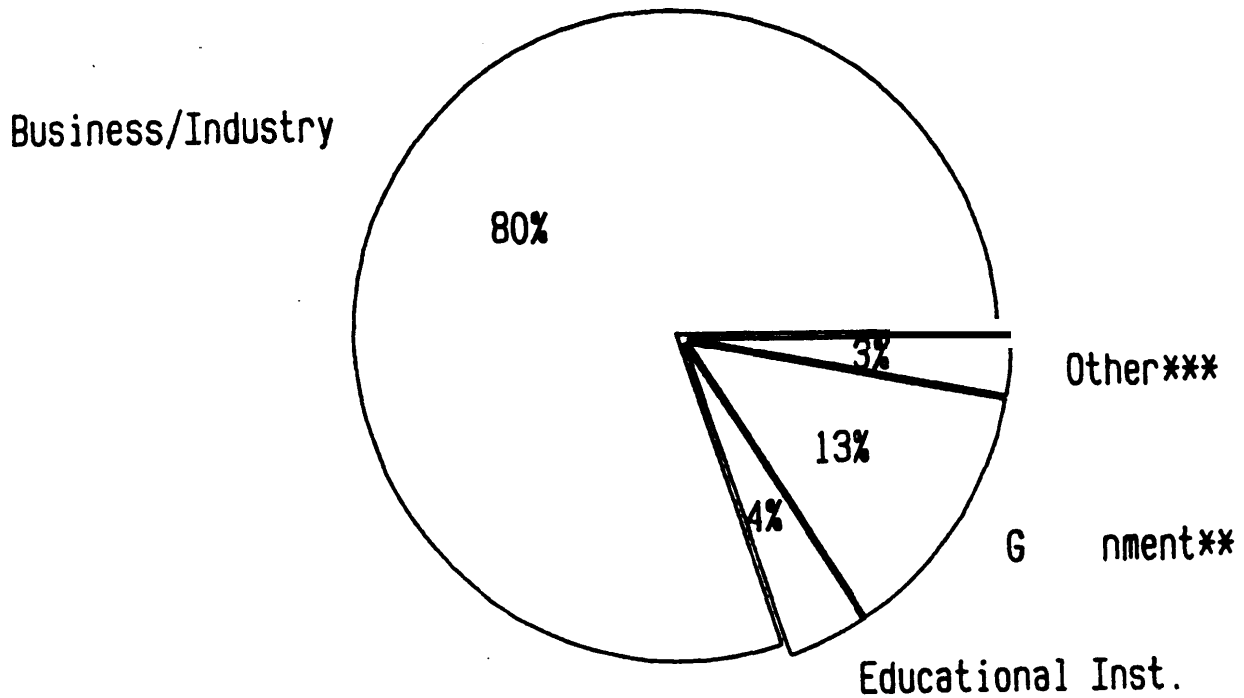
*INCLUDES FEDERAL, STATE/LOCAL, AND OTHER GOVERNMENT

** INCLUDES NONPROFIT INSTITUTIONS, MILITARY AND ALL AND NO REPORT

SOURCE: NATIONAL SCIENCE FOUNDATION


Scientists Employed in S/E* Jobs, 1986
0
10
20
30
40
50
60
70
80
90
100
Physics
Health/Medical
Sci
Chem
Math
Biology
ALL SCI
Comp Spe
Agri
Psych
Oth.SSc
Econ
Field
Percent
*ALL DEGREES
SOURCE: NATIONAL FOUNDATION

Engineers* by Sector of ployment, 1986



*ALL DEGREES

**INCLUDES FEDERAL, STATE/LOCAL, AND OTHER GOVERNMENT

***INCLUDES NONPROFIT INSTITUTIONS, MILIT AND ALL OTHER, AND

SOURCE: NATIONAL SCIENCE FOUNDATION REPORT

mathematicians and physicists) emigrate to other fields. This mobility stems both from a recognition of individual versatility (in pursuing research problems and funding) and the continuing oversupply of Ph.D.s relative to opportunities for research positions in one's original field.

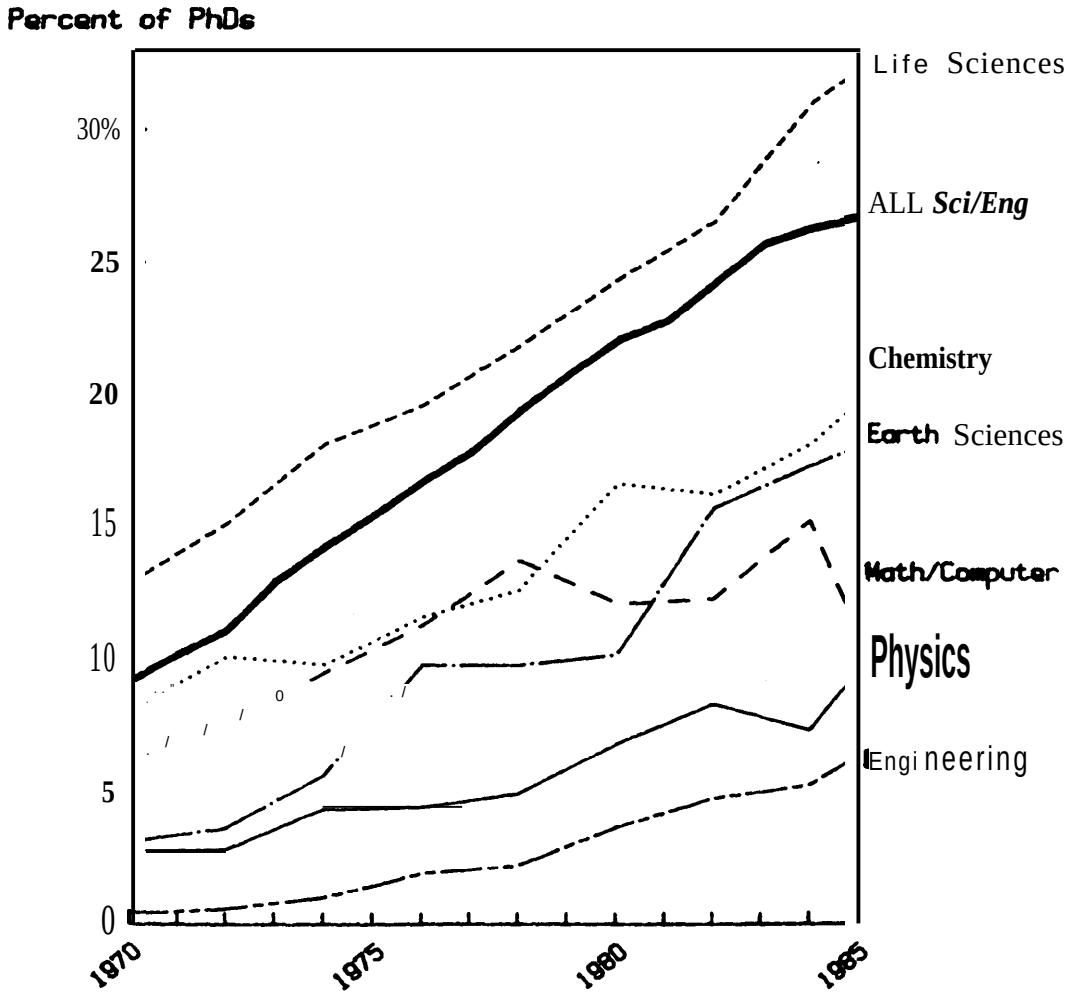
7. Recent engineering graduates seem well able to shift to meet new challenges; scientists are flexible to a lesser degree because of their longer and more specialized professional training. Engineering students can be more responsive than science students to current market conditions because of the relatively short time lag between selecting an engineering specialty, sometimes as late as the junior year of college, and obtaining the professional credential of a bachelor's degree. The total number of B.S.* degrees awarded in engineering doubled between 1975 and 1985. Computer and electrical engineering exceeded this rate and added over 15,000 to the work force during this period.

8. The scope of fields and the boundaries between them a.re constantly changing. Whether a researcher in laser optics should be counted as a physicist or an engineer is a matter of judgment rather than hard-and-fast definition. New interdisciplinary fields emerge from cross-fertilization between subfields or as spinoffs from a fruitful line of research in an established discipline. Categories tend to lag the reality of emerging disciplines. This makes it especially difficult to track disciplines in their formative years. Reliable data on computer scientists and materials scientists, for instance, are just beginning to be available.

9. The level of women's participation in science and engineering varies significantly by field. Women have made gradual gains over the past 15 years in science and engineering, though increases have slowed in recent years. In 1985, their share of science and engineering Ph.D.s declined for the first time, although the decrease was all

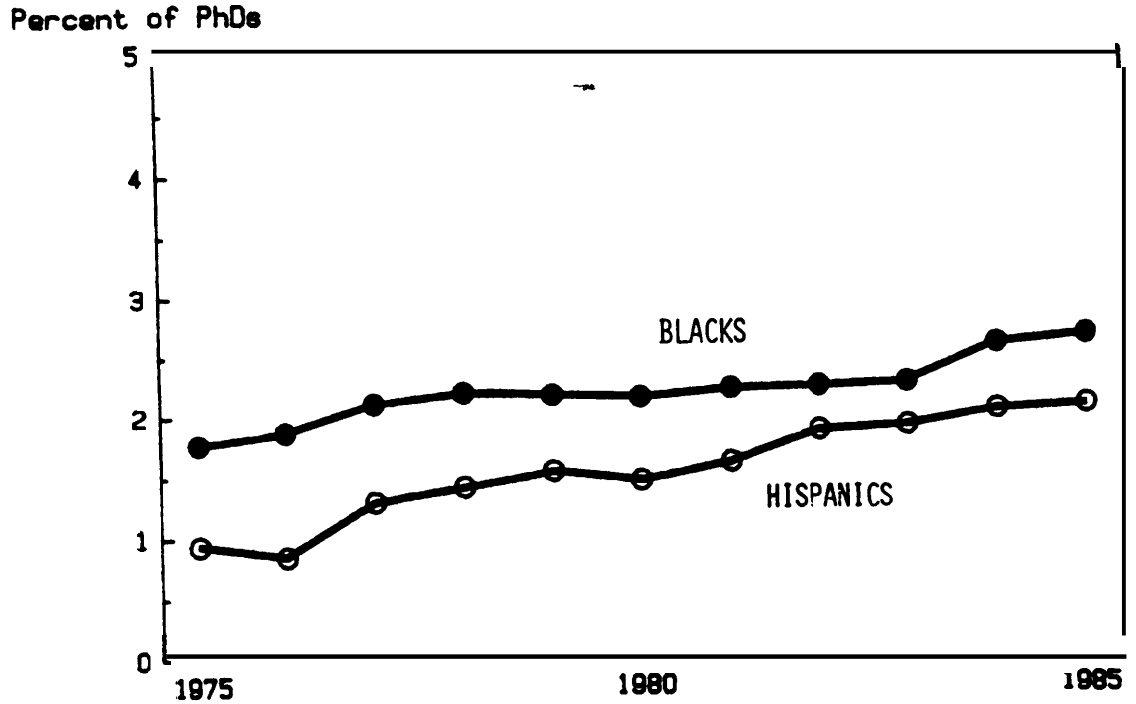
* "B.S." is used throughout the Paper as a shorthand for all baccalaureate degrees by any designation.

Women as a Proportion of PhDs
Al 1 S/E* Fields. 1970-1985



*SCIENCE/ENGINEERING SOURCE: 'NATIONAL RESEARCH COUNCIL

BLACKS AND HISPANICS
AS PROPORTION* OF ALL SCIENCE/ENG
1975-1985



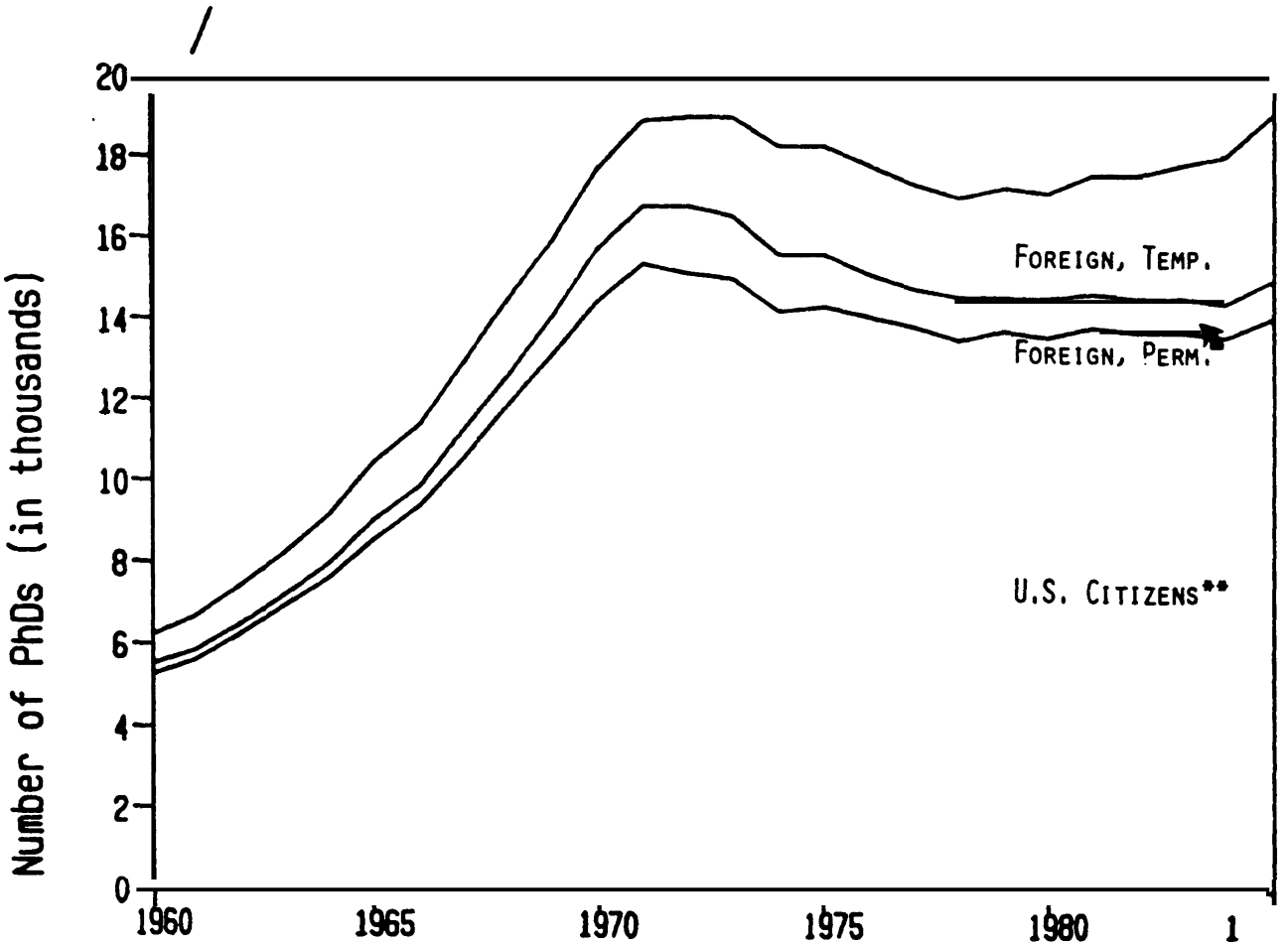
*Percent of U.S. citizens + Foreign. Perm. Visa

Source: National Research Council

in the social sciences. Ph.D. awards to Women in engineering, life, and physical sciences continued upwards. Women receive two out of three psychology bachelor% degrees and over half of psychology and health sciences Ph.D.s, but only 5 percent of physics Ph.D.s and 7 percent of engineering Ph.D.s. Among graduate students, women are twice as likely as men to be in the life sciences or social/behavioral sciences. In engineering, women tend to concentrate in industrial, chemical, petroleum, and electrical engineering. In all fields, women are more likely than men to be unemployed, underemployed, or working part-time; they are also paid less than men with equivalent experience and credentials. In colleges and universities they are less likely to be tenured or on the tenure track. Gender-stereotyped career expectations and differential treatment of women in traditionally male fields continue to deter their participation.

10. Blacks, Hispanics, and American Indians are affected by a variety of socioeconomic factors that lead to weak academic preparation for a science or engineering major and difficulty remaining in the science and engineering pipeline. Black participation has been chronically depressed in science and engineering. They are more underrepresented than Hispanics or American Indians and have made fewer gains over the past 5 years. In all science and engineering fields and at all junctures in the educational pipeline, blacks are the least likely to goon for further education. Less than lo percent of employed black scientists have a Ph.D., compared to nearly 20 percent of white and 30 percent of Asian scientists. Black engineers have slowly increased over the last 10 years, but still represent only 2 percent of the B.S. degrees and employed engineers. Hispanics and American Indians have shown a similar slow but steady increase in their share of B.S. engineering degrees.

11. Despite their minority status, Asian-Americans have attained a strong presence insolence and engineering and continue to make rapid gains. Asians continue to outpace all others (including whites)in science and engineering participation. Most Asian scientists and engineers, if not foreign citizens, are foreign-born or first-generation



*SCIENCE/ENGINEERING **INCLUDES UNKNOWN CITIZENSHIP SOURCE: NATIONAL RESEARCH COUNCIL

immigrants. The high profile and rapid gains of Asian scientists and engineers are skewed towards engineering, the mathematical and computer sciences, chemistry, and physics. The most rapid growth is in engineering. There are twice as many employed Asian-American engineers as there are Asian-American scientists; one-third of the science and engineering Ph.D.s awarded to Asian-Americans are in engineering, compared to just over 10 percent for Hispanics, less than 10 percent for whites, and less than 4 percent for blacks. Asians are more likely to continue on for higher degrees than any group.

12. The increasing presence of foreign nationals is most visible in academic engineering. Foreign nationals are about one-third of all engineering graduate students, more than 40 percent of full-time graduate students, and just under half of recent Ph.D.s. A paucity of American Ph.D. engineers has made universities particularly dependent upon new foreign Ph.D.s to fill faculty teaching and research positions. The high profile of foreign nationals among engineering graduate students, teaching assistants, and faculty raises questions about the quality of teaching in, and attractiveness of engineering for, American students. Foreign students have received a steady 7-9 percent of B.S. engineering degrees since the mid-1970s. In the sciences, foreign students are approximately 15 percent of all graduate students, but the proportion varies widely by field. In 1985, foreign students were much more likely than American students to be pursuing full-time graduate work. Most foreign graduate and postdoctoral students hold temporary visas. About half of graduate foreign engineers stay on to work in the United States, at all degree levels.

A NOTE ON DATA

The field profiles that follow are based on sources that specialize their data analysis and reporting in various ways. This inevitably leads to inconsistencies in definition and methods of counting, be it students enrolled, degrees granted, or scientists and engineers employed. There has been no attempt to reconcile these differences. If estimates differ, this document reports the range and cites the sources. Where systematic differences exist that render one source preferable to another, that source has been used.

The main sources of primary data on scientists and engineers are the National Science Foundation (NSF), Department of Education% National Center for Statistics (NCS), the National Research Council (NRC), the Bureau of Labor Statistics (BLS), the Bureau of the Census, and professional societies. For degree data, NCS provides the only time series at the bachelor% and master% levels; NSF reorganizes these data for reporting purposes. At the doctorate level, the most reliable data are collected by NRC. NSF data begin in 1960; some NRC data go as far back as the 1920s.

Definitions

Some definitions are in order. Foreign nationals can be broken down into those on temporary and those on permanent visas. The latter are equivalent in status to U.S. citizens, and few in number. Most foreign nationals are students or professionals on temporary visas. Many of these protract their stay in the United States for several years through extensions of visas as students: a minority goon to gain permanent visa status.

Minorities fall into two distinct groups. The first are those who are underrepresented in science and engineering relative to their proportion in the U.S. population. These include blacks, Hispanics, and American Indians. They have made few

or no inroads into science and engineering over the past decade. The second groups Asian-Americans, earn science and engineering degrees at a rate above the national average and represent a growing proportion of the science and engineering work force.

Even within these two minority groups, there are significant differences between men and women and among minorities of different national origin, especially among the many Asian cultures. Quantitative analysis of these differences is still limited, however, and will not be discussed in depth in this paper.

Employment

The most comprehensive estimates unemployment come from the National Science Foundation and Bureau of Labor Statistics. BLS reports employer-based data, whereas NSF uses characteristics of the employee: field of highest degree, field of primary work, and self-identification. NSF reports not only employment, unemployment, and underemployment,* but also the type of work that employed scientists and engineers do. NSF reporting generates three groups:

- the total science and engineering work force (including the employed and unemployed);
- employed scientists and engineers (about 98 percent of the total work force, as scientists and engineers have a very low unemployment rate); and
- employed scientists and engineers working in science and engineering jobs.

Discussion and data in this" report generally refer to the last group, scientists and engineers currently employed in science and engineering jobs (primarily research and

* NSF% definition of underemployment includes those who are involuntarily in non-science or engineering jobs or working part-time but seeking full-time employment. NSF adds unemployed and underemployed rates to define an "underutilized" segment of the work force. In 1986, 6.5 percent of scientists and 2.3 percent of engineers were 'underutilized. "

development (R&D) teaching, consulting, R&D management, computing, production, and inspection, according to NSF definitions). This is the active science and engineering work force.

Nearly all employed engineers, but only about three-quarters of employed scientists, are in the active science and engineering work force. For scientists, however, the proportion employed in science or engineering jobs varies widely, from over 95 percent for ocean scientists and physicists to less than 65 percent for economists. Overall, 22 percent of employed scientists are working outside of science or engineering. These people constitute a reservoir of talent. This may reflect excess supply, underutilization, changing career interests or demand that pulls scientifically-trained people into non-science jobs. It should be noted that the definition of a science or engineering job is open to liberal interpretation and subject to the vagaries of self-reporting. As a result, NSF employment data may mask people fulfilling several responsibilities, as well as those not directly working in science or engineering but using their technical training in their work.

Preliminary 1986 estimates of employment and work activity provided by NSF are used in the present profiles. NSF's Division of Science Resources Studies maintains the Scientific and Technical Personnel Data System (STPDS) to report national characteristics of the U.S. science and engineering work force in 27 fields. NSF publishes these data biennially; the 1986 data included here will be published in mid-1987. The STPDS consists of a model that projects changes in the science and engineering work force using field-specific historical growth rates. In addition, several special surveys are conducted, the results of which are used to identify significant deviations in historical growth rates among the fields and characteristics of each. Where appropriate, survey results are incorporated into the STPDS model.

Many professional societies collect extensive data on education, degrees, and employment. In some cases this supply and demand information is limited to individual

or institutional members, while in others data collection spans the entire field. Professional society data in engineering and physics, for example, are both more current and perhaps more accurate than Federal agency data. Source and data idiosyncrasies are discussed below.

Physical Sciences

Professional societies compile detailed degree and employment information in physics, chemistry, and the geosciences. American Chemical Society data correlate well with Federal sources; American Institute of Physics degree figures are consistently higher by as much as 25 percent. The earth and environmental sciences have been treated differently over time and by different sources. The American Geological Institute collects data on enrollments and degrees by subfield of geoscience.

Mathematical and Computer Sciences

Computer science is still closely linked in theory and tools of research to the older field of mathematics. Before 1980, combining data into a single reporting category, as **NRC** has done for research support, may provide a more accurate picture of supply and demand characteristics than do the separate accounts used today.

Reliable data on the separate field of computer science begins around 1980. Data on computer science degrees are uncertain and inconsistent, principally because the relative youth of the field means that most practitioners earned their highest degree in some other field. In addition, there are discrepancies in categorizing mathematics, computer theory, computer and information science, and electrical/computer engineering degrees.

Estimates of the computer science labor force are only slightly better than educated guesses. There is no accepted definition of a computer scientist. NSF and BLS each report about **450,000** in the occupational category 'computer specialists," although

their estimates are based on independent definitions and data. NSF “computer specialists" include self-identified computer and systems analysts as well as computer scientists. Consequently, these estimates significantly overstate the actual number of computer scientists, as the bulk of "computer specialists" are systems analysts. There are no hard and fast rules for distinguishing between someone who uses and maintains computer systems and a computer scientist, or between a senior programmer and a systems analyst. Computer programmers and operators are reported separately. NSF is revising its definition of computer scientist.

The National Research Council reports the 1985 computer science Ph.D. labor force — those who have received doctorates in computer science — to be 3,100 strong. However, the number of Ph.D.s working in computer science is much larger, 13,500 in 1985 (NRC, unpublished data) because so many scientists and engineers with Ph.D.s in other fields have migrated into the young and booming field of computer science.

The Computer Science Board, consisting of the chairmen of university computer science departments, has sponsored surveys of academic computer science and engineering research and graduate education since the early 1970s. Similarly, the American Mathematical Society annually collects data on mathematics faculty, employment, graduate enrollments, doctorate awards, and research and education support. The Conference Board on the Mathematical Sciences, an umbrella organization, also undertakes special data collection and analysis with outside project support.

Life Sciences

Data problems are particularly vexing in the life sciences. A consistent taxonomy of fields does not exist. The NSF’S employment and activity estimates of life scientists do not permit easy comparison with its data on life science doctorate degrees. NRC’s classification of life science Ph.D. fields differs from the NSF classification. Many of the Ph.D. specialties have no common undergraduate program base, making it difficult to track undergraduate and graduate degree trends.

This lack of consistency is unfortunate. The life sciences constitute a large field: one in five of all scientists in science and engineering positions in 1986 are life scientists. In addition, the life sciences receive large amounts of Federal R&D funds. Of the more than $5 billion in Federal obligations to universities for R&D in 1983, the life sciences received over half, most of which was awarded by the National Institutes of Health (NIH). Lastly, the life sciences as research fields are considered to be especially robust with theoretical and empirical developments emerging at a fast pace.

The profiles of the life sciences presented here have been structured to be consistent with the work force and activity classification system used by the National Science Foundation. NSF divides the life sciences into three groups — biological sciences, agricultural sciences, and medical sciences. Several implications of this should be noted. The medical sciences include research specialties and work activities in the health and medical fields not directly involved inpatient care. The agricultural sciences do not count agricultural economics, which is considered a social science when NSF reports doctorate data. Lastly, in order to be more or less consistent with NSF% work force estimates, we consider in this paper certain Ph.D. degree specialties included as biological sciences by NRC as medical/health specialties.

A related but different approach developed by the Committee on National Needs for Biomedical and Behavioral Research Personnel of the Institute of Medicine deserves mention. Responsible for making recommendations concerning the allocation of training awards under the provisions of the National Research Service Awards Act of 1984 (Public Law 93-348 as amended), the Committee produces a well-respected biennial report that addresses the need for biomedical and behavioral research personnel, the specialties requiring additional personnel, and the kind of training required. The Committee analyzes trends and makes its training recommendations using a field classification that organizes doctorate specialties into clinical science, basic biomedical science, behavioral science, health services research, and nursing research. In doing so, the Committee has assembled enrollment, degree, training, and employment data covering a 20-year period.

Finally, the Committee has devised novel methodologies for examining the supply and demand issues associated with these fields. It provides important information concerning the outlook for psychologists who constitute the core of its broad field, ‘behavioral sciences." The Committee’s analysis of the basic biomedical sciences is an important contribution to understanding the dynamics operating in research specialties of primary concern to NIH.

Social and Behavioral Sciences

Comparing degree and employment data turns on what counts as asocial science. Although economics and psychology are the largest subfields and are typically reported separately within the broad category of "social sciences,” fields such as "urbanstudies" or "history" **are** arbitrarily included or excluded by data-collection organizations. The criteria used by NSF and BLS to estimate employment yield predictable disagreements. A psychologist employed as a computer scientist is, according to BLS, a computer scientist. NSF will count that same person as a psychologist if he or she holds a psychology degree and identifies himself or herself as a psychologist. Another data source is the American Psychological Association, which collects extensive data on the employment characteristics of its members.

Engineering

Accurate estimates of the size of the work force, or the proportions in different engineering specialties, are difficult to come by. BLS and NSF data on the engineering work force have consistently diverged, with BLS estimates historically higher than NSF's. In recent years, this pattern has been reversed. A related problem exists with engineering technology and technician degrees. NCS reports 4-year technology degrees separately; the Engineering Manpower Commission (EMC) of the American Association of Engineering Societies provides more current reports on Bachelor of Technology and

engineering bachelor% degrees. Associate degrees are reported by both NCS and EMC, but the numbers do not match. The American Electronics Association, an industry organization, does occasional data collection and projections of employment trends in electrical engineering based on employer estimates.

PHYSICAL SCIENCES

The physical sciences encompass physics and astronomy, chemistry, and the earth and environmental sciences. These fields are more different than they are alike in where scientists are employed, the work they do, and the factors driving the demand for new researchers. Research physicists and astronomers depend primarily upon Federal research and development (R&D) support funneled into universities and national laboratories. In chemistry, basic university research is overshadowed by industrial R&D, which employs large numbers of R&D chemists at all degree levels, particularly Ph.D.s. Environmental sciences (comprised of earth, atmospheric, and ocean science specialties) is a small field, with a core of geologists dependent upon the economic health of the oil and mining industries and a collection of interdisciplinary researchers responding to environmental R&D priorities.

Generally, undergraduate degrees in the physical sciences have risen slowly but steadily since 1975. Graduate enrollments declined rapidly in the early 1970s, stabilized through the late 1970s and early 1980s, and have increased slightly but steadily since 1982. There is a risk of oversimplifying career patterns of physical scientists, yet there are two primary paths: physical scientists at the doctoral level are employed primarily in research and teaching, and baccalaureate and master% graduates are employed in a variety of jobs and fields. Young scientists respond both to the employment market of a field and the more volatile demand for particular specialties and skills. Growth in graduate enrollments and the number of Ph.D.s conferred, especially in physics, is due almost solely to increases in foreign students.

A continuing oversupply of physicists relative to physics research opportunities has made a Ph.D. and several years of postdoctoral experience necessary preparation for a research career. Students have continued to enter physics despite the dearth of research opportunities, perhaps because of the proven ability of bachelor’s and Ph.D. physicists to

move into other science and engineering fields. Astronomy is a small, university-based, basic research field, with near-total dependence on Federal support, but a theoretically challenging science that attracts many good students. In 1975, the astronomy community began discouraging entry of students into the field and diversifying graduate training to increase the job mobility of new astronomers.

Industrial and academic demand for research chemists has been relatively stable, with increasing emphasis on a graduate education for an industrial R&D position. The preferred entry level degree for earth scientists is the master%; there is smaller demand for basic researchers in this field. Many earth scientists are employed in the petroleum and mining industries, which are buffeted by business cycles and resource policies.

Physics and chemistry students prolong postdoctoral appointments during periods of sluggish demand. Unemployment is low among Ph.D. physical scientists, higher for recent bachelor% and master's graduates. Within each of these fields, however, shortages and surpluses occur for specific research specialties. Thus, there are current surpluses of new graduates in particle physics and petroleum geology, and at the same time shortages in optical physics and geochemistry. In some instances, there is a continuing mismatch between supply and demand, as in the continuing overproduction of particle physicists and theoretical physicists relative to research opportunities; other mismatches are transitory, such as the cyclical demand for geologists in oil industry exploration and R&D.

Women and non-Asian minorities are consistently underrepresented in the physical sciences. They receive only a small share of graduate degrees, particularly in physics, and an even smaller share of faculty positions.

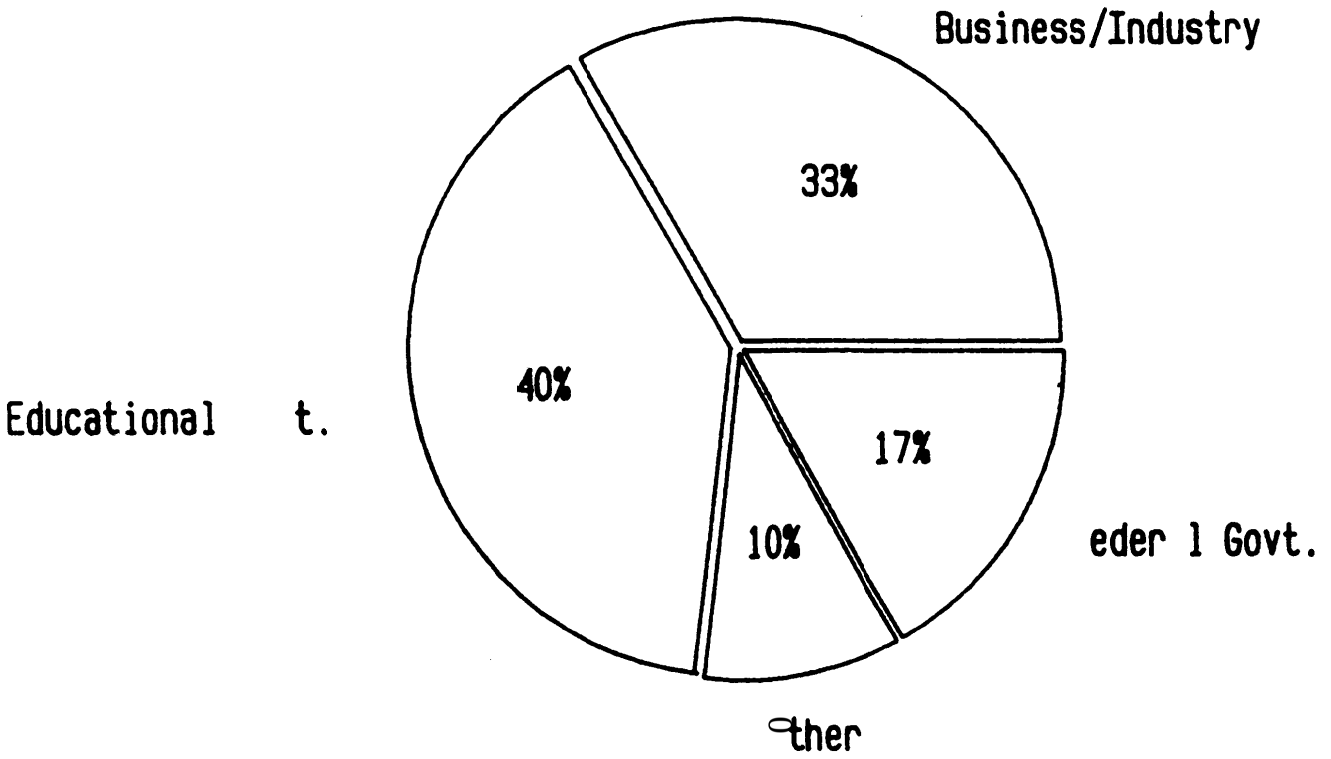
PHYSICS AND ASTRONOMY

Employment

- There are 40,000 to 70,000 employed physicists and astronomers in the United States.[1] The vast majority are employed in science and engineering (S/E) positions. These figures include astronomers, who represent about 10 percent of the total.
- Of physicists and astronomers working in S/E positions, most are employed by educational institutions, lesser proportions by industry and the Federal Government.[2]
- The primary work activity of physicists and astronomers employed in S/E is research and development; almost one-half of these are doing basic research. Another one-quarter are in various management positions and about 20 percent are engaged primarily in teaching.[3]
- There is a surplus of Ph.D. physicists relative to the number of physics research slots* This surplus is highly mobile and employable; more physics Ph.D.s are working in other fields than is true for any other science.
- of employed Ph.D. physicists, one-half work in academia. The rest are divided almost equally between industry and government (including national laboratories).[4]

1. Estimates of employed physicists and astronomers vary widely. For example, in 1985 the Bureau of Labor Statistics reported 40,000, which included 13,000 teachers. The National Science Foundation% preliminary 1986 estimate is 70,800. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Table B-1, unpublished data.
2. Ibid., Table B-13.
3. Ibid.
4. National Science Foundation, Characteristics of Doctoral Scientists and Engineers in the United States: 1983, NSF 85-303 (Washington, DC: 1985), p. 19,–Table B-5.

Where Physicists* Work, 1986



*ALL DEGREES

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Education and Supply

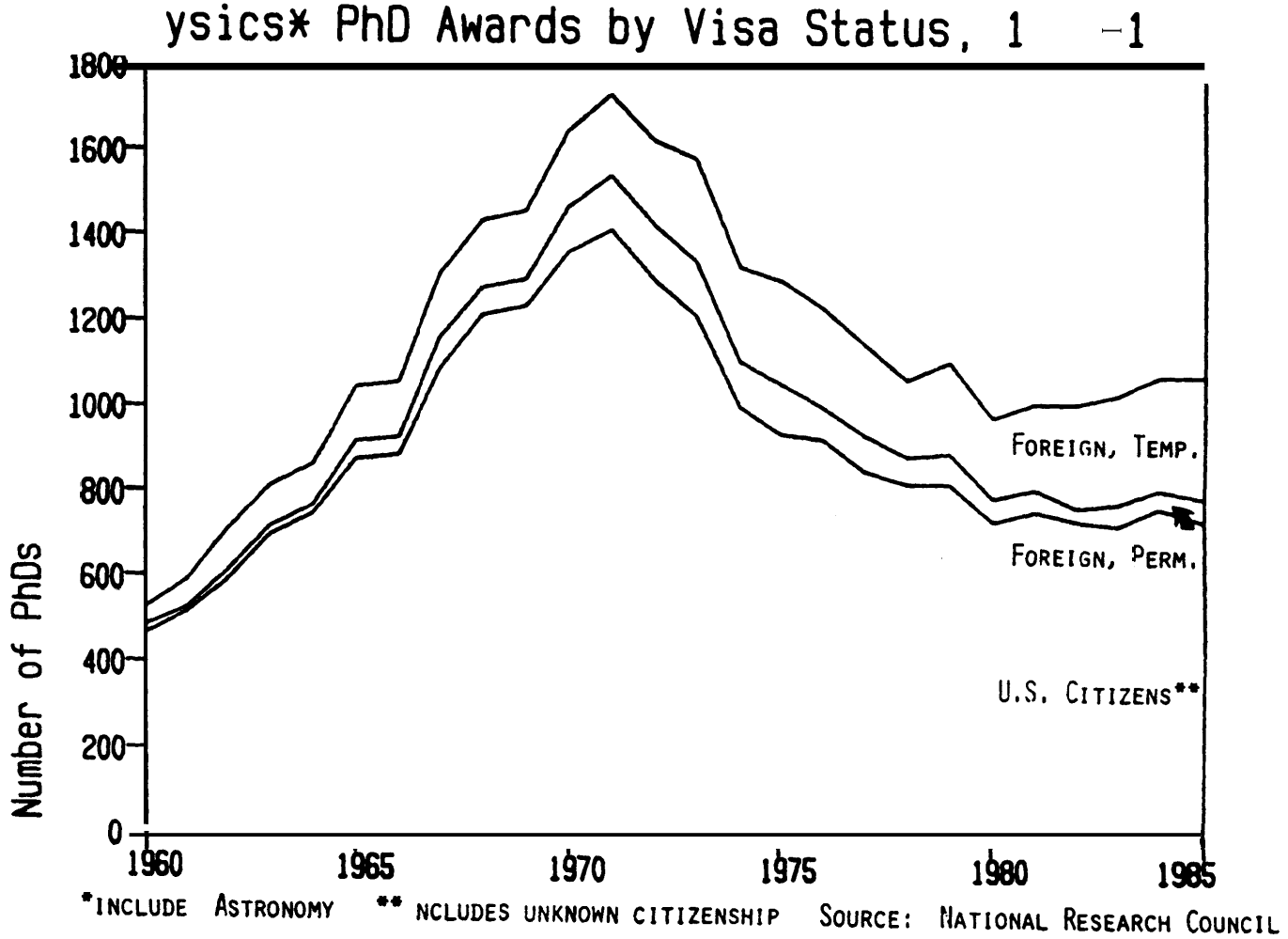
- The number of baccalaureate physics awards dropped rapidly through the 1970s, but has turned around and increased steadily since 1980. A smaller proportion are going on to graduate study; about one-half of baccalaureate physicists continue with some kind of graduate study, down from 60 percent 10 years ago. However, the decline is due to those changing fields; one-third of physics bachelors' continue with physics graduate study.[5]
- Graduate enrollments in physics have increased slowly and steadily in the 1980s. However, the increases are solely due to increases in foreign students; the number of U.S.-born physics graduate students has been stable since 1980.[6]
- Solid state, elementary particle, and nuclear physics are the leading specialties, but optics, medical physics, and plasma physics are expanding. Increasing attention to industry and government-related studies in graduate education has bolstered interdisciplinary study, particularly with engineering.
- Many physics graduate students take terminal master's degrees. Among those who earn a Ph.D., almost half accept postdoctoral appointments. This largely reflects the poor job market for physicists over the past decade.

Foreign Nationals, Women, and Minorities

- The presence of foreign nationals in physics has increased rapidly since the mid-1970s. Twenty-seven percent of physics Ph.D.s were awarded to foreign students on temporary visas in 1985, an additional 3 percent to those on permanent visas. Over one-third of currently enrolled physics graduate students are foreign nationals[7] Among the sciences, physics has a high proportion of foreign nationals

5. National Research Council, Physics Survey Committee, Physics Through the 1990s: An Overview (Washington, DC: National Academy Press, 1986), p. 110.

6. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, NSF 85-300 (Washington, DC: 1985), pp. 104, 130-31, tables C-6, C-27, C-28, and unpublished NSF data on 1984 and 1985 enrollments.


ysics* PhD Awards by Visa Status, 1 -1
Number of PhDs
1800
1600
1400
1200
1000
800
600
400
200
0
1960
1965
1970
1975
1980
1985
FOREIGN, TEMP.
FOREIGN, PERM.
U.S. CITIZENS**
*INCLUDE ASTRONOMY ** NCLUDES UNKNOWN CITIZENSHIP SOURCE: NATIONAL RESEARCH COUNCIL

among employed Ph.D.s — nearly 8 percent.[8]

- Women are still scarce in physics. Their participation is the lowest of all sciences, at all degree levels. Between 1980 and 1985, women received just over 7 percent of the physics Ph.D.s awarded.
- Blacks and Hispanics combined are 3 percent of employed Ph.D. physicists; Asians represent 9 percent. In the past 10 years, Asian-Americans have received seven times as many physics Ph.D.s as blacks and five times as many Hispanics. Although U.S. citizens, many of these Asian-Americans are foreign-born.

Astronomy

- There is a continuing oversupply of astronomers; research jobs are severely limited. Over half of Ph.D. astronomers work in Ph.D.-producing universities, many as non-faculty researchers and postdoctorates; many of the rest work in government.

7. Ibid.
8. National Science Foundation, Characteristics of Doctoral Scientists and Engineers in the United States: 1983, op. cit., p. 12, Table B-3.

CHEMISTRY

Employment

- The chemistry work force is large and heavily industrial. Chemistry is second only to the biological sciences in number of researchers.
- There are between 129,000 and 195,000 chemists employed in the United States, most in S/E positions. Over two-thirds of S/E chemists are employed in industry, about 20 percent in academia and over 10 percent in Federal, State and local government.[9]
- Over one-third of the S/E employed chemists are engaged in R&D. Another 25 percent are in management positions and 14 percent in teaching.[10]
- The demand for chemists is driven in great part by industry. Industry conducts a significant amount of chemistry research; about 25 percent of the basic research community works in industry. The chemical industry employs the highest proportion of Ph.D.s of any industry.
- Of employed chemists, one-quarter hold the Ph.D. and the master's, respectively. The terminal degree of the rest is the bachelor%. There is no shortage of chemists. Chemistry is a flexible discipline; when one segrnent of the industry is in a downturn, chemists find related jobs. Chemists are relatively mobile; in 1983, 'one in three Ph.D. chemists were employed in other fields, compared to one in five computer science and two in five physics/astronomy Ph.D.s.[11]

9. In 1985, the Bureau of Labor Statistics reported 129,000 chemists, including 18,000 teachers. The Census Bureau estimated 110,620 chemists in 1980. The National Science Foundation% preliminary 1986 estimate is 195,200. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Table B-l, unpublished data.
10. Ibid., Table B-13.
11. National Research Council, Office of Scientific and Engineering Personnel, Science, Engineering and Humanities Doctorates in the United States: 1983 Profile (Washington, DC: National Academy Press, 1985), p. 18, Table 2-2.

- Technicians are particularly important to chemistry R&D and production, but little is known about them. Some have a bachelor% in chemistry and many enter the market with 2-year associate degrees. The chemical industry employs around 40,000 chemical technicians; perhaps another 20,000 are employed in other manufacturing industries. [12]

Education

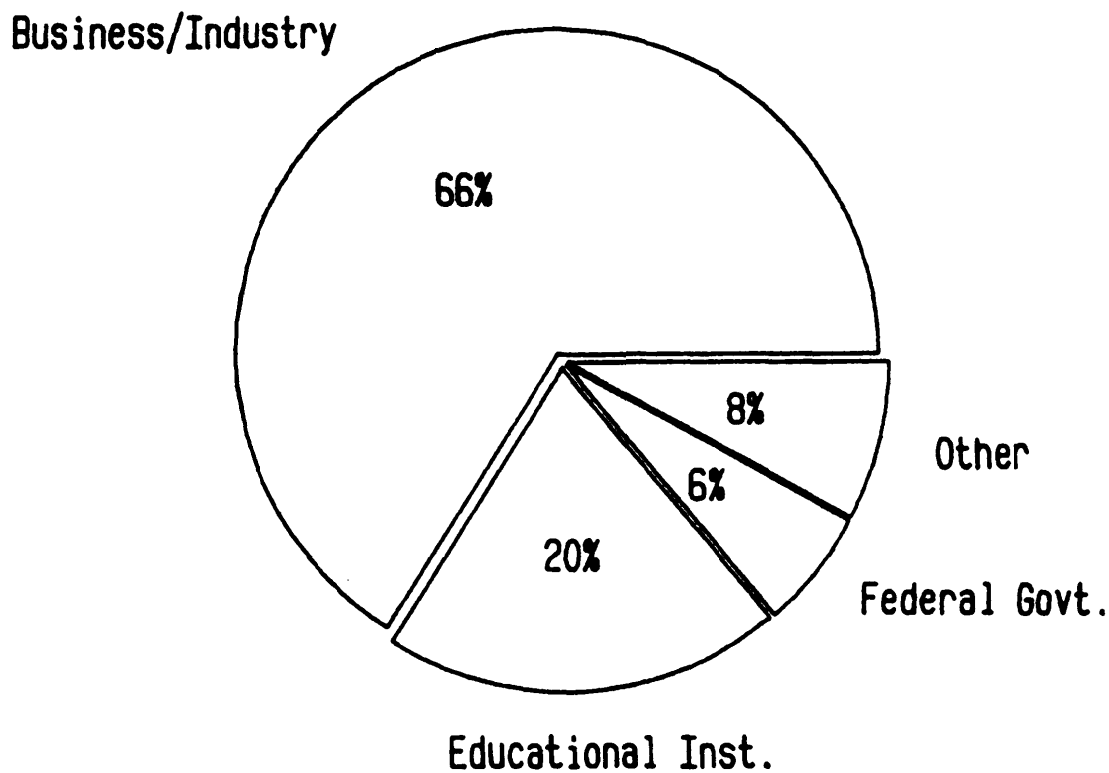
- Increasingly, a Ph.D. is the accepted qualification not only for academic employment in chemistry, but for industrial employment as well. About 1,800 Ph.D.s are awarded annually in chemistry.
- About 11,000 students get a bachelor% degree in chemistry each year. Fewer than 2,000 of these students go on for a Ph.D.; another 1,000 get a master%. The average time to Ph.D. for 1984 chemistry Ph.D.s was slightly over 6 years since the bachelor%, the fastest of all fields.
- One or more years of postdoctoral research is accepted preparation for an academic research career. Almost one-half of new Ph.D.s goon to a postdoctoral appointment. [13]

Foreign Nationals

- The number of foreign graduate students in chemistry is rising slowly, although it is not as high as in physics and engineering. In 1985, nearly one in five of the Ph.D.s awarded went to foreign nationals on temporary visas; an additional 5 percent went to foreign nationals on permanent visas.

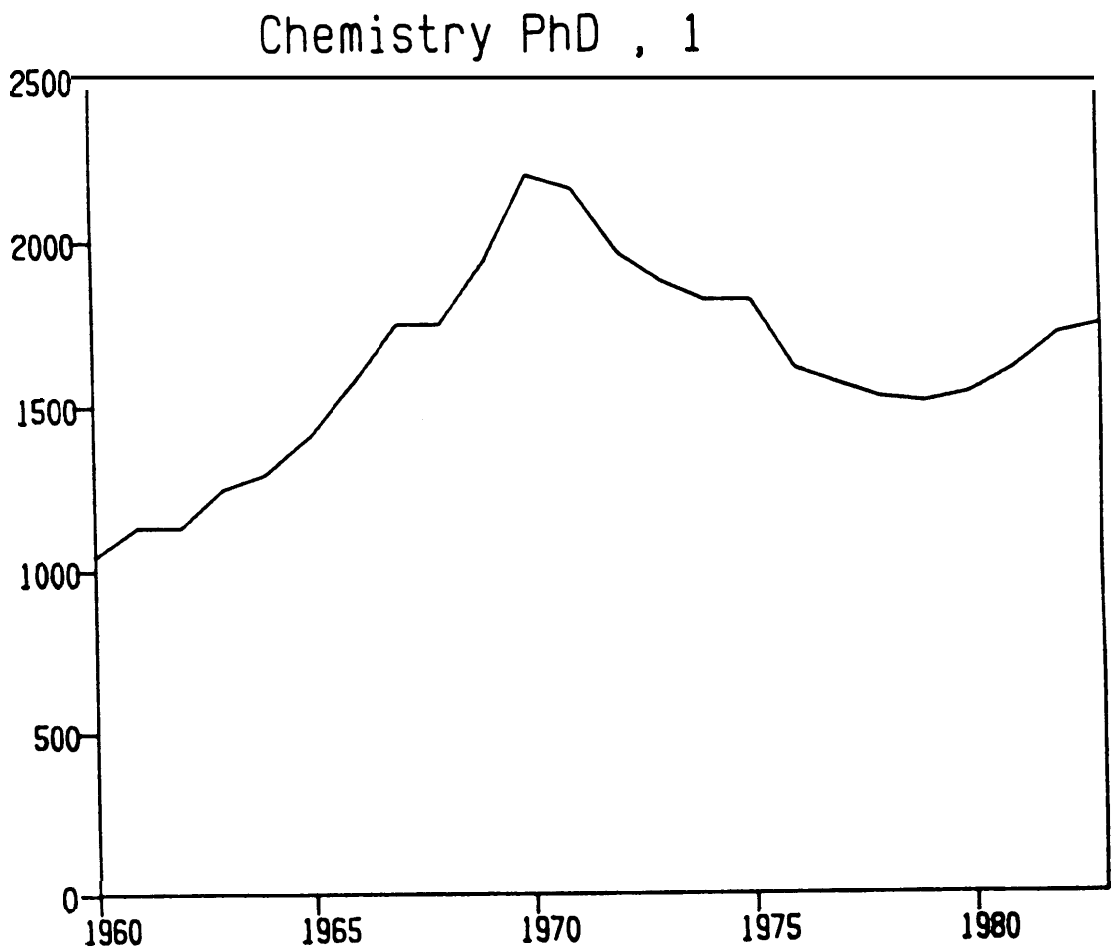
12. National Science Foundation, Scientists, Engineers, and Technicians in Manufacturing Industries: 1983, NSF 85-328 (Washington, DC: 1985), p. 23, Table D-2.
13. National Research Council, Office of Scientific and Engineering Personnel, Doctorate Recipients from United States Universities: Summary Report 1984 (Washington, DC: National Academy Press, 1986), p.34, Table 2.

Where Chemists* W 1986



*ALL DEGREES

SOURCE: NATIONAL SCIENCE FOUNDATION



SOURCE: NATIONAL RESEARCH COUNCIL

- More foreign students are staying in the United States after receiving their doctorate. Three in five on temporary visas enter postdoctoral research, with only 5 percent going directly into industry.

Women and Minorities

- Women have made slow but steady progress in chemistry at all degree levels. The proportion of chemistry Ph.D.s earned by women has doubled in 10 years, from 10 percent in 1975 to nearly 20 percent in 1985.
- Women are 13 percent of employed chemists (up from 6 percent a decade ago), but over one-quarter of unemployed chemists seeking work. Women chemists in academia are more likely to be in junior positions, untenured, and more than twice as likely to be working part time.
- Blacks and Hispanics have made no gains in chemistry in the past IO years. Blacks receive fewer than 2 percent of chemistry Ph.D.s, and barely more than 2 percent of bachelor's degrees. In comparison, Asian-Americans earned 6 percent of the chemistry Ph.D.s in 1985, up from 1 percent in 1975.

EARTH AND ENVIRONMENTAL SCIENCES

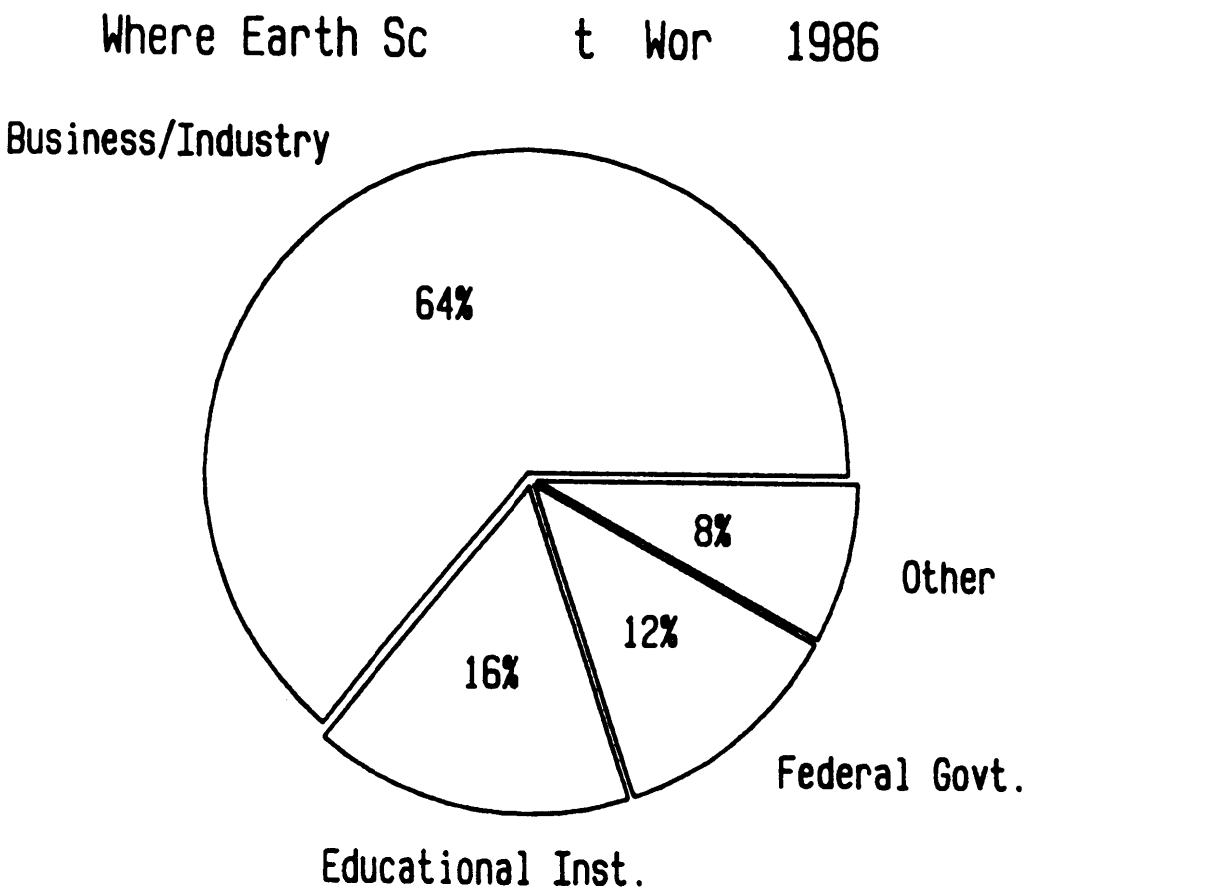
Overview

- The earth and environmental sciences encompass marine and atmospheric sciences in addition to the traditional core of geological sciences and geophysics. The field is small and interdisciplinary.
- Demand is especially unpredictable in the earth sciences. Expansion through the mid-1970s was halted by the OPEC-triggered recession. In 1981, 60 percent of companies reported a shortage of petroleum engineers; 2 years later, the shortage was down to 20 percent.[14] There is currently no shortage.
- There is a surplus of bachelor% and master% earth scientists who began their education just before the current downturn in the petroleum and mining industries curtailed exploration and surveying. Government employment is more stable, but modest. The academic market is poor.

Employment

- There are between 60,000 and 112,500 earth and environmental scientists employed in the United States.[15] With 90 percent in science and engineering (S/E) positions. Of these, earth scientists outnumber atmospheric scientists and oceanographers combined 4 to 1.[16]

14. Basedon 1981-85 tabulationsof the Rapid Industry Limited Response Survey Panel on Science/Engineering Personnel Resources, reported in Joel Barriers, "Shortages Increase for Engineering Personnel in Industry," Highlights, NSF 85-309 (Washington, DC: March 29, 1985).
15. In 1985, the Bureau of Labor Statistics reported 63,000, which included 58,000 geoscientists plus 5,000 earth, environmental and marine science teachers. The National Science Foundation% preliminary 1986 estimate is 112,500 employed in the U.S. work force. This includes 94,300 earth scientists, 14,400 atmospheric scientists, and 3,700 oceanographers. National Science Foundation, Science Resources Studies Division, op. cit., Table B-1.
16. Ibid., Table B-13.



*ALL DEGREES

SOURCE NATIONAL FOUNDATION

- Of the 86,000 earth scientists estimated to be employed in S/E positions in 1986, two-thirds are employed in industry, while the rest distribute almost equally between academia and the Federal Government.[17]
- One-third of the S/E employed earth scientists are engaged in research and development, one quarter are in production activities, less than one-fifth in management. Less than 10 percent are estimated to be primarily engaged in teaching. [18]
- Earth and environmental science Ph.D.s exhibit the lowest mobility of all science and engineering doctorate holders. In 1983, only one in five was employed outside, his/her specialty.[19] In 1985, however, less than 1 percent of Ph.D. earth and environmental scientists were unemployed and seeking jobs.[20]

Education

- The master's, and to a lesser extent the bachelor%, are entry level degrees. Earth scientists are much less likely than physicists or chemists to have a Ph.D.
- Bachelor% awards in earth science, now about 7,000 per year, have increased steadily since the mid-1960s. About 2,000 master's degrees are conferred each year.[21]
- Earth sciences Ph.D.s have fluctuated around 600-650 per year for the past 10 years, with geological sciences slightly more than half the total.[22] The production

17. Ibid.
18. [bid.
19. National Research Council, Office of Scientific and Engineering Personnel, Science, Engineering and Humanities Doctorates in the United States: 1983 Profile, op. cit., p. 18, Table 2-2.
20. National Research Council, Office of Scientific and Engineering Personnel, unpublished data from the seventh (1985) biennial survey of U.S. doctorate recipients.
21. Earth sciences degree data based on surveys conducted by the American Geological Institute, cited in Manpower Comments, vol. 23, No. 5, June 1986, p. 18.
22. National Science Foundation, Science and Engineering Doctorates: 1960-82, NSF 83-328 (Washington, DC: no date), p. 17, Table 1. Data for 1983-85 from National Research Council, Office of Scientific and Engineering Personnel, Doctorate Recipients from United States Universities, op. cit.

of Ph.D.s rose steadily through the 1960s and plateaued in the early 1970s. Recent graduate enrollments have declined, probably in response to the poor job market.

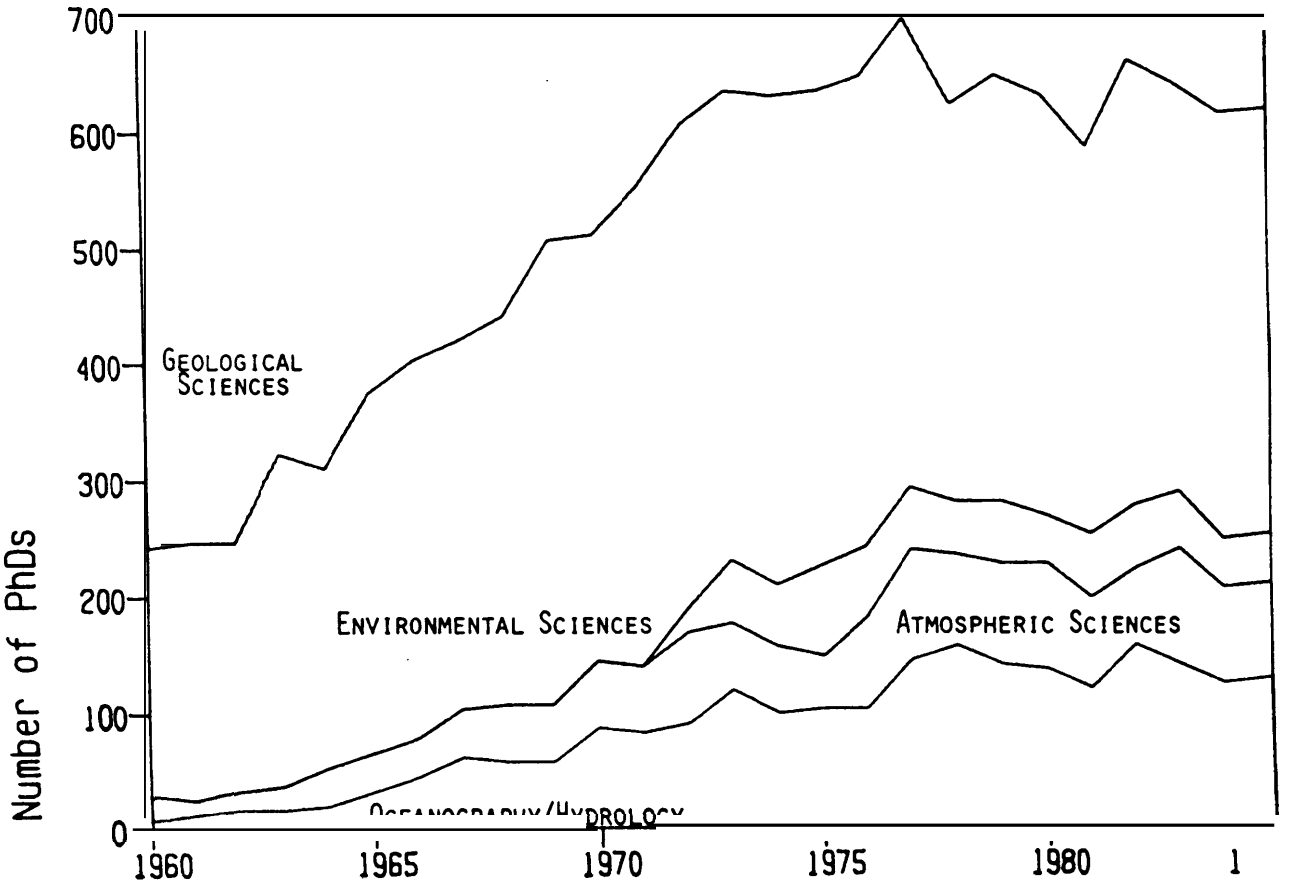
Women, Minorities, and Foreign Nationals

- The number of female earth scientists has increased rapidly since 1970, but there are still relatively few among professional ranks. Women earn about me-quarter of bachelor% and master% earth science degrees, and almost one-fifth the Ph.D.s awarded. However, they are still only 6 percent of employed Ph.D. earth scientists and at best 10 percent of all such scientists.[23]
- Minorities have not made inroads into the earth sciences. Blacks are less than 1 percent of employed earth scientists, Hispanics and Asians about 2 percent each.[24] Earth sciences attract fewer Asians than do other sciences. Among recent earth science Ph.D.s, 0.5 percent are black, 1 percent Hispanic, and 3-5 percent Asian-American.[25]
- The earth sciences attract fewer foreign students than other physical sciences; even so, one in five 1985 Ph.D.s were foreign students on temporary visas.[26] The proportion of foreign nationals in earth and environmental science graduate

23. National Science Foundation, "U.S. Scientists and Engineers: 1984", unpublished data, 1984, p. 100, Table B-9; and National Science Foundation, Science and Engineering Personnel: A National Overview, NSF 85-302 (Washington, DC: 1985), p. 116, Table B-12b.
24. National Science Foundation, U.S. Scientists and Engineers: 1984, op. cit., p. 53, Table B-5.
25. National Research Council, Office of Scientific and Engineering Personnel, 'Doctorate Recipients from United States Universities: Summary Report 1985," unpublished data.
26. Ibid.; data for 1985 are unpublished.

programs increased slightly between 1980 and 1985. In 1985, foreign nationals represented about 15 percent of full-time earth and environmental graduate students.[27]

27. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support: Fall 1983, **op.cit.,** p. 102, Table C-5; and National Science Foundation, Division of Science Resources Studies, Science and Engineering Education Sector Studies Group, 'Selected Data on Graduate Science/Engineering Students and Postdoctorates by Citizenship," unpublished data, October 1986, Tables B-13 and B14.



SOURCE: NATIONAL RESEARCH COUNCIL

MATHEMATICAL AND COMPUTER SCIENCES

The mathematical and computer sciences are a union of old and new that is altering both fields. Computer science is a young and interdisciplinary field with theoretical roots in mathematics and close ties to engineering. Computer science emerged from mathematical computer theory during the 1960s. Research in the two fields is intimately connected. For this reason, they are profiled in a section of their own.

Mathematics is closely tied to advances in computer theory and applications. In turn, high-speed computer graphics and numerical analysis have spurred new advances and directions in mathematical research. Because of close ties in research, theory, and financial support, it is difficult to separate data and analysis of degrees, the work force, and financial support in the two fields. For example, the 15-year decline in mathematical degrees has been accompanied by an increase in computer science degrees.

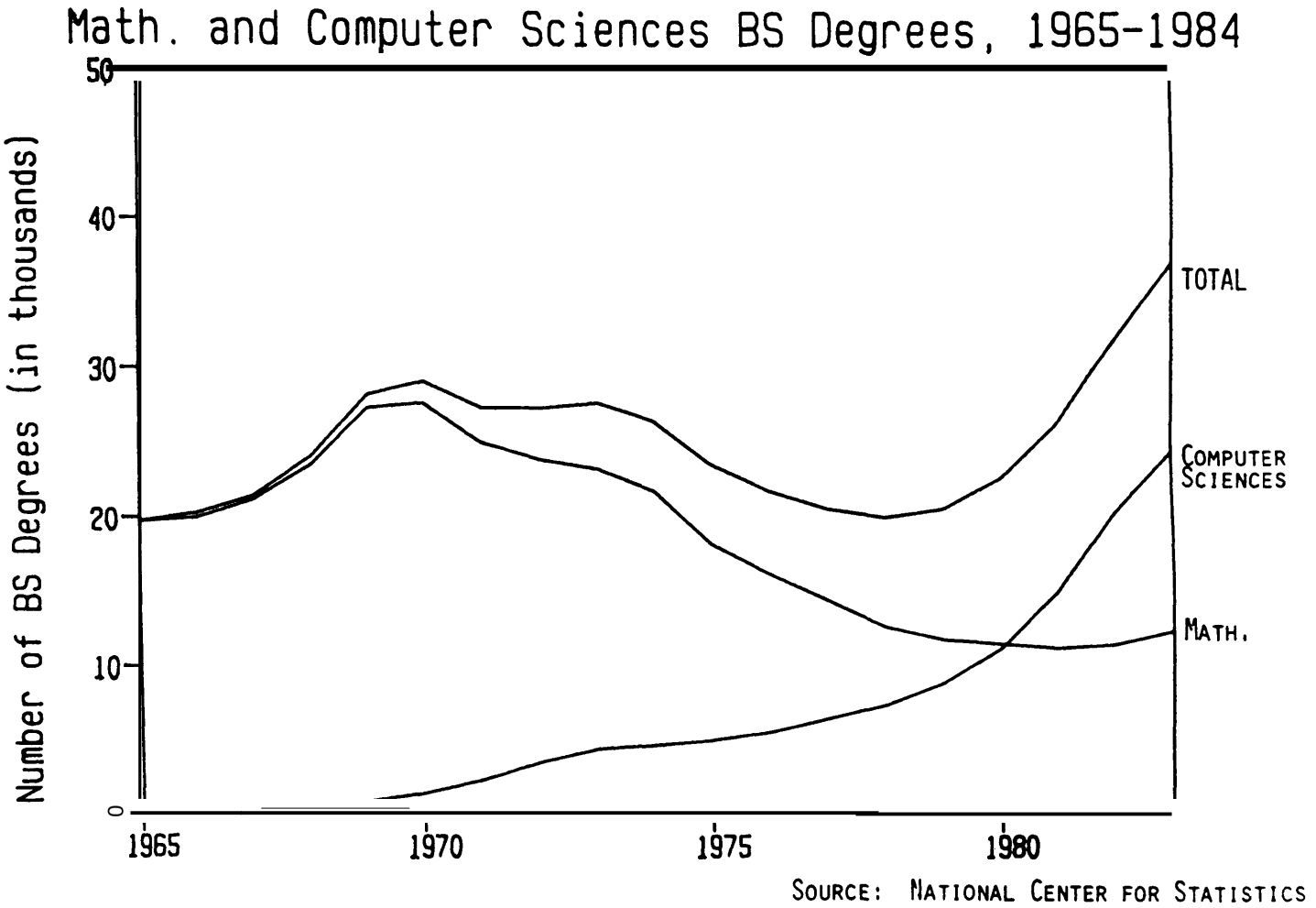
In addition, much of industry demand for computer scientists has been interchangeable with demand for electrical engineers. Data and trends in computer science are related to computer engineering, the fastest growing engineering specialty.

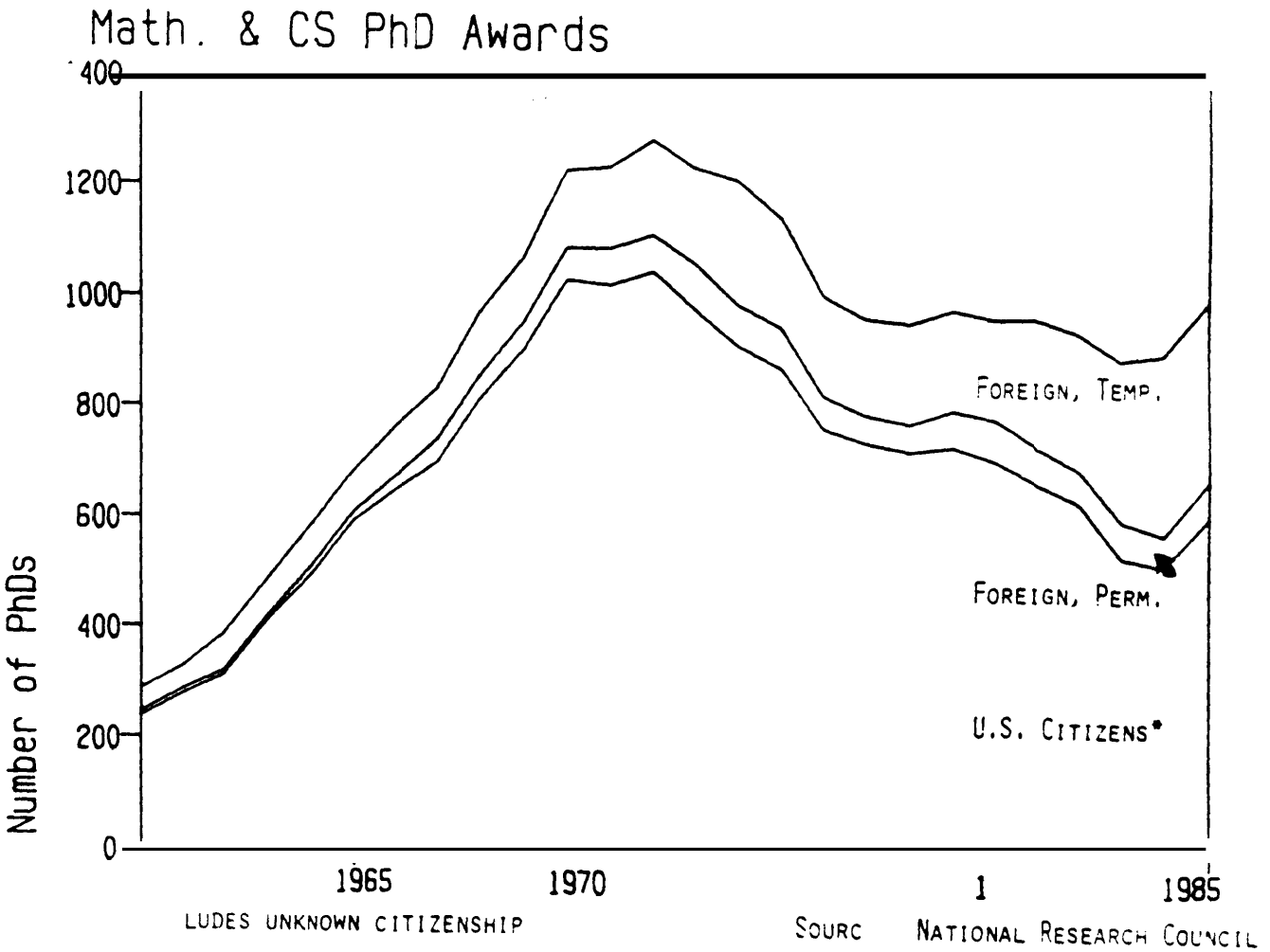
In 1984, the David Report argued vigorously for increased Federal support of mathematical research as a resource to other fields.[28] The recent Griffiths Report on the mathematical sciences reinforces this view:

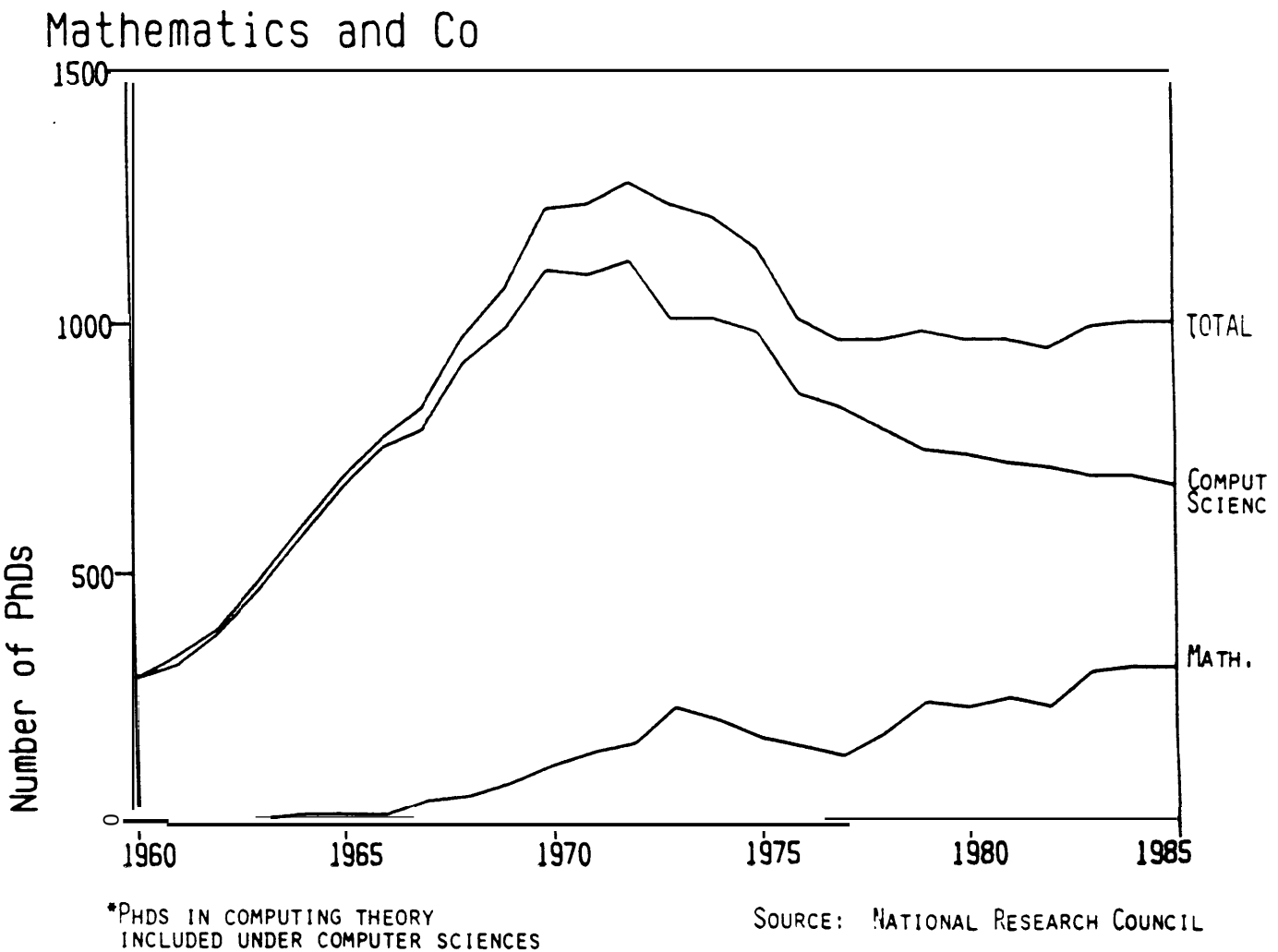
> Mathematics is the underpinning of revolutionary changes taking place in all scientific and engineering fields as a result of the advent of powerful computers. The development of scientific computing has not only highlighted a host of critical new mathematical matical problems, it has introduced new tools for mathematicians.[29]

28. National Research Council, Renewing U.S. Mathematics: Critical Resource for the Future (Washington, DC: National Academy Press, 1984).
29. National Research Council, Panel on Mathematical Sciences, Mathematical Sciences: A Unifying and Dynamic Resource (Washington, DC: National Academy Press, 1986), p. 5.

For these reasons alone, education and employment in the mathematical and computer sciences are seen as especially vital to the future health of U.S. science and technology.


Math. and Computer Sciences BS Degrees, 1965-1984
Number of BS Degrees (in thousands)
50
40
30
20
10
0
1965
1970
1975
1980
TOTAL
COMPUTER SCIENCES
MATH.
SOURCE: NATIONAL CENTER FOR STATISTICS


Math. & CS PhD Awards
400
1200
1000
800
600
400
200
0
Number of PhDs
1965
1970
1985
FOREIGN, TEMP.
FOREIGN, PERM.
U.S. CITIZENS*
LUDES UNKNOWN CITIZENSHIP
SOURC NATIONAL RESEARCH COUNCIL



*PHDS IN COMPUTING THEORY INCLUDED UNDER COMPUTER SCIENCES

SOURCE: NATIONAL RESEARCH COUNCIL

MATHEMATICAL SCIENCES

Employment/Demand

- ***In*** 1986, there are estimated to be 116,400 mathematicians and statisticians employed in the United States. Ninety percent are employed in science and engineering (S/E) positions, with one-third working in industry, one-half in academia, and most others in the Federal Government.[30]
- The basic research community in the mathematical sciences numbers between 4,000 and 7,000, representing over 90 percent of the mathematics college and university faculty.[31] Research in applied mathematics and Statistics Often extends to problems in other fields such as engineering, computer science, optics, and biology.
- Mathematicians are the most likely of all doctorate scientists to be academically employed. In 1986, one-half of all mathematicians are estimated to be working principally in teaching. Based on the 1985 the National Research Council survey, three out of four Ph.D. mathematicians are employed in educational institutions.[32] Ph.D. statisticians, however, are less likely to work in academia. Mathematicians have the highest tenure rate of all scientists, 70 percent.

Education/Supply

- Ph.D. awards in mathematics peaked in 1970 (at 1,236), sharing in the across-the-board proliferation in science funding and enrollment during the 1960s.[33] These

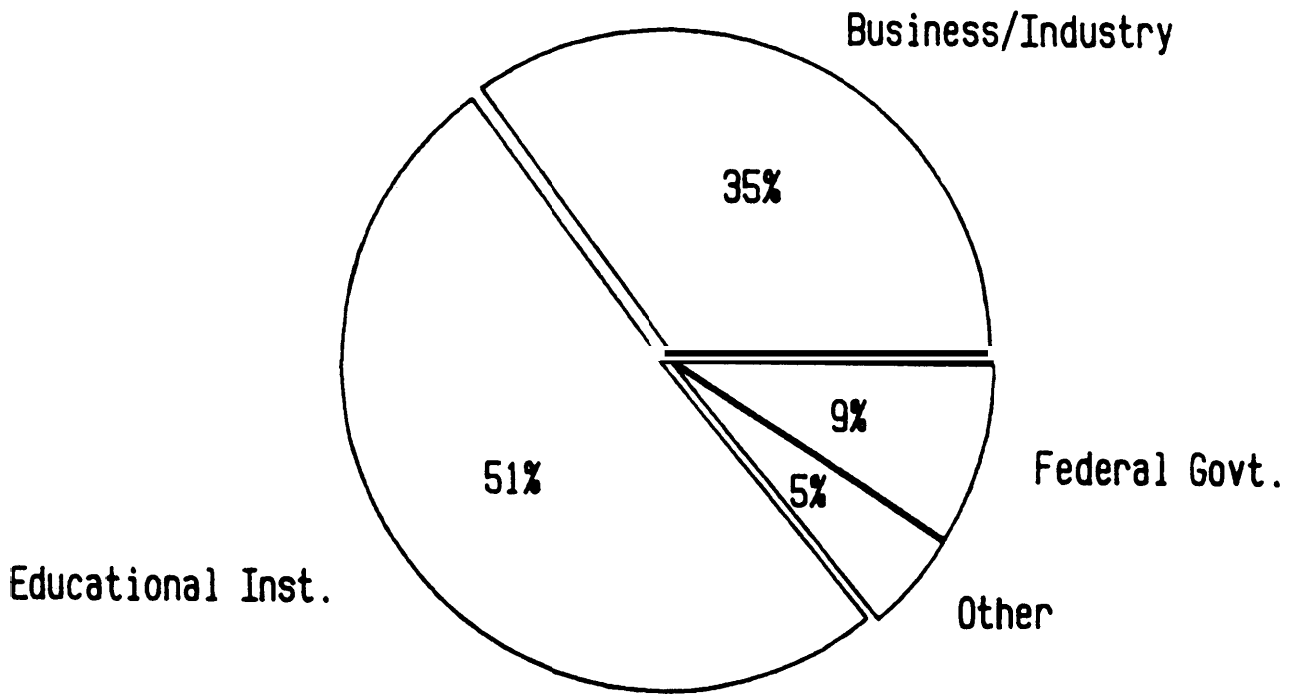
30. National Science Foundation, Division of Science Resources Studies, preliminary 1986 estimates, unpublished data, Tables B-land B-13.
31. National Research Council, Panelon Mathematical Sciences, op. cit., p. 34.
32. National Research Council, Office of Scientific and Engineering Personnel, unpublished data, 1985.
33. National Science Foundation, Science and Engineering Degrees: 1950-80. A Source Book, NSF 82-307 (Washington, DC': 1982), p. 49, Table 29; and National Research Council, Office of Scientific and Engineering Personnel, unpublished data, 1985.

graduates created a substantial bulge in the supply of mathematicians; while Federal support fell (in real terms) during the 1970s, the number of mathematical researchers doubled.

- Ph.D. awards dropped 41 percent between 1970 and 1980 and a further 7 percent from 1980 to 1985.[34] Surveys by the Mathematical Association of America indicate that the demand for undergraduate mathematics teaching exceeds the supply of fully qualified teachers. More undergraduates are being taught by part-time faculty.
- There are about 10,000 enrolled graduate students, but only about 700 Ph.D.s are awarded in mathematics each year. The average length of graduate study for those who do get degrees is nearly 7 years.
- In 1983, one in five math Ph.D.s planned postdoctoral study. A higher proportion of foreign students go on to a postdoctorate; in 1985 one-half of the mathematics postdoctorates were foreign nationals.[35]
- Mathematics bachelor% and master% degrees peaked in 1970 and 1969, respectively, dropped precipitously through the 1970s, and have rebounded slightly in the 1980s. Graduate enrollments have also risen slightly, though the rebound has not increased Ph.D. awards.
- It is important to look at mathematics and computer sciences degree data together, since the decline in mathematics degrees during the late 1970s was accompanied by an increase in computer science degrees. At the bachelor% level, a rapid rise in computer sciences during 1975 to 1985 masked a continuing drop in mathematics

34. Ibid.; data for 1981-84 from the National Research Council, Office of Scientific and Engineering Personnel, annual surveys of doctorate recipients from U.S. universities, 1985 unpublished data (does not include Ph.D.s in computer science).
35. National Science Foundation, Division of Science Resources Studies, "Selected Data on Graduate Science/Engineering Students and Postdoctorates by Citizenship" op. cit., Table A-24.

Where Math. Scient t Work, 1



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URCE: NATIONAL SCIENCE FOUNDATION

degrees. By 1983, bachelor% degrees had started rising and the drop in mathematics Ph.D.s had slowed.

Foreign Nationals

- The proportion of mathematics Ph.D.s awarded to non-U.S. citizens is substantial and increasing. In 1985, one in three mathematics Ph.D.s were awarded to non-U.S. citizens on temporary visas, up from one in five in 1976, Between 1980 and 1984, the number of mathematics Ph.D.s awarded to non-U.S. citizens rose 30 percent, while the total number of mathematics Ph.D.s fell.[36]
- Half as many U.S. citizens received mathematical sciences Ph.D.s in 1985 as in 1973. Of foreign mathematics Ph.D. recipients with temporary visas, perhaps one-half stay in the United States for some time. For those who had firm post-graduation plans, 60 percent planned to stay in the United States for study or work in 1982, up from 40 percent in 1972.[37]
- Over 90 percent of new foreign Ph.D.s on permanent visas stay in the United States. In 1982, 5 percent of employed mathematicians were foreign nationals and more than 10 percent were naturalized citizens.[38]

Women and Minorities

- Women have long had a significant presence in mathematics, particularly at the bachelor% level. One in five employed mathematicians is a woman.[39] Although

36. National Science Foundation, Science and Engineering Doctorates: 1960-82, op.cit., pp. 44-45, Table 2. Data for the 1981-85 period from, National Research Council, Office of Scientific and Engineering Personnel, op. cit.
37. National Science Foundation, Division of Science Resources Studies, Directorate for Scientific, Technological, and International Affairs, Foreign Citizens in U.S. Science and Engineering (Washington, DC: 1985), p. 63, Chart 3.10.
38. Oak Ridge Associated Universities, Labor and Policy Studies Program, Foreign National Scientists and Engineers in the U.S. Labor Force, 1972-1982 (Oak Ridge, TN: June 1985), p. 42, Table A-17.
39. National Science Foundation, "U.S. Scientists and Engineers: 1984, ''op. cit., p. 57, Table B-6.

over 40 percent of bachelor% degrees are awarded to women, only 30 percent of employed baccalaureate mathematicians, and less than 10 percent of employed Ph.D. mathematicians are women.[40]

- The 1984 unemployment rate for women in mathematics was 2.8 percent; for men it was 2 percent. The 1984 underemployment rate was 6.1 percent for women and 2 percent for men.
- Women receive about one-third of master's degrees in mathematics. This share has been fairly steady since the beginning of the 1970s, and was not much lower during the 1960s.
- Women receive about 15 percent of the Ph.D.s in mathematics and only recently have achieved even this level of participation. (The picture is similar in statistics.) The advance of women in the mathematical sciences seems to have plateaued during the 1980s.
- Seven blacks received mathematics Ph.D.s in 1985— about 1 percent of the mathematics Ph.D.s granted that year.[41] Blacks receive about 5 percent of bachelor% degrees in mathematics. Minority students, and to a lesser extent women, are handicapped by their lower exposure to mathematics in high school.
- Blacks represent less than 5 percent of all employed mathematicians at all degree levels. This proportion is the same for Asians, but even smaller for Hispanics. In addition, blacks and Asians are more likely to be in teaching and less likely to be in research and development.

40. National Science Foundation, Science and Engineering Degrees: 1950-80, op. cit., p. 49, Table 29; and National Science Foundation, Science and Engineering Personnel: A National Overview, op. cit., p. 115, Table B-12b.
41. National Research Council, Office of Scientific and Engineering Personnel, op. cit.

COMPUTER SCIENCE

Education/Supply

- Computer science is the fastest growing science. Between 1977 and 1985, the number of computer science graduate students rose more than 15 percent per year, from 9,000 to nearly 30,000.[42]
- In 1985, about 315 computer science Ph.D.s were awarded. Over the past 3 years, computer science Ph.D. awards have increased 5-15 percent per year, and the rate is accelerating.[43]
- Graduate students in computer science come from a wide variety of undergraduate degrees and the majority of practicing computer scientists do not have a formal degree in the area. Less than 20 percent of recent computer science Ph.D.s have a bachelor% in computer science.
- Significant in-mobility of Ph.D.s into computer science is from mathematics and physics. With a declining supply of mathematics Ph.D.s and a growing pool of computer science Ph.D.s, this influx should dwindle through the 1980s as the field matures.[44]
- More than half of computer science graduate students in 1985 were part time, by far the highest of all sciences and engineering. Computer science also has the smallest proportion of postdoctorates of any science or engineering field.

- Over 6,000 master% degrees in computer science were granted in 1984, more than doubling since 1978. But the most explosive growth in computer science has been

42. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, op. cit., p. 62, Table B-1; and unpublished data.
43. National Research Council, Office of Scientific and Engineering Personnel, annual survey of doctorate recipients in U.S. universities, unpublished data, 1985.
44. The Computer Science Board, Committee on Research Funding in Computer Science, Imbalance Between Growth and Funding in Academic Computer Science: Two Trends Colliding (April 9, 1986), pp. 8-9.

at the bachelor% level. There ‘were 32,000 bachelor% degrees awarded in 1984, compared to less than 5,000 in 1975, an annual growth rate of 20 percent. And this pace has accelerated since 1980 to 30 percent per year.[45] Many universities are limiting undergraduate computer science enrollments while expanding their faculty to meet continuing demand.[46] This trend, however, will probably not continue* Only half the number of freshmen in 1985 as in 1983 indicated plans for a computer science major.

Employment/Demand

- Just under half of recent computer science Ph.D.s work in universities and colleges, and just under half in industry research and development. Demand for computer scientists is high, particularly at the Ph.D. level where it is three or four times current production.[47]
- Ph.D. computer scientists earn the highest salaries among scientists at the same experience level. Academic salaries are also well above the average and approach those of engineering and business faculty.
- Academic demand is still high and will continue to increase, though it has eased significantly from the near-crisis of the 1970s when potential faculty and graduate students flocked to lucrative jobs in industry.
- Federal funding and industry financial and equipment support have improved academic departments. The number of graduate departments of computer science increased from 91 in 1976 to 146 in 1983.[48]
- Departments are still understaffed, and shortages for computer science faculty in 4-year colleges are particularly high. One analyst estimates that only half of

45. National Center for Statistics, unpublished data, 1984, Table 112.
46. The Computer Science Board, op. cit., p. 6.
47. [bid., p. 8.
48. Ibid., p. 25, Table la.

current computer science faculty have a Ph. D., and only half of these have their Ph.D. in computer science.[49]

- Competition among universities, colleges, high-paying industry, and large research institutes for a limited pool of Ph.D.s is brisk. Fifteen percent of academic positions for computer science went unfilled in 1981-83.[50]
- Computer scientists are the youngest and least tenured of academic scientists. Almost 40 percent of faculty in graduate departments are assistant professors, with 35 percent full professors.[51]
- Over three-quarters of baccalaureate computer scientists go directly into industry, where salary offers are the highest among the sciences and almost as high as engineering.

Foreign Nationals

- Foreign students have joined the technological gold rush to computer science. Foreign students on temporary visas received one-third of the computer science Ph.D.s awarded in 1985, up from 11 percent in 1977. This pace is similar to that in engineering.[52]
- Forty percent of full-time graduate students in Ph.D. schools are foreign. Foreign students receive about 5 percent of bachelor% and 20 percent of master% degrees in computer science.

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49. John W. Hamblen, Computer Manpower — Supply and Demand by States, 1984 (Tallahassee, FL: Quad Data Corp, 1984), cited in The Computer Science Board, op. cit., p. 10.
50. Scientific Manpower Commission, The Technological Marketplace: Supply and Demand for Scientists and Engineers, 3rd ed. (Washington, DC: May 1985), p. 38, Table 29.
51. David Gries, The Computer Science Board, The 1984-85 Taulbee Survey (Ithaca, NY: Department of Computer Science, Cornell University, June 1986), p. 6.
52. Ibid.; The Taulbee Survey reports 122 foreign nationals out of a total of 326, 0r37 percent, in 1985. The National Research Council, Office of Scientific and Engineering Personnel, annual survey of doctorate recipients in U.S. universities, 1985, unpublished data, reports 89 foreign nationals out of 311, or29 percent.

- Most foreign computer scientists — at both the bachelor% and Ph.D. levels — remain to work in the United States, more than in any other field.[53] Foreign computer scientists are important as new hires in the electronics and computer industries as well as academia. In Silicon Valley companies, they may constitute as much as one-third of the work force.[54]
- Foreign computer scientists comprise over one-third of university faculty, a proportion unmatched across the sciences or engineering.

Women and Minorities

- Computer science has been an accepting field of graduate study and employment for women. Nine percent of employed computer science Ph.D.s are women, the highest proportion outside the social and biological sciences. Women earned 10 percent of the Ph.D.s in 1985 and over one-third the bachelor% degrees in 1984.[55] one-quarter of full-time graduate students are women, as are those the National Science Foundation (NSF) classifies as "computer specialists."
- Minorities, with the exception of Asians, have not shared in the expansion of the field. Blacks have made no gains in the past 5 years; they currently receive 5-6 percent of Bachelor's degrees and less than 1 percent of Ph.D.s. Hispanics receive about 3 percent of bachelor's degrees and 1-2 percent of Ph.D.s.
- Asians have doubled their participation over the past 5 years to over 5 percent of bachelor's and Ph.D. computer science degrees.

53. U.S. General Accounting Office, Plansof Foreign Ph.D. Candidates: postgraduate Plans of U.S. Trained Foreign Students in Science/Engineering, GAO/RCED-86-102FS (Washington, DC: February 1986), p. 3.
54. National Science Foundation, Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook, op. cit., p. 75, Charts 5.1 and 5.2.
55. National Research Council, Office of Scientific and Engineering Personnel, annual survey of doctorate recipients in U.S. universities, 1985, unpublished data, reports 33 of 311 Ph.D.s, or 10.6 percent, and the Computer Science Board, reports 32 women out of 326 Ph.D.s, or 9.8 percent; bachelor's data from National Center for Statistics.

- Among NSF "computer specialists" 6 percent are Asian, 3 percent black, 2 percent Hispanic, and 0.4 percent American Indian. Under NSF/Bureau of Labor Statistics definitions, the single largest area of employment of minority scientists and engineers is computers.

LIFE SCIENCES

The life sciences represent a large number of fields that span the biological sciences, the health/medical sciences, and the agricultural sciences. Life sciences specialties are classified differently by data source. Their assignment to the biological or the health sciences sometimes depends on the academic department, school, or college which offers the program leading to the Ph. D., making comparisons difficult.

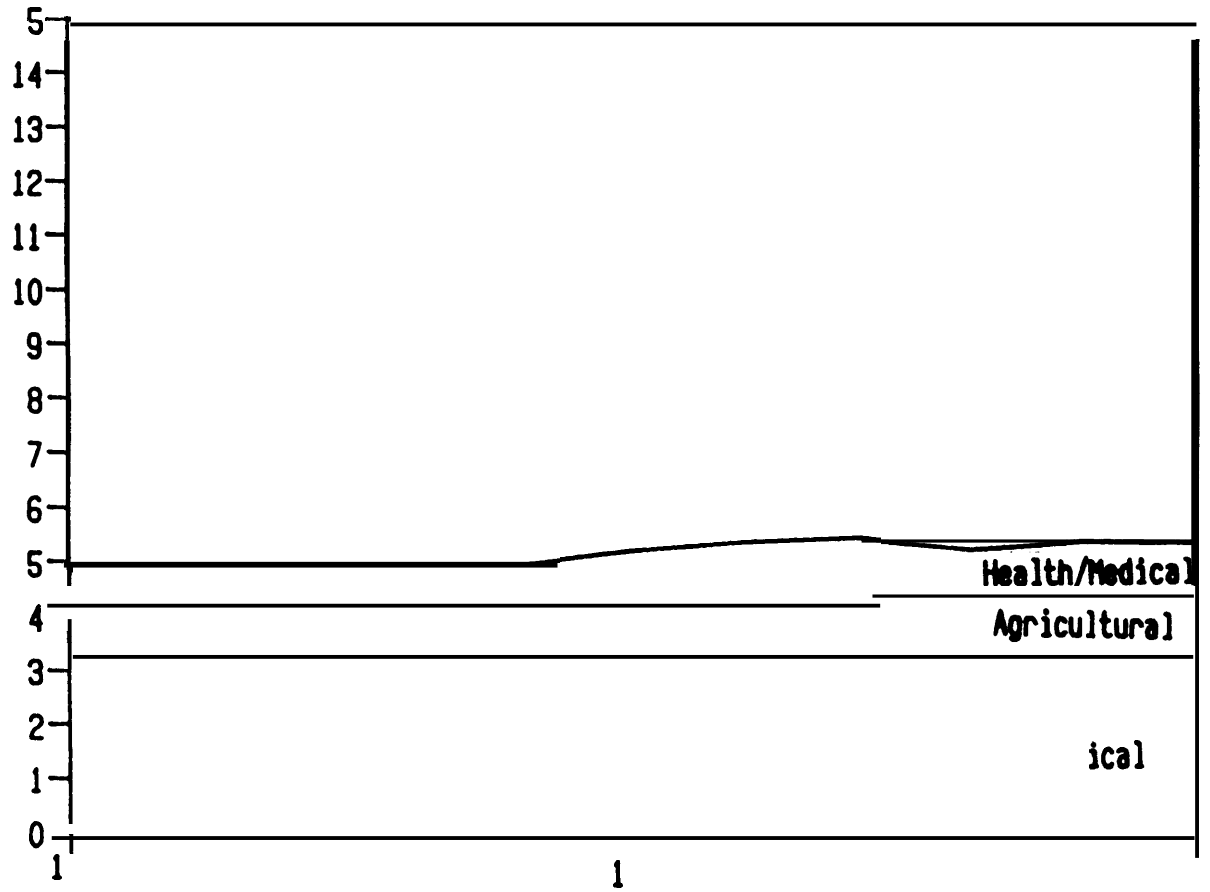
The biological sciences are comprised of a core set of disciplines devoted to the understanding of human and animal life. As the application of new and sophisticated instrumentation and the pace of biological discovery have accelerated, the boundaries between fields continue to blur. Basic biological fields represent the largest and most vibrant segment of the life sciences. In 1985, the biological sciences accounted for two-thirds of all life sciences Ph.D.s. Biochemistry is the largest disciplinary specialty; biochemistry plus microbiology, molecular biology, and physiology represented 41 percent of all life sciences Ph.D.s in 1985.

The health/medical sciences are a diverse set of health-related research specialties not directly involved in clinical care. These include environmental and public health, epidemiology, pathology, pharmacology, and nursing. Pharmacy/pharmacology represented one-third of all health/medical sciences doctorates awarded in 1985. These plus nursing and public health accounted for roughly three of every five health/medical sciences Ph.D.s conferred in 1985.

The agricultural sciences also consist of an array of fields and specialties. These include agronomy, animal science, plant science, soil science, food science and technology, range “science, horticulture, fish and wildlife science, and forestry. The agricultural sciences represented one-fifth of the life sciences Ph.D.s awarded in 1985. Four broad specialties — agronomy, animal science, plant science, and food science — accounted for almost two-thirds of the 1985 agricultural sciences doctorates. This

category does not include agricultural economics. The National Science Foundation science and engineering work force data count this field as asocial science. About 160 Ph.D.s in agricultural economics are awarded each year (which the National Research Council classifies under the agricultural sciences).

The Nation% colleges and universities continue to produce large numbers of agricultural sciences graduates. Despite the currently widespread depression of the U.S. food and agricultural economy, agricultural products continue to constitute a large portion of U.S. exports and about 20 percent of U.S. civilian jobs are in food and agricultural industries. Much of the growth and relative stability in the employment of agricultural scientists is in the extensive nationwide network of U.S. Department of Agriculture research facilities and the State agricultural experiment stations associated with the land-grant universities.



SOURCE: NATIONAL RESEARCH COUNCIL

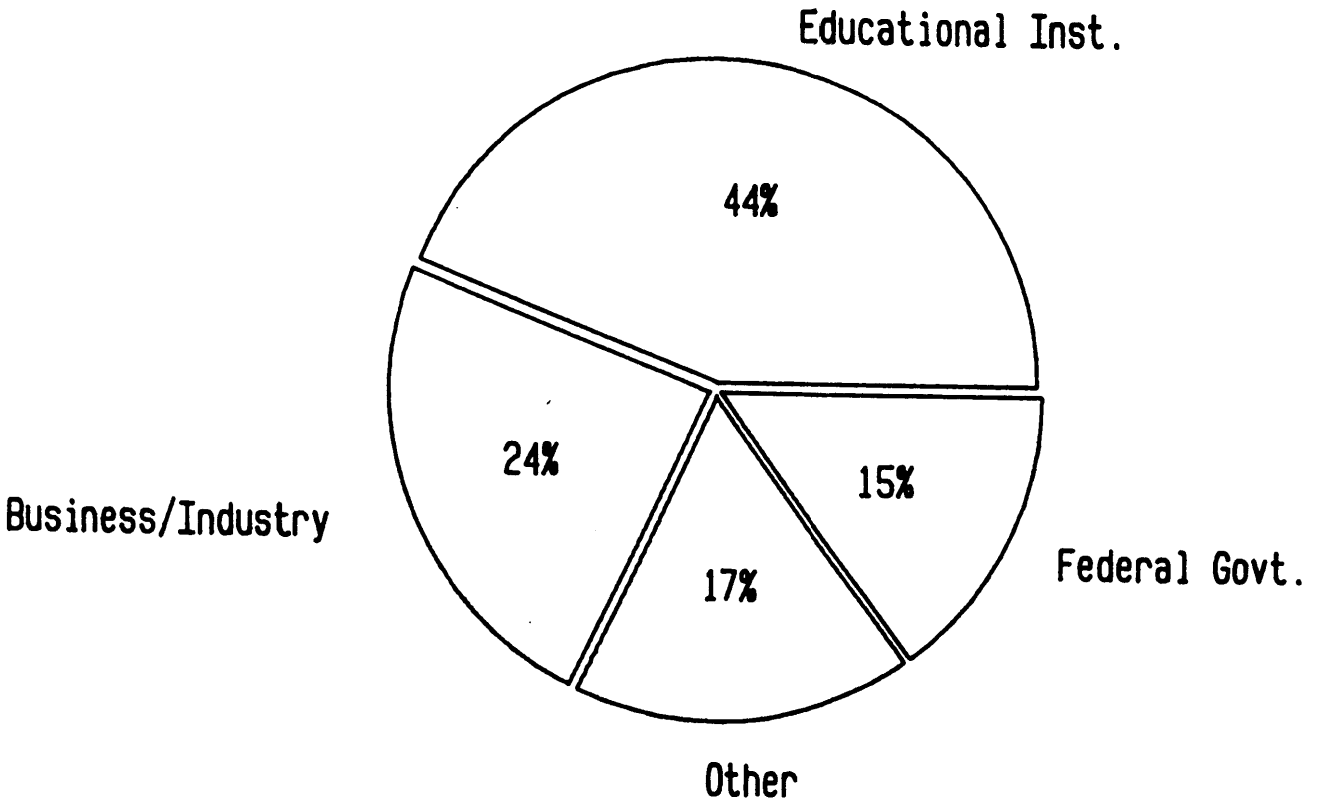
BIOLOGICAL SCIENCES

Employment

- There are 90,000 to 275,000 biological scientists employed in the United States. Of these, over 80 percent are employed in science and engineering (S/E) positions.[56]
- Less than one-half of the biological sciences S/E work force is employed by educational institutions. Industry employs about one-quarter and the Federal Government 15 percent.[57]
- Ž About 40 percent of biological scientists in the S/E work force are engaged primarily in research and development (R&D), with more than half of them conducting basic research. One-fifth are in various management and teaching positions respectively .58
- There are about 66,500 Ph.D.s in the biological sciences work force — about a quarter of the total; master% degrees holders represent another one-third of this work force.[59]
- More than one-half of biological sciences Ph.D.s are principally employed in R&D positions, with over 20 percent in teaching, and 10 percent in various management positions.[60]

56. The Bureau of Labor Statistics reports 90,000 in 1985 (unpublished data); the National Science Foundation estimates 272,000 in 1986. National Science Foundation, Division of Science Resources Studies, preliminary 1986 estimates, Table B-1, unpublished data.
57. National Science Foundation, Division of Science Resources Studies, preliminary 1986 estimates, Table B-13, unpublished data.
58. Ibid.
59. Ibid., Table B-Ii.
60. National Science Foundation, Science and Engineering Personnel: A National Overview, op. cit., pp. 116, 120, Table=-=

Where Bioscientists* Work, 1986



DEGREES

SOURCE: NATIONAL IENCE FOUNDAT ON

Education

- The number of bachelor% degrees awarded in the biological sciences has followed an erratic path. In 1950, slightly more than 24,000 bachelor's degrees were conferred. This number declined steadily through 1955 and began an increase to over 40,000 in 1970. The number of degrees peaked in 1976 at 59,000 and has declined each year since then. In 1984, 38,640 bachelor% degrees were awarded.[61]
- The number of Ph.D.s conferred in the biological sciences doubled between 1950 and 1960 to about 1,200 a year, reaching 2,100 in 1966. Between 1974 and 1985 the number of Ph.D.s has been between 3,100 and 3,500 each year.[62]
- The number of full-time graduate students in the biological sciences enrolled in doctorate-granting institutions declined slightly between 1977 and 1983, but has since turned upwards.[63]

Women, Minorities, and Foreign Nationals

- Women's share of biological sciences bachelor% degrees increased from about 20 percent in 1950 to about 45 percent in 1984.[64] In 1985, women accounted for one in three Ph.D.s conferred in the biological sciences.[65]
- In 1986, women constitute one-fourth of the biological sciences work force and one-fifth of the doctorate-level contingent of this work force.[66]

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61. National Science Foundation, Science and Engineering Degrees: 1950-80, op. cit., p. 53, Table 33. Data for 1981-84 from the U.S. Department of Education," National Center for Statistics, unpublished.
62. Ibid.; Ph.D. data for 1981-85 from National Research Council, Office of Scientific and Engineering Personnel, Doctorate Recipients From United States Universities (Washington, DC: National Academy Press, annually).
63. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, op. cit., p. 113, Table C-14; National Science Foundation, Division of Science Resources Studies, 'Selected Data on Graduate Science/Engineering Students by Enrollments Status, Fall 1985/' unpublished data, Tables A-land C-6.
64. National Science Foundation, Science and Engineering Degrees: 1950-80, op. cit, and National Center for Statistics, unpublished data.
65. National Research Council, Office of Scientific and Engineering Personnel, Doctorate Recipients From United States Universities, op. cit.
66. National Science Foundation, Division of Science Resources Studies, preliminary

- Blacks are severely underrepresented in the biological sciences. They represent only 2 to 3 percent of the biological sciences work force and **1.5** percent of the doctorate-level employees.[67]
- **0ver 15 percent of the 38,000 full-time graduate students in the biological sciences in 1985 were foreign citizens— up from about 10 percent in 1976.**[68]
- **In 1985, foreign students** on temporary visas received 11 percent of Ph.D.s award in the biological sciences.[69]
- ***Of*** the biological sciences Ph.D.s conferred in **1985, Asians accounted for** 4 percent, black and Hispanics each under 2 percent.[70]

1986 estimates, Tables B-l, B-11, unpublished data.
67. ibid.,TableB-12.
6a. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support: **Fall** 1983, op. cit., pp. 130-31, Tables **C27 and C28, and** National Science Foundation, Division of Science Resources Studies, **"Selected** Data on Graduate Science/Engineering Students and Postdoctorates by Citizenship/top. cit., Table A-9.
69. National Research Council, Office **of** Scientific and Engineering Personnel, Doctorate Recipients From United States Universities, op. cit.
70. Ibid.

HEALTH/MEDICAL SCIENCES

Employment

- There are an estimated 32,000 to 47,000 health/medical scientists employed in the United States. Of these, over 90 percent are employed in S/E positions.[71]
- About 60 percent of the health/medical sciences S/E work force is employed by educational institutions. Industry and nonprofit institutions account for about 17 percent each and the Federal Government for 4 percent.[72]
- About 40 percent of the health/medical sciences S/E work force is engaged primarily in R&D, with 25 percent in some form of management and in teaching, respectively.[73]
- About two-thirds of health/medical scientists hold a doctorate. Less than 1 percent hold a master% degree.[74] Of the employed doctorate holders, one in three is engaged in R&D, one in five in teaching, and in some form of management.[75]

Education

- The number of Ph.D.s awarded annually in the health/medical sciences increased between 1975 and 1982 by 50 percent. [n 1985, 1,082 Ph.D.s were conferred.[76]

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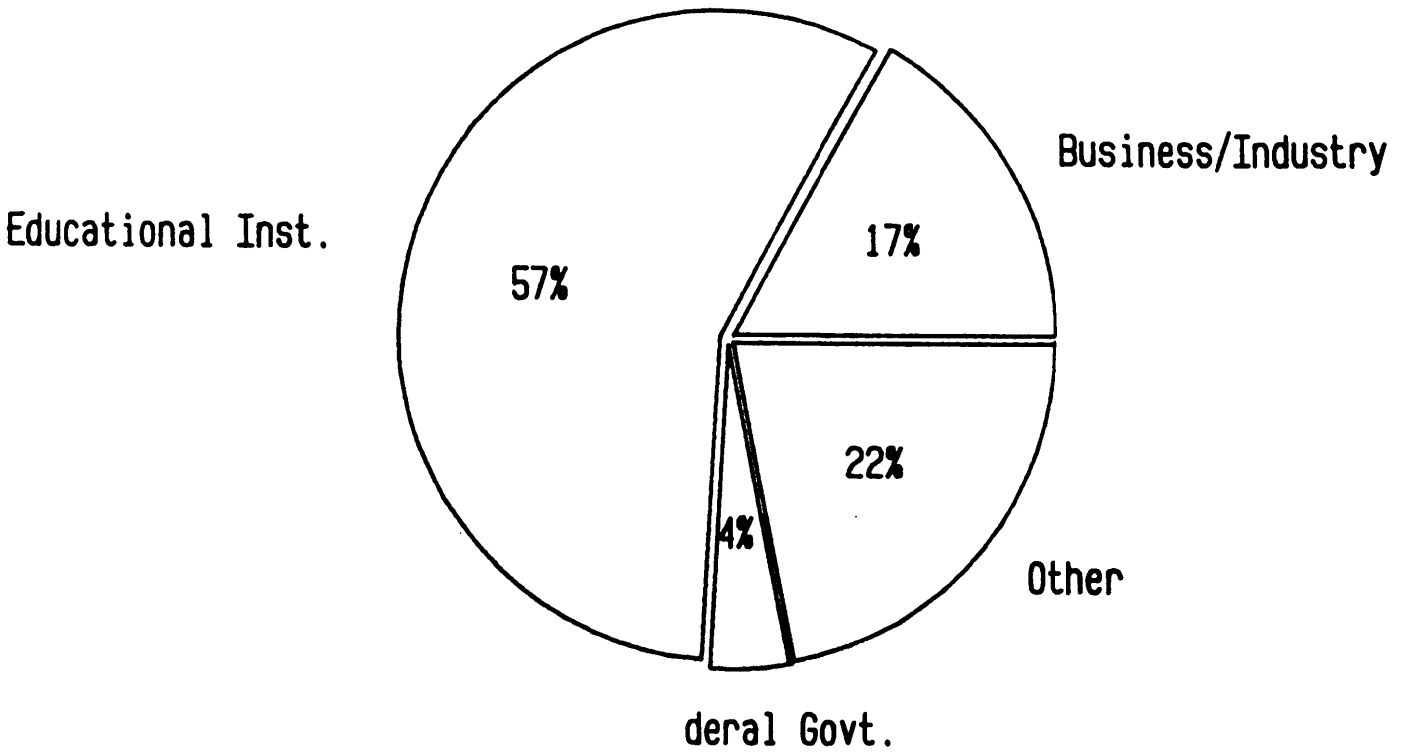
71. The Bureau of Labor Statistics reports 47,000 in 1985 (unpublished data); National Science Foundation estimates 32,000 in 1986. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Table B-1, unpublished data.
72. Ibid., Table B-13.
73. Ibid.
74. Ibid., Table B-11.
75. National Science Foundation, Science and Engineering Personnel: A National Overview, op. cit., pp. 116, 120, and 124, Table B-12b.
76. National Research Council, Office of Scientific and Engineering Personnel, Doctorate Recipients from United States Universities: Summary Report 1983, op. cit., p. 47, Appendix Table B. Data for 1985 are unpublished. Certain changes in the National Research Council doctorate fields were made to parallel National Science Foundationts occupational categories; degrees awarded in parasitology, pathology, and pharmacology were subtracted from the biological sciences and added to the health sciences.

Where Health Scientist Work, 1986



*ALL DEGREES

SOURCE: NATIONAL SCI FOUNDATION

- The number of full-time graduate students in the health/medical sciences enrolled in doctorate-granting institutions increased between 1976 and 1980, declined slightly and has now plateaued.[77]

Women, Minorities, and Foreign Nationals

- Women earn a majority of the health/medical sciences doctorates. [n 1985, women represented 60 percent of the Ph.D.s conferred in these fields.[78]
- Women's recent gains in earning doctorates have not yet shown up in the workplace. In 1984, women were over 20 percent of both the employed health/medical scientists and of the work force holding doctorates.[79]
- Blacks and Hispanics are severely underrepresented in these fields. In 1986, blacks and Hispanics each constituted slightly over 1 percent of the health/medical science work force and of the doctorate-holders in that work force.[80] In 1985, blacks received 3 percent of the health sciences Ph.D.s awarded.[81]
- The number of foreign full-time graduate students enrolled in doctoral programs has steadily increased since 1976, representing 11 percent of the health/medical sciences enrollment in 1985.[82]
- In 1985, foreign citizens on temporary visas received 13 percent of the health sciences Ph.D.s awarded.[83]

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77. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, op. cit., p. 113, Table C-14; and unpublished data.
78. National Research Council, Ph.D. data for 1985 from Office of Scientific and Engineering Personnel, unpublished data.
79. National Science Foundation, U.S. Scientists and Engineers: 1984, op. cit., pp. 37, 110, Tables B-1 and B-11.
80. National Science Foundation, Division of Science Resources Studies, preliminary 1986 estimates, Table B-12, unpublished data.
81. National Research Council, Office of' Scientific and Engineering Personnel, unpublished data.
82. National Science Foundation, Division of Science Resources Studies, "Selected Data on Graduate Science/Engineering Students and Postdoctorates by Citizenship," op. cit., Table A-15.
83. National Research Council, Ph. D. data for 1985 from the Office of Scientific and Engineering Personnel, unpublished data.

AGRICULTURAL SCIENCES

Education and Supply

- The number of students earning bachelor% degrees in agricultural and natural resources fields declined markedly between 1950 and 1961 from 15,000 to under 6,000 annually. After 1961 the fields showed steady growth, peaking at 22,000 in 1979 and declining slightly each year to about 19,000 in 1984. Master% degrees have followed a similar pattern since 1970 with over 4,000 conferred in 1984.[84]
- The number of Ph.D.s awarded nearly doubled between 1960 and 1970 to 800. Despite sharp fluctuations in the last 15 years, Ph.D. production has increased. Over l,l00 were awarded in 1985.
- No single discipline within the agricultural sciences accounts for more than 20 percent of the Ph.D.s. In 1985, the distribution was plant science and animal sciences, 18 percent each; food science, 12 percent; soil science and forestry, 9 percent each; and horticulture, and fish and wildlife, 7 percent each.

Employment

- There are an estimated 65,000 to 102,000 agricultural scientists employed in the United States. Of these, almost 80 percent are employed in S/E positions.[85]
- Nearly one-half of the agricultural science S/E work force is employed in industry. About one-third are employed in academia and 10 percent in the Federal Government.[86]

84. National Science Foundation, Science and Engineering Degrees: 1950-80. A Source Book, op. cit., p. 52, Table 32 and National Center for Statistics, unpublished data.
85. The Bureau of Labor Statistics reports 65,000 in 1985 (unpublished); National Science Foundation estimates 101,900 in 1986. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Table B-1.
86* Ibid., Table B-13.

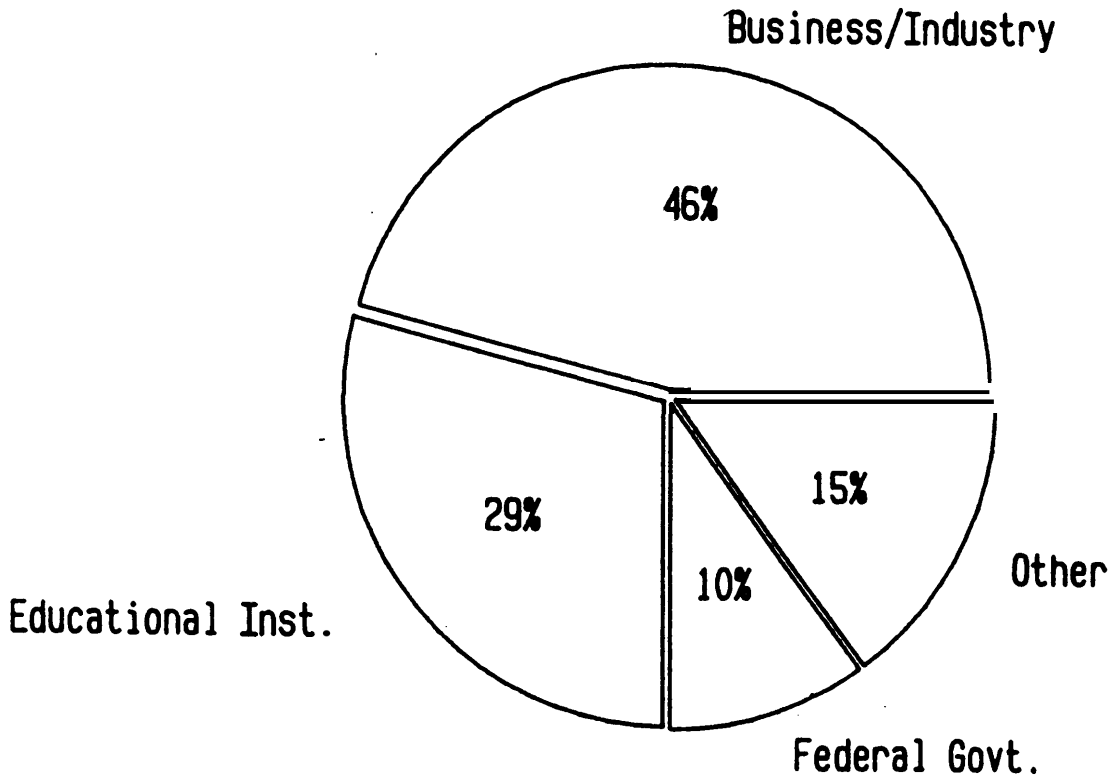
- Slightly less than one-third of the agricultural science S/E work force are primarily engaged in R&D activities. About one-quarter are in various management positions and over one-fifth are involved in production/inspection. Less than 10 percent are engaged in teaching.[87]

Women, Minorities, and Foreign Nationals

- Women increased as a proportion of the agricultural sciences S/E work force from 4 percent in 1976 to 19 percent in 1986. The majority of female agricultural scientists are employed in business and industry and 20 percent by educational institutions. About 30 percent preengaged in R&D activities.[88]
- only 5 percent of agricultural science doctorates employed in 1986 are women, even though the proportion of Ph.D.s granted to women in agricultural science fields tripled from 5 to 15 percent in the 1975-85 decade.
- Minorities are likewise underrepresented. Blacks, Asians, and Hispanics each account for only 2 percent of the agricultural sciences work force in 1983. In 1985, Asians earned over 2 percent of the Ph.D.s awarded, blacks 1.4 percent, and Hispanics less than l percent (10 out of 1,100).[89]
- Foreign nationals receive about one-third of the Ph.D.s awarded, a proportion unchanged since 1975. The vast majority return to their country of origin after completing doctoral study.

87. Ibid.
88. National Science Foundation, Science and Engineering Personnel: A National Overview, op. cit., Table B-2, p. 54 and National Science Foundation, Division of Science Resources Studies, preliminary 1986 estimates, Tables B-4 and B-6, unpublished data.
89. National Research Council, Office of Scientific and Engineering Personnel, 1985 unpublished data from the survey of doctorate recipients in United States universities.

Where Agricultur l Scientists* Work, 1986



DEGREES

SOURCE NAT ONA SCIENCE FOUNDATION

SOCIAL AND BEHAVIORAL SCIENCES

The social and behavioral sciences encompass a variety of fields. They include anthropology, geography, political science, sociology, and two large but very different fields which are often reported on separately, economics and psychology. Some data sources treat psychology as a behavioral science, separate from other social sciences.

The bachelor% degree is insufficient for professional employment in the social and behavioral sciences. Thus, graduate enrollments and degrees are the best indicators for forecasting the supply of social scientists. Ph.D.s have been steady at around 6,000 a year since 1975, with psychology taking an increasing share while other social sciences have declined. Bachelor% degrees in social and behavioral sciences peaked in 1974 and have been dropping steadily ever since. Freshman interest has been fairly steady since the late 1970s, although it dipped in 1980-1983 at the same time that interest in engineering peaked. For all these fields combined, about 14 percent of bachelor% graduates earn a master's and 5 percent a Ph.D.[90]

It is difficult to estimate the number of social and behavioral scientists working in this broad field; the Bureau of Labor Statistics estimates 325,000 in 1985 while the National Science Foundation (NSF) estimates 621,000 in 1986. Outside of psychology, according to NSF'S 1986 estimates, social scientists number about 382,000 members of the labor force, including 70,000 Ph.D.s.[91] psychologists add 240,000 to that number, including 55,000 Ph.D.s.

In general, social scientists are more likely to work in industry than in educational institutions, and a larger proportion work in the non-profit sector and in Federal, State,

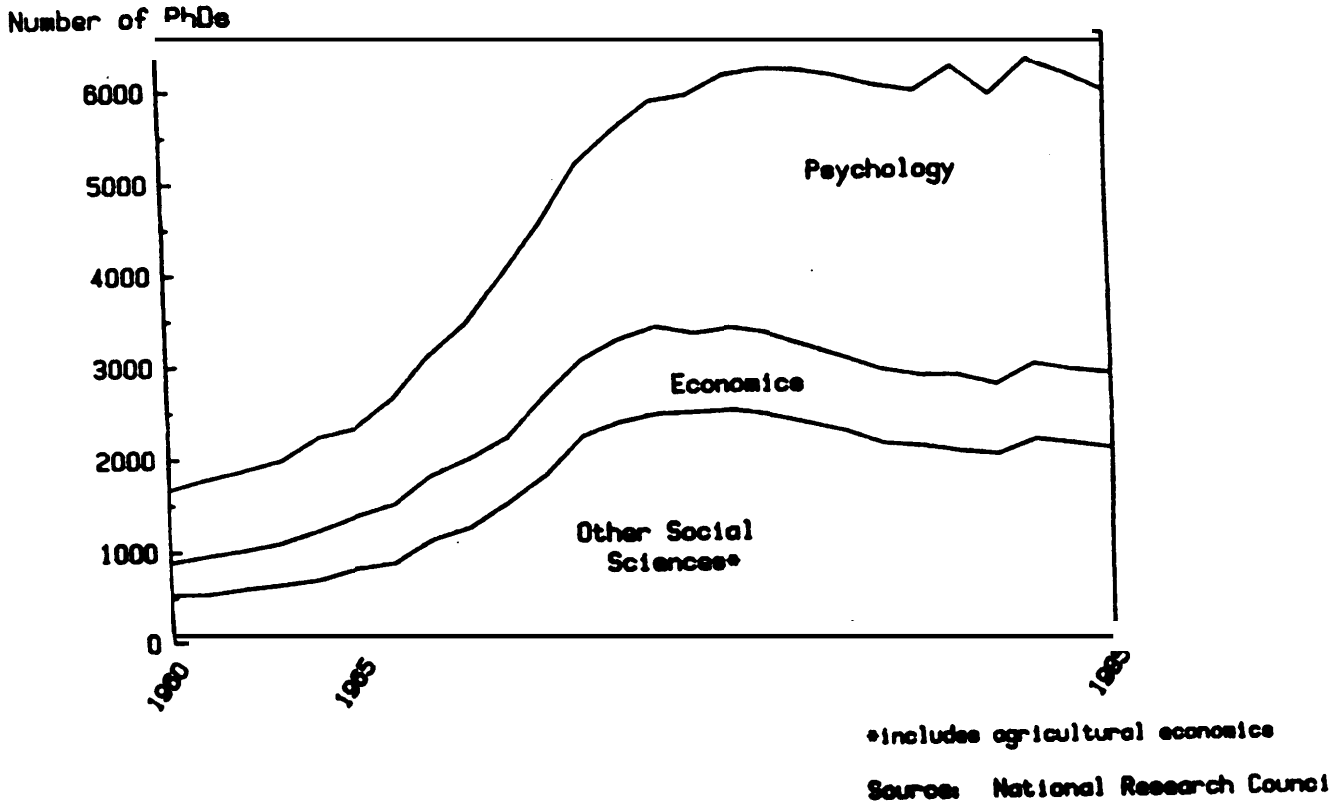
90. National Science Foundation, Science and Engineering Degrees: 1950-80. A Source Book, op. cit., p. 54. Bachelor'sand master% degree data for 1981-83 are from the U.S. Department of Education, National Center for Statistics, unpublished. Ph.D. data are from the National Research Council's Surveysof Earned Doctorates in the United States.
91. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Tables B-1 and B-n, unpublished data.

and local government compared to other sciences. Unemployment is traditionally higher among social and behavioral scientists than other scientists and engineers, indicating a chronic oversupply.

The social sciences attract more women and fewer foreign students than other fields. Within specific disciplines, however, large differences exist. Psychology and economics, for example, are mirror images in terms of enrollments of women and foreign nationals. Non-Asian minorities are better represented in the social sciences than in other sciences. Indeed, the social and behavioral sciences have been viewed as fields of educational opportunity. But they, together with the life sciences, have the lowest salaries and the highest unemployment and underemployment rates. Almost one-third of the Ph.D.s trained in asocial science were working outside their doctorate field in 1983. Nearly one-fifth of Ph.D.s work outside science and engineering altogether.

The market for social science Ph.D.s is still predominantly academic. This is not likely to change soon, though the more applied degrees and specialties will continue to fare better in business, industry, and State and local government.

Soc al/Behavioral Sci PhDs
1960-1985



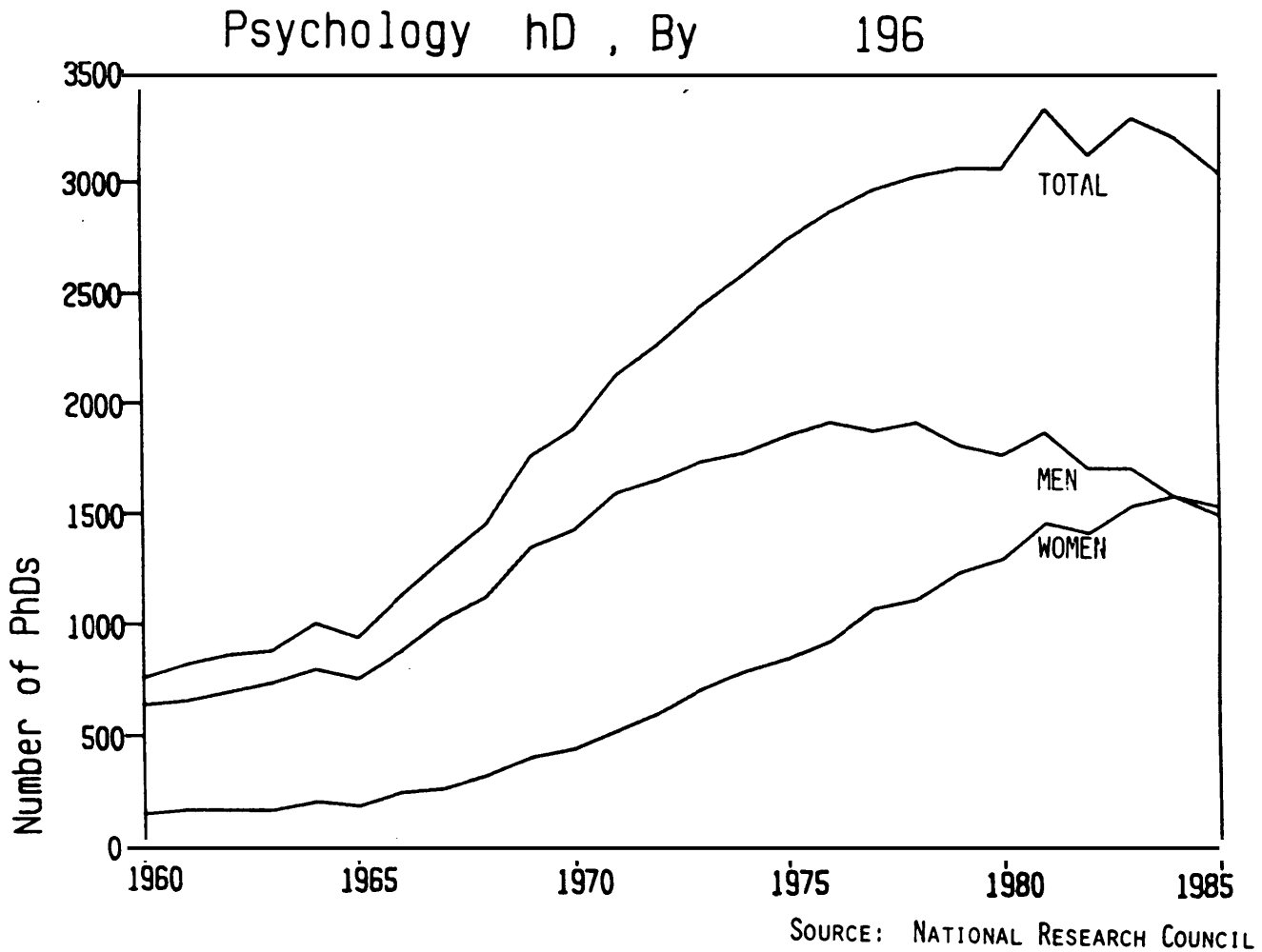
Enrollments and Degrees

- Psychology is the largest social and behavioral science field, accounting for one-half of Ph.D.s and one-third of bachelor's degrees in social sciences. Although Ph.D.s in the social sciences have declined since 1976, Ph.D.s in psychology have continued at about 3,000 per year since 1977.[92] In 1985, this number represented 16 percent of the doctorates granted in all science and engineering.
- Current graduate enrollments in doctoral degree programs are about 60 percent in clinical specialties, 40 percent in research and experimental specialties.[93]
- Bachelor% graduates in psychology are more likely than other social scientists to complete one or more graduate degrees.

Employment Patterns

- There are 170,000 to 240,000 psychologists employed in the United States. Of these, three out of four are employed in science and engineering (S/Expositions.[94]
- In 1986, over 20 percent of psychologists in S/E positions were employed in business and industry; another 20 percent work in nonprofit organizations, and almost one-half in academia.[95]
- The work of psychologists in S/E positions differs from those of other S/E professionals. Only 9 percent of psychologists are engaged in research and development, 22 percent in teaching, and 17 percent in some type of

92. National Science Foundation, Science and EngineeringD octorates: 1960-82, op. cit., p. 19, Table 1.
93. Georgine M. Pion, et al., Summary Report of the 1984-85 Survey of Graduate Departmentsof Psychology (Washington, DC: American Psychological Association, June 1985), p. 28, Table 11.
94. The Bureau of Labor Statistics reports 169,000 employed psychologists in 1985; the National Science Foundation estimates 239,700 in 1986. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Table B-l.
95. Ibid., Table B-13.


Psychology hD , By 196
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Number of PhDs
TOTAL
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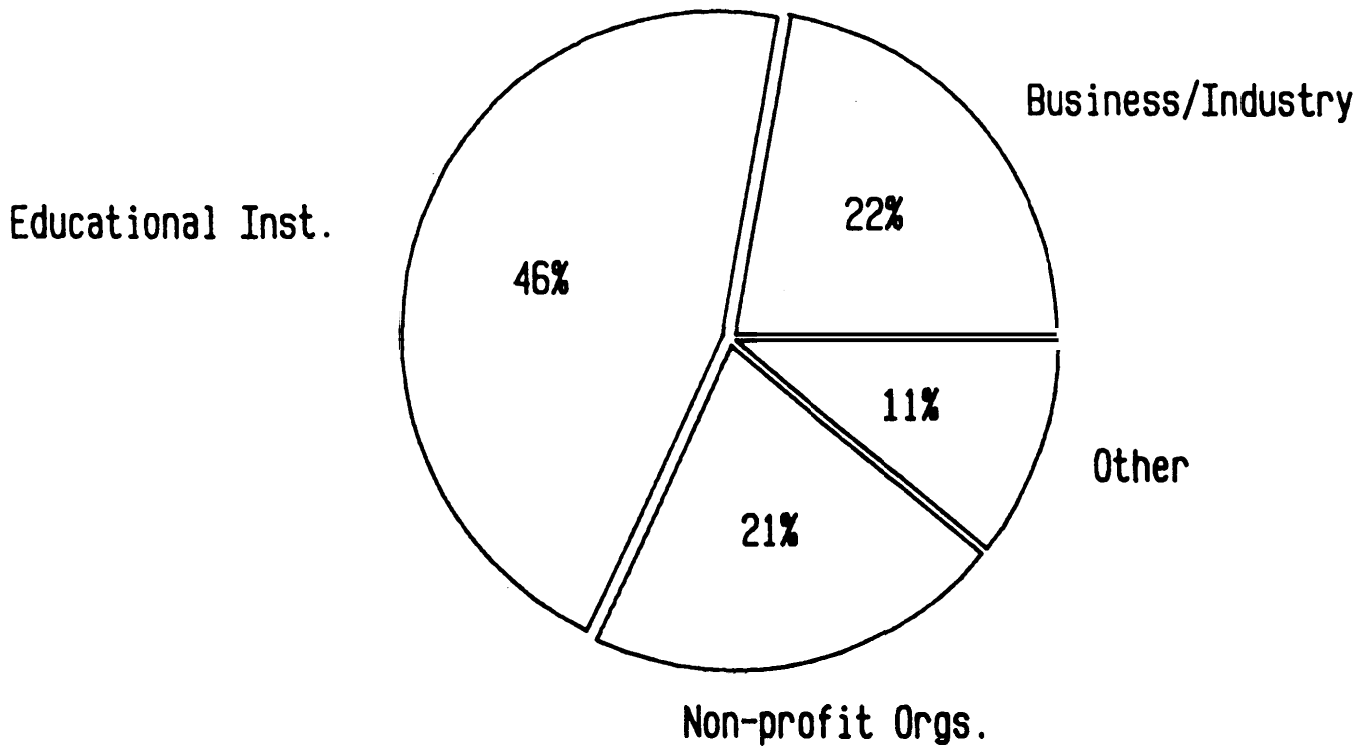
WOMEN
1960
1965
1970
1975
1980
1985
SOURCE: NATIONAL RESEARCH COUNCIL

Where Psychologists* Work, 1986



*ALL DEGREES

SOURCE: NAT ONAL SCIE FOUNDATION

management.[96] Part of this may be explained by the large numbers of psychologists in clinical practice.

- Compared to other doctoral-level scientists, psychologists exhibit relatively low mobility into other scientific fields.[97] Instead, they may move out of science altogether in times of oversupply, as indicated by the high proportion of psychology Ph.D.s reporting non-science/engineering employment.
- Psychologists generally follow two career paths. Clinical psychologists, with a bachelor's or master%, work in industry or hospitals and other health service occupations. Two-thirds of clinical psychologists are bachelor% or master's holders. Experimental psychologists earn a Ph.D. and enter academic research, or, to a lesser extent, industry; three out of four of psychologists active in research hold a Ph.D.[98]
- Between 1972 and 1984, subfields associated with academic research—experimental, comparative, and physiological— declined while clinical specialties thrived. Over half of recent Ph.D.s in psychology have been awarded in clinical subfields, and new Ph.D.s increasingly enter private or public clinical practice (health service provider) instead of pursuing traditional academic careers.[99]

Women, Minorities, and Foreign Nationals

- The composition of the psychology degree pool is distinctive: women dominate at the bachelor% level (two of every three bachelor's awarded) and earn half of the

96. [bid.
97. National Research Council, Office of Scientific and Engineering Personnel, Science, Engineering, and Humanities Doctorates in the United States: 1983 Profile, op. cit., pp. 18-19, Table 2-2.
98. Joy Stapp, et al., 'Census of Psychological Personnel: 1983," American Psychologist, vol. 40, No. 12, December 1985, pp. 1,334-1,341.
99. Georgine M. Pion and Mark W. Lipsey, 'Psychology and Society: The Challenge of Change," American Psychologist, vol. 39, No. 7, July 1984, pp. 739-754; and Ann Howard, et al., "The Changing Face of American Psychology: .4 Report from the Committee on Employment and Human Resources," unpublished manuscript.

Ph.D.s, the highest proportion among the sciences.[100] Women tend to congregate in developmental, educational, and clinical psychology, while men hold more research positions.

- Despite receiving a majority of psychology degrees, women are less likely to be tenured or on a tenure track, and more likely to be working part time. In graduate departments of psychology, two-thirds of the faculty are male.
- Minority participation in psychology is very low: 3 to 6 percent black, 3 percent Hispanic, and 1 percent Asian and Native American.
- There are very few foreign nationals in psychology; they comprise only 4 percent of current graduate enrollment, compared to 20 percent for other social sciences.[101]

100. Commission on Professionals in Science and Technology, Professional Women and Minorities: A Manpower Data Resource Science, 6th ed. (Washington, DC: February 1986), pp. 232, 241-242.
101. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, op. cit., p. 27, Table A-8.

ECONOMICS

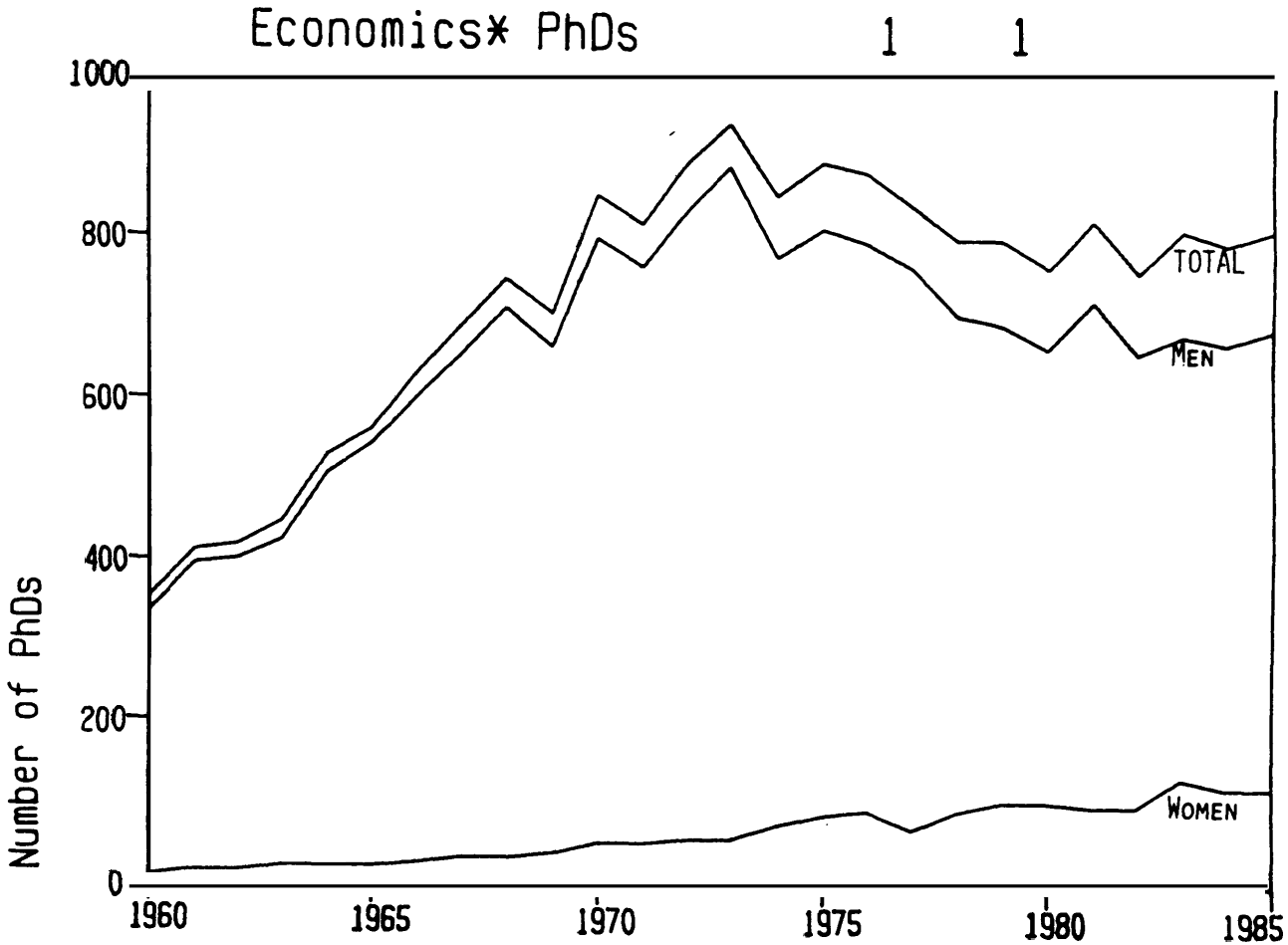
Education and Supply

- For 25 years economics has attracted many students. Baccalaureate production more than doubled to 17,000 in 1970, declined slightly to mid-decade, and has climbed ever since, surpassing 20,000 in 1983.
- Master% degrees exhibit a similar pattern to baccalaureates, plateauing in 1980 around 2,000 and holding stable. Ph.D. production has fluctuated between 700 and 800a year since 1970.[102]

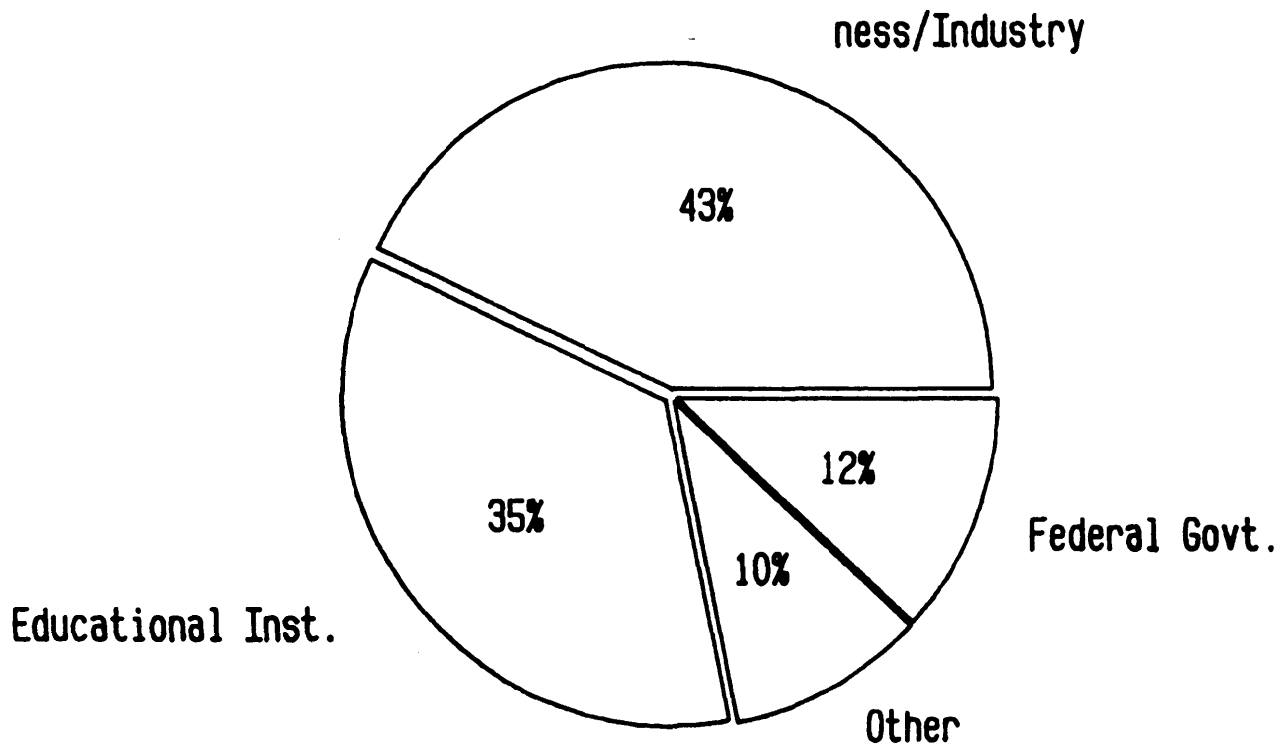
Employment Patterns

- There are 111,000 to 145,500 economists employed in the United States. Of these, three out of five are employed in S/E positions. [103]
- In 1986, 42 percent of the economists holding S/E positions are working in business and industry, 35 percent in academia and 12 percent in the Federal Government. [104] In the last decade, economists have doubled their number in the work force.
- The principal work activity of S/E economists in 1986 is management/administration (25 percent), followed by teaching (24 percent), and

102. National Science Foundation, Science and Engineering Degrees: 1950-80. A Source Book, op. cit., p. 56.
103. The Bureau of Labor Statistics reported 110,000 employed economists in 1985; the National Science Foundation estimates 145,500 in 1986. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Table B-1, unpublished data.
104. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates.


Economics* PhDs
1000
800
600
400
200
0
Number of PhDs
1960
1965
1970
1975
1980
1985
TOTAL
MEN
WOMEN
*INCLUDES ECONOMETRICS
SOURCE: NATIONAL RESEARCH COUNCIL

Where Economists* Work, 1986



*ALL DEGREES

SOURCE: NATIONAL SCIENCE FOUNDATION

research and development (19 percent). [105]

- The profile for the 20,000 Ph.D. economists in the work force is more academic, with almost half having teaching as their primary work activity and one-quarter engaged in R&D.[106]
- The average salary for a Ph.D. economist in 1983 was $42,000. This exceeds the average for scientists/engineers in all fields combined by almost $3,000 and in social sciences by $6,000.[107] Although new job openings were down in 1985 from the year before, the academic market has accommodated new Ph.D.s seeking entry-level positions.[108]

Women, Minorities, and Foreign Nationals

- Women have historically fared poorly in economics. They receive disproportionately fewer of the degrees awarded at all levels, 33 percent of bachelor's, 24 percent of master's, and 16 percent of Ph.D.s. Women have slowly increased their share of degrees over the past decade, although this increase has slowed. According to one survey, the percentage of female economics assistant professors doubled to 16 percent between 1976 and 1984. Still, in that year only 4 percent of the tenured economics faculty were women.[109]
- Blacks and Hispanics are not well represented in economics, while Asians are doing somewhat better. In 1983, black economists in the work force totaled 3 percent, Asians 7 percent, and Hispanics 2 percent. Black economists have remained

105. Ibid.
106. National Science Foundation, Science and Engineering Personnel: A National Overview, op. cit., pp. 117, 121, 125, 129, Table 12-b, and unpublished data 1986 estimates.
107. Ibid., p. 140, Table B-18.
108. C. Elton Hinshaw, 'Report of the Director: Job Openings for Economists," in Proceedings of the 98th Meeting of the American Economic Association, American Economic Review, vol. 76, No.2, May 1986, pp. 443-444.
109. Isabell Sawhill, "Report of the Committee on the Status of Women in the Economics Profession," in Proceedings of the 98th Meeting of the American Economic Association, American Economic Review, vol. 76, No. 2, May 1986, pp. 452-457.

between 1 and 2 percent of Ph.D.s since 1973, while Asians have doubled their participation to 9 percent. Ph.D. data for 1985 show this trend continuing: blacks, Hispanics, and American Indians combined account for less than 4 percent of the doctorates granted.[110]

- Foreign nationals holding temporary visas are a large share of the economics talent pool. In 1960, they received 19 percent percent of the Ph.D.s conferred in economics; in 1985, that percentage was 34.[111]

110. National Research Council, Office of Scientific and Engineering Personnel, Doctorate Recipients from United States Universities: Summary Report 1984, op. cit., p. 32.

111. Data for 1960-82 are from National Science Foundation,. Science and Engineering Doctorates: 1960-1982, NSF 83-328 (Washington, DC: 1983), pp. 44-45, Table 2. Data for 1983-85 are from National Research Council, Doctorate Recipients from United States Universities: Summary Report 1984, op. cit.

ENGINEERING

Overview

The engineering labor force differs markedly from the scientific labor force. This section discusses engineering as a degree and work category, then examines two engineering specialties, electrical engineering and chemical engineering.

The bachelor% is the entry-level professional degree and the one held by the vast majority of employed engineers. A master's degree or the 5-year engineer degree is an important credential, unlike most of the sciences where the master% is merely a stepping-stone to a Ph.D. or a consolation for not continuing doctorate study.

The six largest engineering specialties, in approximate rank order according to the Bureau of Labor Statistics estimates, are electrical and electronic, with over 500,000 engineers in the labor force and more than 22,000 degrees awarded in 1985, mechanical, civil, industrial, chemical, and aeronautical and aerospace. These specialties include about 80 percent of all engineers. [112]

The labor market varies considerably among engineering specialties. The market for electrical engineers may boom, while aerospace engineers are unable to find jobs. Within each engineering specialty, new skills may be in critical demand while others are

112. Estimates of the number of engineers employed in the United States compiled by the two major sources of labor force data, the Bureauof Labor Statistics (BLS) and the National Science Foundation (NSF), differ greatly due to differences in definition and data collection:

	BLS(1985)	NSF(1986 est.)
Electrical	544,000	581,300
Mechanical	272,000	513,700
Civil	221,000	365,700
Industrial	178,000	150,900
Aeronautical	95,000	111,600
Chemical	64,000	163,100
TOTAL ENGINEERS	1,683,000	2,560,600

NSF data from National Science Foundation, Science Resources Studies Division, preliminary 1986 data, Table B-1, unpublished data.

outmoded. New specialties, such as materials, bioprocess, or computer engineering, often emerge as offshoots of a traditional specialty and fall between the cracks of existing data collection, making it difficult to track their progress.

Industrial requirements for engineers change rapidly to take advantage of new technologies or to match swings in production. To satisfy this changing demand, education of new engineers is complemented by retraining and migration (field mobility). Much of this migration occurs within the engineering population, as a growing engineering specialty draws upon others and changes the distribution among specialties. Market forces are particularly influential in the career choice of young engineers. There is a relatively stable total pool of engineers.

Education/Supply of Engineers

- Together with computer science, engineering has been the fastest growing area of study since the early 1970s. But growth has slowed as the job market settles from boom into slower growth and as the supply of 18-year-olds starts downward. The largest increase has been in bachelor% awards, which doubled between 1975 and 1985 from 38,000 to over 77,000.[113] During that same period, average grwth in bachelor% awards in all fields was less than 20 percent.
- Engineering bachelor's graduates nearly doubled their share of all bachelor's degrees between 1975 and 1985, from 4.5 percent to 8 percent. The years 1984-85 mark a turning point in engineering: the slowdown in bachelor% degrees and the upswing in Ph.D.s. Master's awards continue their steady climb.

113. Engineering Manpower Commissions Engineering and Technology Degrees (Washington, DC: American Association of Engineering Societies, published annually). Unless otherwise noted, engineering degree data are from the Engineering Manpower Commission. The Commission data at all degree levels tend to be slightly higher than data reported by the National Research Council and the U.S. Department of Education's National Center for Statistics, but follow a similar pattern.

- The unprecedented surge in undergraduate engineering enrollments of the 1970s is settling down as college students respond to the downturn in the job market, particularly in the electronics and computer industries. Freshman enrollment started down in 1983.
- Projections based on current undergraduate enrollment levels, coupled with the declining college age population, indicate a substantial decline in the number of bachelor's engineering awards in the late 1980s, down from the 77,000 awarded in 1985 to 70,000-72,000 in 1989; the trend is expected to continue downward through the 1990s.[114]
- Engineering Ph.D.s, like the sciences, peaked in 1970-72 and then declined rapidly. The substantial decline in engineering Ph.D. awards relative to bachelor% awards in the 1970s testifies to the powerful influence of the attractive job market for bachelor's and master's level engineers.
- Over the past 3 years, engineering doctorate awards have increased and regained their 1975 level. Slightly over 3,100 engineering Ph.D.s were awarded in 1985.[115] Graduate enrollments have been rising since 1978, signaling a continuing increase in engineering Ph.D. awards at least into the early 1990s, up to about 4,000.
- Very few engineering students undertake postdoctoral study. There are currently about 1,200 postdoctoral students, over 60 percent of whom are foreign.

114. Commission on Professionals in Science and Technology, Washington, DC, unpublished data. Enrollment and degree data are from the U.S. Department of Education, National Center for Statistics; freshmen intentions from Cooperative Institutional Research Program, The American Freshman: National Norms for Fall, 1985 (Los Angeles, CA: Higher Education Research Institute, December 1985).
115. The National Research Council reported 3,165 engineering Ph.D.s in 1985; Engineering Manpower Commission reported 3,383. National Research Council, Office of the Scientific and Engineering Personnel, unpublished data from annual survey of doctorate recipients from United States universities, and Engineering Manpower Commission, Engineering and Technology Degrees, op. cit.

Employment/Demand for Engineers

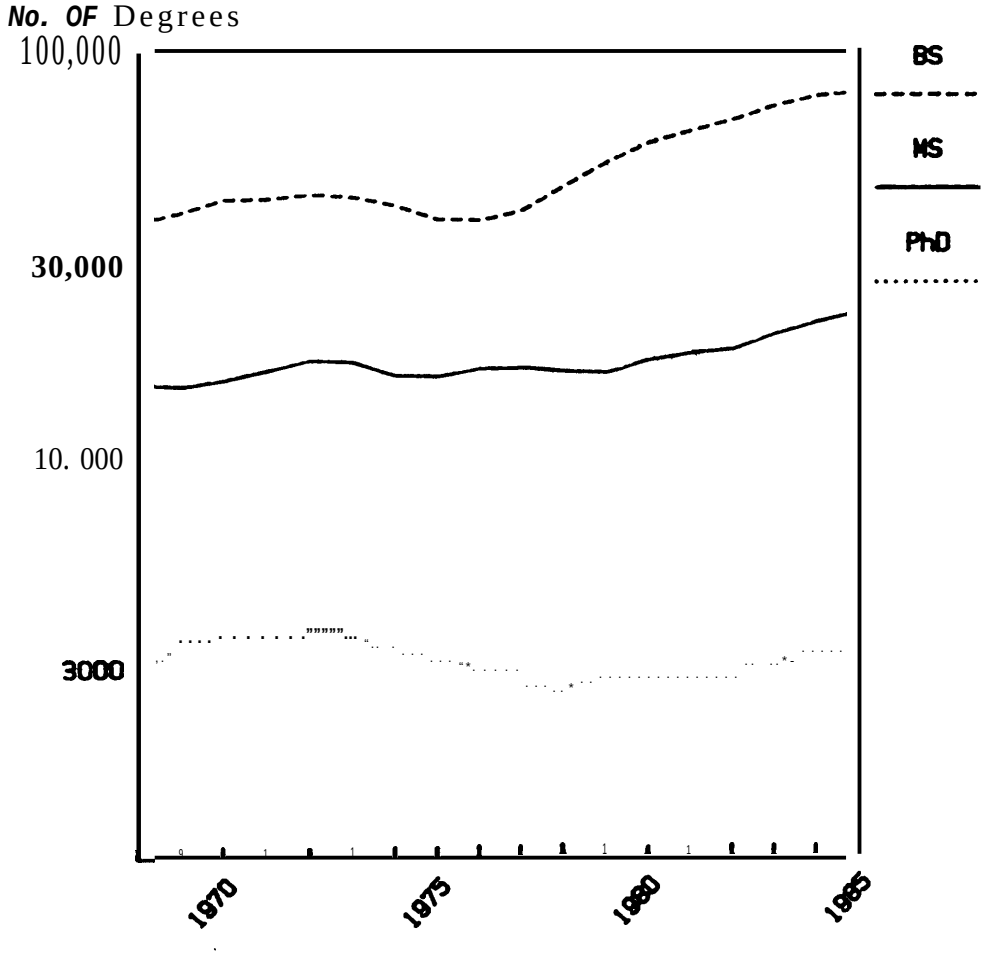
- Engineering has been one of the fastest growing occupations in the 1980s.[116] In 1986, there were 2,560,600 engineers employed in the United States. Over 90 percent are employed in science and engineering (S/E) positions. Women make up slightly more than 3 percent of the engineering S/E work force. Only about 3 percent of employed engineers hold doctorates. About 80 percent of S/E employed engineers work in business/industry.[117]
- The labor market for an engineering specialty largely depends upon the diversity of the labor market and the economic health of key industry employers. For example, only one-third of chemical engineers work in the chemical industry, while three-quarters of aerospace engineers work in the aircraft industry.[118] Mechanical engineers work in a variety of settings, and seem able to weather business cycles by shifting to related jobs. Demand for more petroleum or nuclear engineers, on the other hand, rides the roller coaster of the energy and resource industries which dominate their market.
- Universities and colleges trying to hire faculty to handle high undergraduate enrollments face a continuing shortage of Ph.D. engineers interested in academic positions, particularly in electrical and computer engineering. Universities and colleges employ only 4 percent of all engineers, but about one-third of doctorate engineers.

Engineering Technicians and Technologists

- Engineering technicians are an important part of the engineering labor force and a source of new engineers through mobility and training.

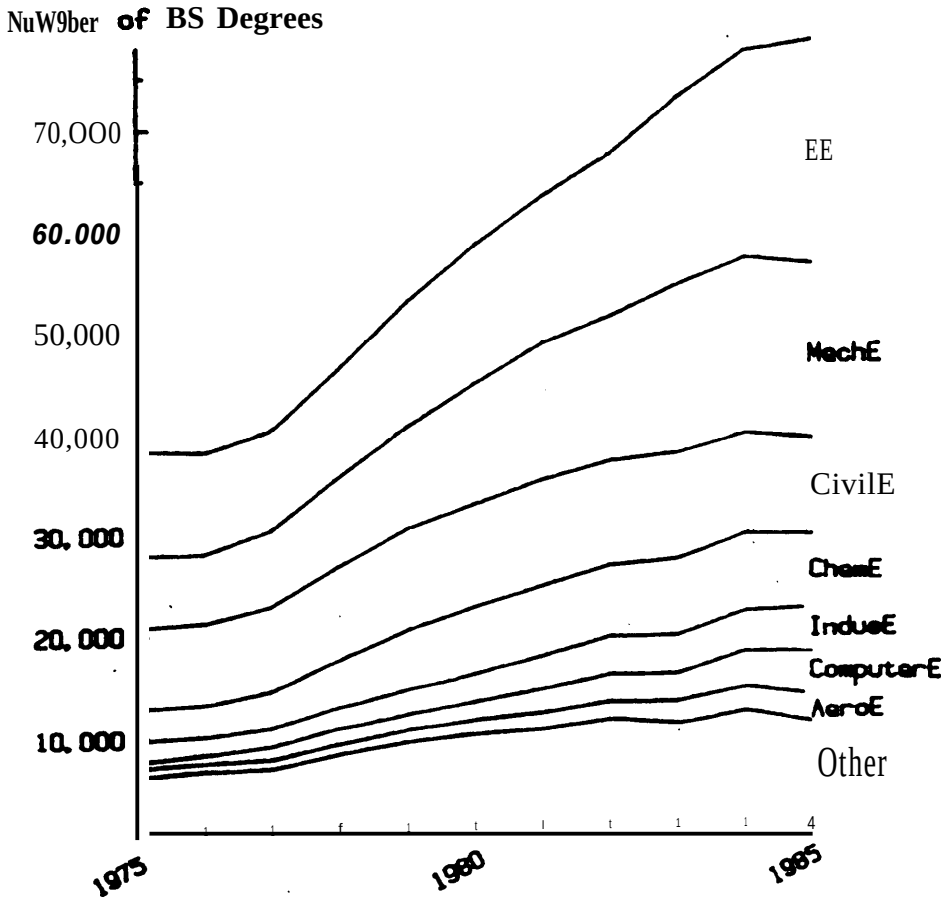
116. National Science Board, Science Indicators: The 1985 Report, NSB 85-1 (Washington, DC: National Science Foundation, 1985), p. 56.
117. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Tables B-1, B-11, B-13, unpublished data.
118. National Science Board, op. cit., p. 57.

Total Engineering Degrees. 1968-1985
ES, MS. and PhD

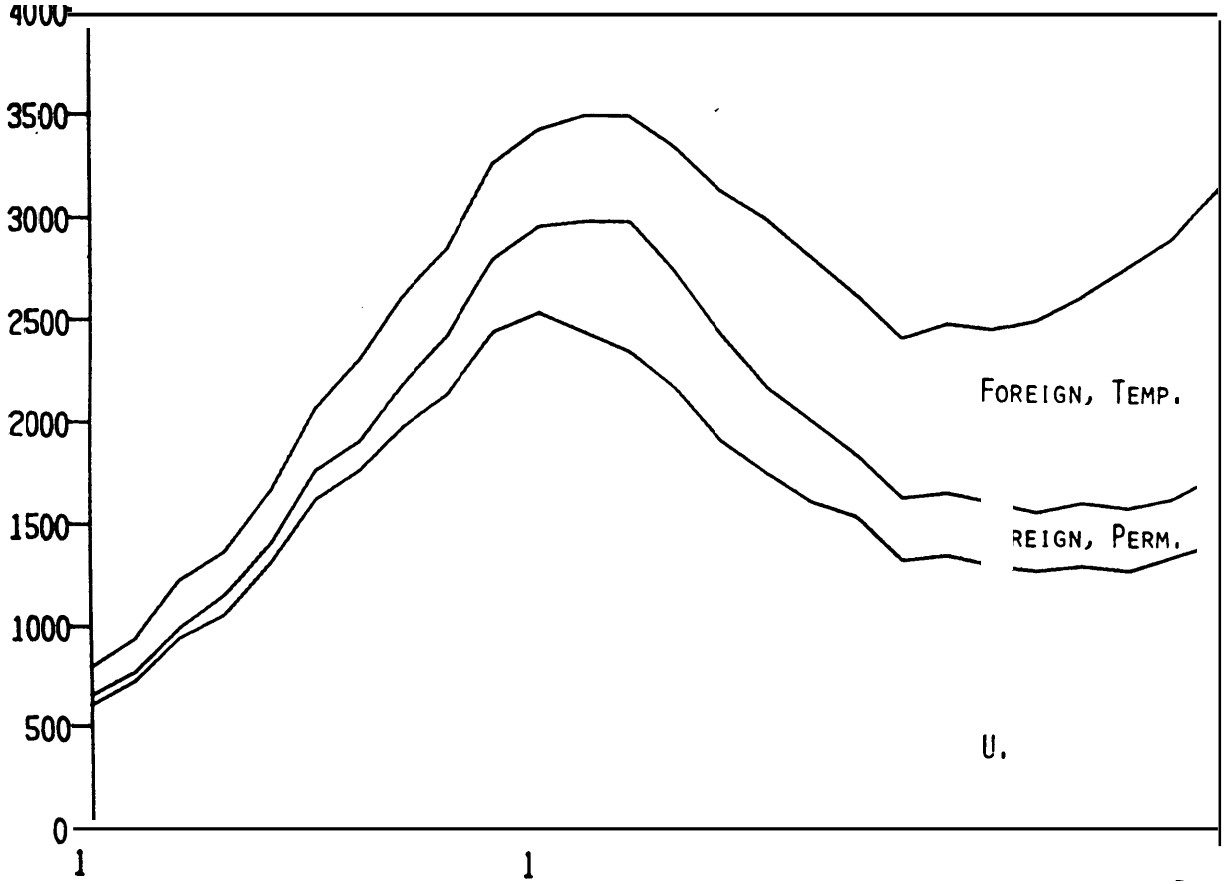


Source: Engineering Manpower Commission

BS Degrees in Engineering
1975-1985



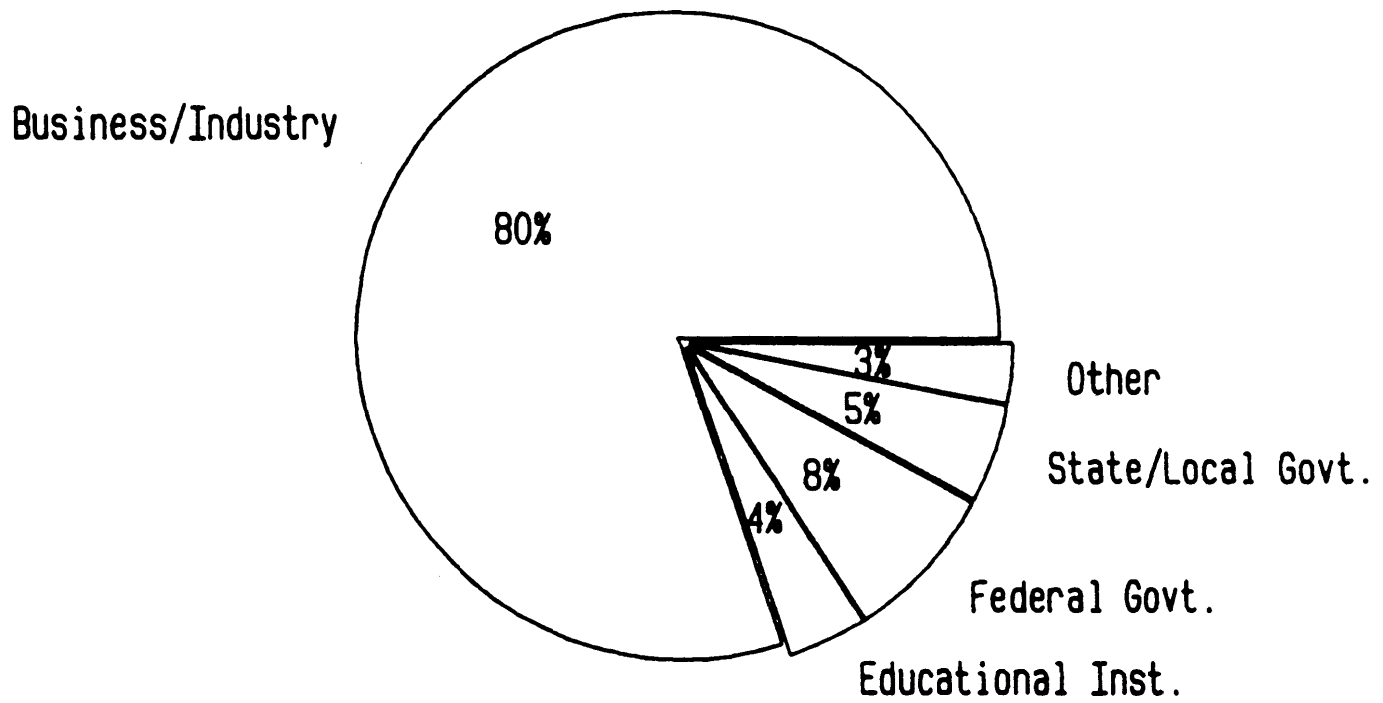
Source: Engineering Manpower Commission



*INCLUDES UNKNOWN CITIZENSHIP

SOURCE: NATIONAL RESEARCH COUNCIL

Wher≤ ^ll Engineers* Work, 19



*ALL DEGREES

SOURCE: NA ONAL ENC FOUNDATION

- There are approximately one million engineering technicians.[119] A minority are trained in 2-year and 4-year specialized engineering technician and technology programs (about 12,000 4-year bachelor% degrees and 14,000 to 20,000 2-year associate degrees were awarded in engineering technology in 1984).[120]
- Electronics and electrical technicians are by far the largest category, about 40 percent of engineering technicians and technician level degrees.[121]

Foreign Nationals

- The influx of foreign students is particularly apparent in engineering. Over 40 percent of recent engineering Ph.D.s have been awarded to foreign students on temporary visas (over 50 percent including those on permanent visas), up from 30 percent in 1975.[122]
- Forty-two percent of full-time graduate students in Ph.D.-granting institutions are foreign.[123] (They are 30 percent of all graduate students, as they are much more likely than the U.S. students to study full-time and to continue on for a Ph.D.). Foreign students have received a steady 7 to 9 percent of bachelor's engineering degrees since the mid-1970s. Their share of master% degrees increased slightly during the 1970s to 25-28 percent, which has held steady since 1980. Foreign

119. Betty *M.* Vetter and Eleanor L. Babco, Professional Women and Minorities: A Manpower Data Resource Service, 5th ed. (Washington, DC: Scientific Manpower Commission, August 1984), p. 198, Table 7-31.
120. Ibid., p. 192, Table 7-25. Unpublished data for 1984 furnished by Betty Vetter.
121. Estimates of engineering technician population providedby Betty Vetter, Scientific Manpower Commission, basedon the Bureau of Labor Statistics data and the Engineering Manpower Commissionfs Engineering and Technology Degrees series. Vetter estimates 384,000 electrical/electronic technicians out of 984,000 total in 1985. Department of Education% National Center for Science unpublished data on engineering technology/technician degrees is significantly higher than Engineering Manpower Commission data.
122. National Science Foundation, Science and Engineering Doctorates: 1960-82, op. cit., pp. 30-31, 42-43, Table 2.
123. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, op. cit., p. 28, Table A-9.

engineering students are particularly important at the graduate level due to the paucity of American graduate students.

- The high demand for engineers has made it easier for foreign students to study and work in the United States. In particular, the shortage of academic engineering faculty has made university and college departments particularly dependent on foreign Ph.D.s.
- About half of foreign engineers (at all degree levels) stay on to work in the United States, after graduation. When those with permanent visas are included, the percentage rises to over 60 percent.[124] Foreign engineering students are much more likely to hold temporary visas than foreign science students; all of the increase in engineering Ph.D. awards has been due to foreign students on temporary visas.
- About 70 percent of the foreign students who receive engineering Ph.D.s are Asian,[125] and over 90 percent of Asian-American Ph.D. scientists and engineers are foreign born.[126]

Women and Minorities

- Women have shared in the engineering boom but their enrollment and degree-taking is now leveling off after a decade of rapid growth. [n 1985, women received 6 percent of engineering Ph.D.s, 11 percent of master's degrees, and 15 percent of bachelor% degrees.

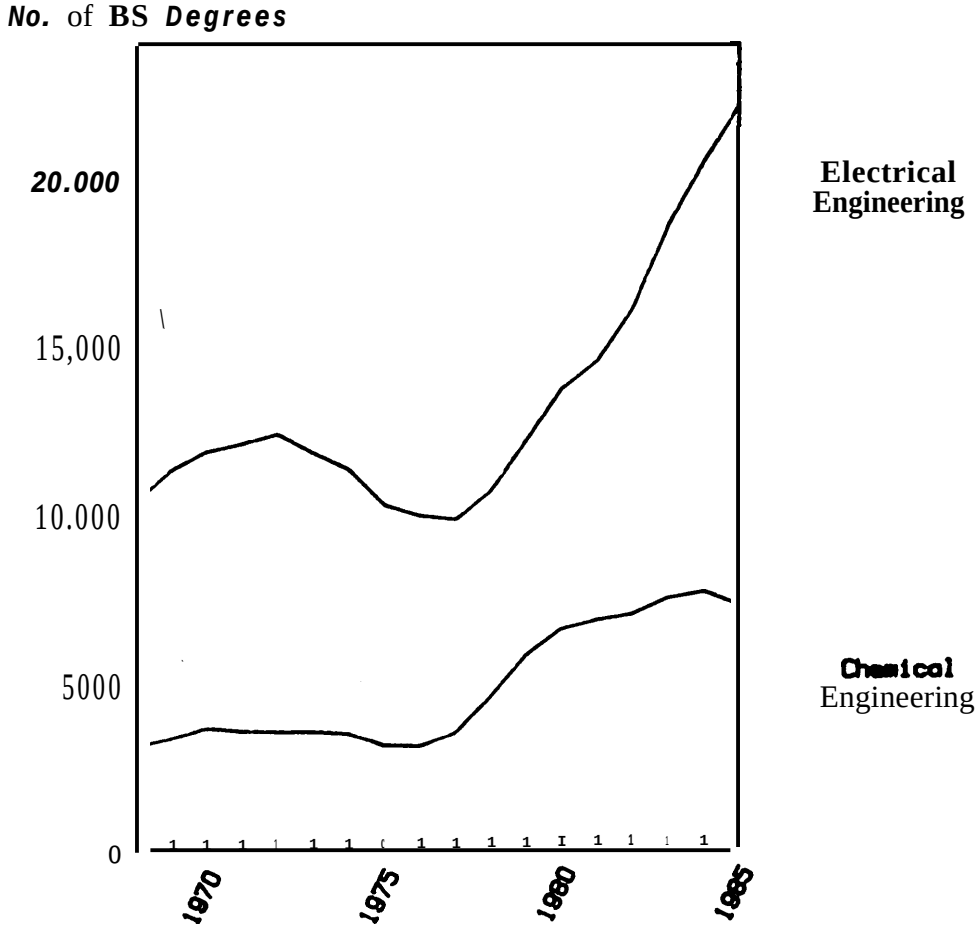
124. Oak Ridge Associated Universities, Labor and Policy Studies Program, Foreign National Scientists and Engineers in the Labor Force, 1972-1982, 0p. cit., p. 5.
125. National Science Foundation, Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook, op. cit., p. xiii.
126. National Research Council, Office of Scientific and Engineering Personnel, unpublished data from 1985 survey of doctorate recipients from U.S. universities.

- Women make up 3-6 percent of the engineering labor force.[127] **women engineers** tend to concentrate in certain subfields, particularly chemical, petroleum, and industrial engineering, and are less likely to choose electrical and computer engineering. Their greatest increase has been in mechanical engineering.
- The slow inroads of blacks and Hispanics into engineering have stalled. The attrition rate for blacks and Hispanics in engineering is much higher than for whites or Asians; about half of Hispanics and just one-third of blacks among engineering freshmen successfully complete an undergraduate engineering program, compared to an average for all freshmen of 70 percent.
- Blacks are about 2 percent of all employed **engineerss.**[128] Together, blacks, Hispanics, and Native Americans are about 5 percent of engineers. Asian-Americans are an additional 7 percent.
- Minorities in engineering are particularly underrepresented at the Ph.D. level in comparison to the sciences. Between 1958 and 1983, blacks received 0.5 percent of engineering Ph.D.s. Of 1985 bachelor's engineering degrees, less than 3 percent went to blacks, and less than 4 percent to Hispanics and over 5 percent to Asians.
- Asians are doing well in engineering. They received over 5 percent of the bachelor's and over 7 percent of the Ph.D. degrees awarded in engineering in 1985. Most of these degree recipients, however, are foreign-born Asian immigrants.

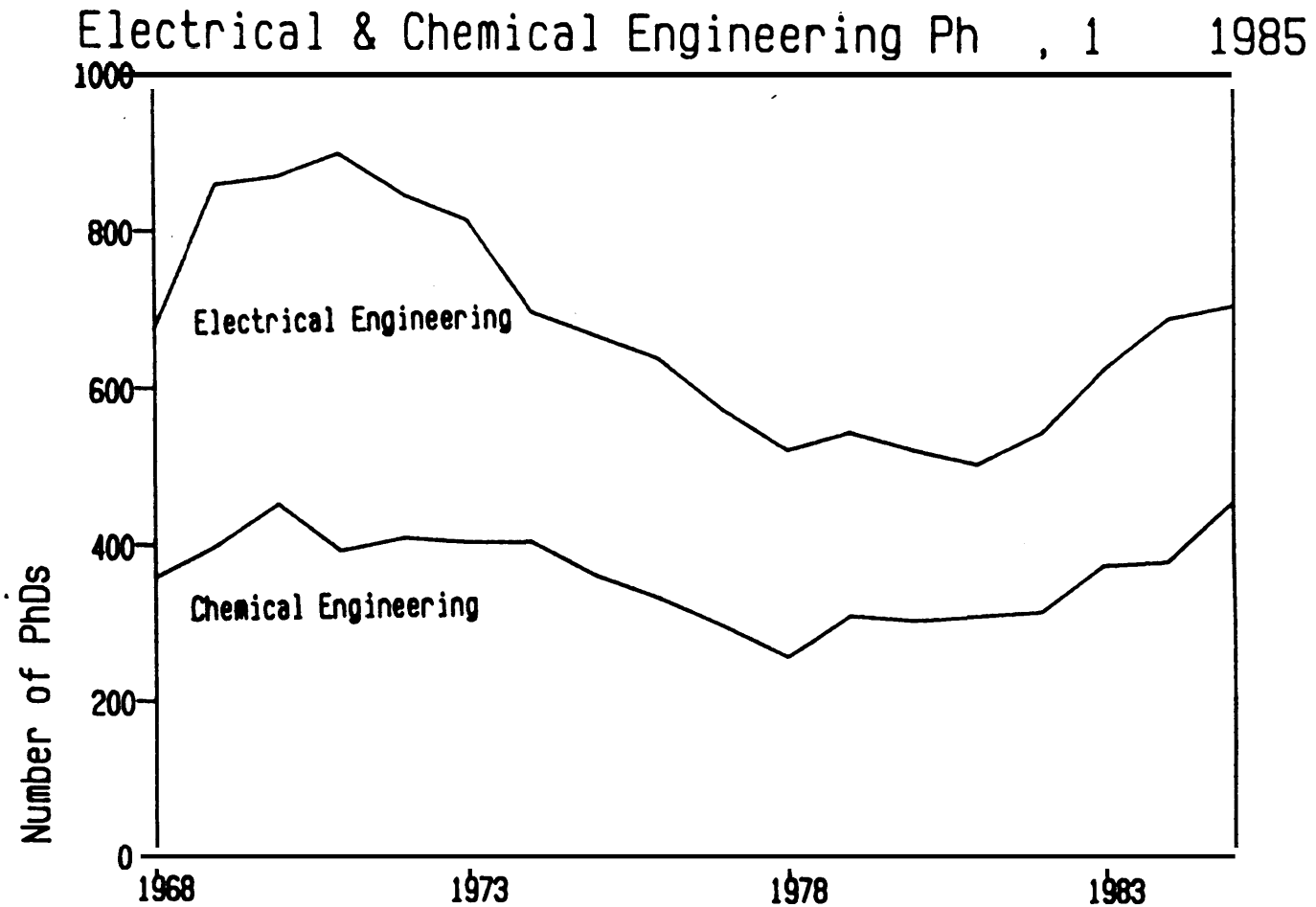
127. The National Science Foundation estimates 3.3 percent in 1984, the Bureau of Labor Statistics reports 6.7 percent in 1985. National Science Foundation, U.S. Scientists and Engineers: 1984, op. cit., p. 37, Table B-1.

128. National Science Foundation estimates 1.8 percent in 1986, the Bureau of Labor Statistics reports 2.6 percent in 1985. ibid.,p. 42, Table B-2.

Engineering ES Degrees, 1968-1985



Source Engineering Commission



SOURCE: ENGINEERING MANPOWER COMMISSION

CHEMICAL ENGINEERING

Supply and Demand

- There are 64,000 to 163,000 chemical engineers employed in the United States. Of these, over 90 percent, are employed in S/E positions. Women make up about 7 percent of the chemical engineering S/E work force. Over 90 percent of the S/E chemical engineers work in business and industry, mostly in industries related to chemical production and petroleum refining.[129] Consequently, the job market fluctuates with the business cycles of the petroleum industry.
- Currently there is an excess of chemical engineers, particularly at the bachelor% level, where unemployment is among the highest for recently graduated engineers. Changes in industry research and development (R&D) priorities have generated the current surplus of petrochemical engineers and shortage of biochemical/bioprocess engineers.
- Undergraduate interest in chemical engineering tracks the current job market, with a 4-year lag in degrees. The 7,300 bachelor% degrees awarded in 1985 is down from 1984, following a steady increase through the 1970s and early 1980s. Master's degrees were awarded to 1,600 in 1985, continuing a slow increase. Ph.D. awards have increased slowly since 1980, to 460 in 1985. Dauffenbach and Fiorito project a small rise in chemical engineering bachelor% degrees by 1995, and faster increases in master's and Ph.D. degrees.[130]
- Chemical engineers (and petroleum engineers) are twice as likely as other engineers to go on for a Ph.D. and are the most likely to do postdoctoral research. This may

129. The Bureau of Labor Statistics reported 64,000 chemical engineers in 1985; the National Science Foundation estimates 163,100 chemical engineers employed in the United States for 1986. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Tables B-l and B-13, unpublished data.
130. Robert C. Dauffenbach and Jack Fiorito, The Engineering Degree Conferral Process: Analysis, Monitoring, and Projections (Washington, DC: Engineering Manpower Commission, November 1984), p. 58, Table IV-1.

in part be due to the relatively more R&D-intensive, centralized structure of the chemical industry, their major employer.

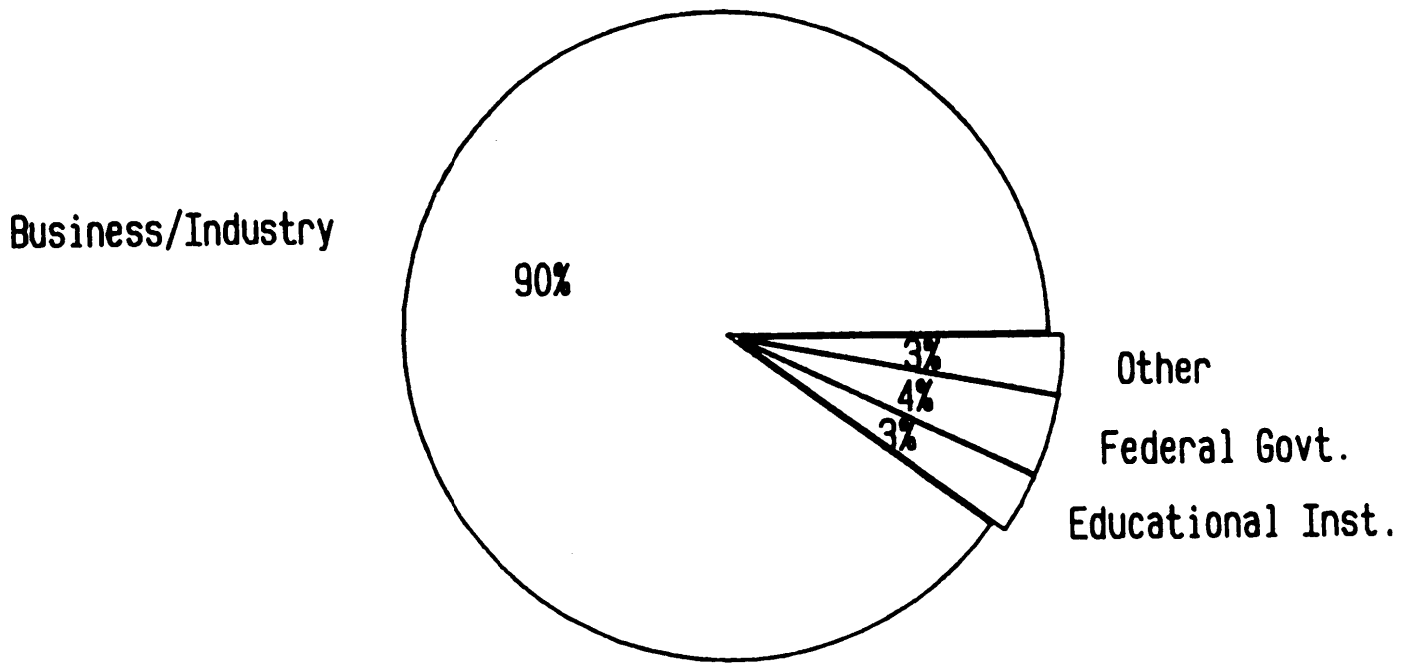
- There are about 7,000 employed Ph.D. chemical engineers, about 40 percent in R&D. They and petroleum engineers are the highest paid engineers. Most Ph.D.s still go into industry rather than academia— two-thirds are in industry, one-quarter in universities and colleges, 3 percent in nonprofit institutions, and 2.5 percent Federally employed.[131]

Women, Minorities, and Foreign Nationals

- Chemical engineering has long been one of the most fruitful engineering specialties for women. Women now earn over a quarter of bachelor's chemical engineering degrees, 11 percent of master's degrees, and 6 percent of Ph.D.s.[132] They are 15 percent of graduate students and about 6 percent of chemical engineers in universities and colleges.
- Minority representation in chemical engineering is typical: among bachelor% recipients, 3 percent are black, 1-2 percent are Hispanic, and 5 percent are Asian.[133]
- Chemical engineering attracts relatively few foreign students; they earn about 5 percent of bachelor's chemical engineering degrees, a proportion that exceeded 8 percent in 1976.

131. National Science Foundation, Characteristics of Doctoral Scientists and Engineers in the United States, NSF85-303 (Washington, DC: 1985), p. 22? Table B-5.
132. Engineering Manpower Commission, Engineering and Technology Degrees (Washington, DC: American Association of Engineering Societies, published annually).
133. Ibid.

Where Chemical Engineers Work, 1986



*ALL DEGREES

SOURCE: NATIONAL SCIENCE FOUNDATION

- Chemical engineering is the only engineering specialty where foreign nationals have steadily decreased as a proportion of full-time graduate enrollments (since 1977).[134] However, the most recent National Science Foundation estimates show an increase in the proportion of foreign full-time graduate students to 40 percent.

134. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, op. cit., pp. 104, 130-31, Tables C-6, C-27, C-28.

ELECTRICAL ENGINEERING

Supply and Demand

- Electrical and electronic engineering is the largest engineering specialty. In 1986, there are 580,000 electrical and electronic engineers employed in the United States. According to the National Science Foundation, of these, 95 percent are working in S/E positions with over 80 percent employed in business and industry, primarily the electronics and computer industries. Women make up 2 percent of the electrical and electronic engineering work force. About 3 percent of all employed electrical and electronic engineers hold Ph.D. degrees. [135]
- Slightly more than one-quarter of all engineering bachelor's degrees and slightly less than one-quarter of all engineering Ph.D.s are in electrical engineering. [136]
- High industrial demand and high salaries spurred a doubling of bachelor's awards in electrical engineering between 1975 and 1985, from 10,000 to 22,000. Master% awards have slowly increased since 1979 to 5,500. Following the engineering-wide decline in Ph.D. awards through the 1970s, electrical engineering Ph.D. awards did not begin to increase until 1981, in great part because of the high demand for bachelor's electrical engineers.
- Dauffenbach and Fiorito project a 65 percent increases in bachelor's wards and [20] percent increase in Ph.D.s by 1995 due to continued expansion of computer and electronics applications in all industries. [137]
- Electrical engineering is a bachelor% level field. Of the over one-half million employed electrical engineers, less than 5 percent have a Ph.D. Those who do earn

135. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Tables B-l$_s$B-ll, and B-13, unpublished data.
136. Engineering Manpower Commission, Engineering and Technology Degrees, op. cit.
137. Robert C. Dauffenbach and Jack Fiorito, The Engineering Degree Conferral Process: Analysis, Monitoring, and Projections, op. cit., p. 58, Table IV-1.

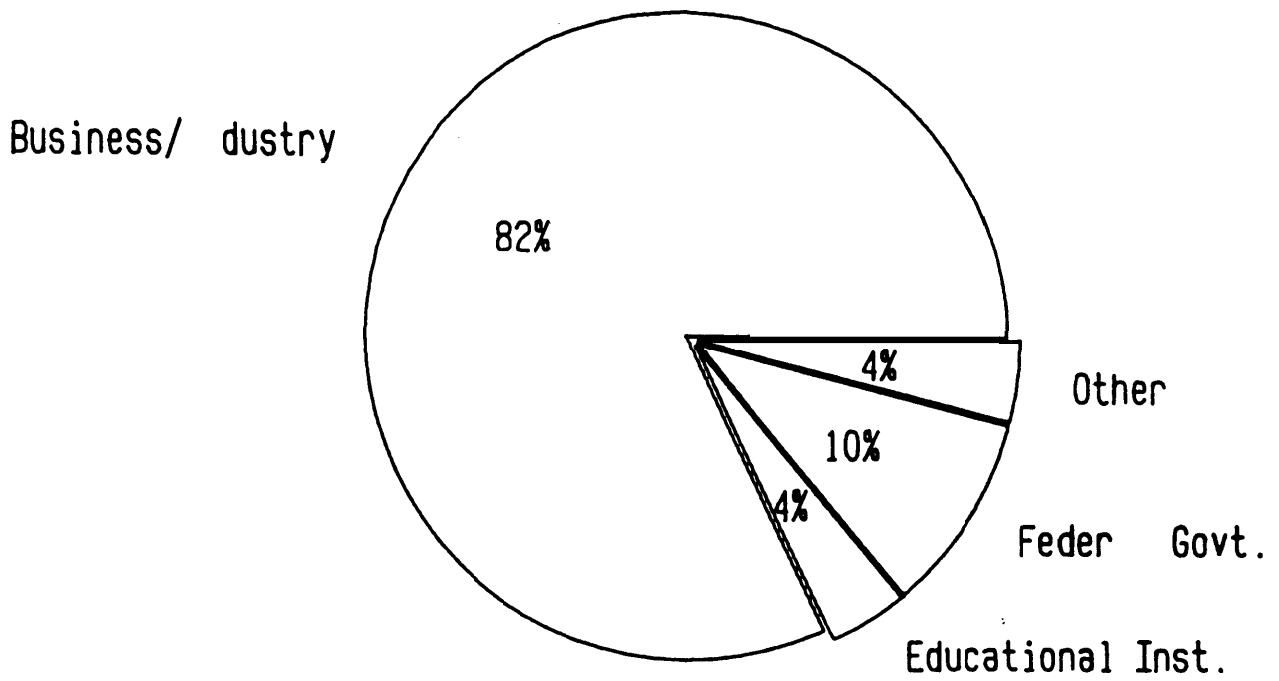
a Ph.D. are more likely to go into academic teaching than are chemical engineers. Most Ph.D.s, however, still go into industry. [138]

Foreign Nationals, Minorities, and Women

- The vigorous worldwide computer and electronics market has attracted many foreign students to enroll in U.S. electrical engineering programs. Foreign students have earned 8 to 9 percent of bachelor's electrical engineering degrees since 1980 and nearly half of Ph.D.s. Electrical and computer engineering host the fastest growing number of foreign students.
- Asian-Americans have been particularly successful in electrical engineering, while other minorities lag behind. Blacks and Hispanics each earn a constant 3 percent of bachelor's degrees, while Asians have increased their share to over 8 percent of bachelor's awards. Among graduate students, Asians outnumber both blacks and Hispanics by four to one.
- Women have slowly but surely made their way into electrical engineering. They earn about 10 percent of the bachelor's degrees, but account for only 2 percent of the employment in electrical engineering.

138. National Science Foundation. Characteristics of Doctoral Scientists and Engineers in the United States 1983, op. cit., p. 22, Table B-5.

Where Electrical Engineers* Work, 1986



*ALL

SOURCE: NATIONAL SCIENCE FOUNDATION