National Science Board

Science and Engineering Indicators 2006

Volume 1

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Cover Image

Computer simulation of the merger of two black holes and the ripples in spacetime—known as gravitational waves—born of the merger.

This simulation is one of a series depicting orbiting black holes and represents the first time that three-quarters of the full orbit of a black hole has been computed. Researchers from the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Potsdam, Germany, created the simulations in 2002 on the National Center for Supercomputing Applications (NCSA) Itanium-based Linux computational cluster. The visualizations are by Werner Benger of the Albert Einstein Institute and the Konrad-Zuse-Zentrum in Berlin. *(Credit: scientific contact, Ed Seidel, eseidel@aci.mpg.de; Max Planck Institute for Gravitational Physics—Albert Einstein Institute [AEI]; Werner Benger, Zuse Institute and AEI.)*

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National Science Board

January 13, 2006

The Honorable George W. Bush
The President of the United States
The White House
Washington, DC 20500

Dear Mr. President:

It is my honor to transmit to you, and through you to the Congress, the seventeenth in the series of biennial Science Indicators reports, *Science and Engineering Indicators 2006*. The National Science Board submits this report in accordance with Sec. 4(j)1 of the National Science Foundation Act of 1950, as amended.

The Science Indicators series was designed to provide a broad base of quantitative information about U.S. science, engineering, and technology for use by public and private policymakers. With each new edition, the Board seeks to continually expand the data sources and pertinence to the broad user community. *Science and Engineering Indicators 2006* contains analyses of key aspects of the scope, quality, and vitality of the Nation's science and engineering enterprise and global science and technology.

The report presents information on science, mathematics, and engineering education at all levels; the scientific and engineering workforce; U.S. and international research and development performance and competitiveness in high technology; and public attitudes and understanding of science and engineering. A chapter on state-level science and engineering presents state comparisons on selected indicators. Because of the widespread upgrading of scientific and technological capabilities around the world, the Overview chapter of this report focuses on global science and technology, including international trends and the U.S. position in the global context.

I hope that you, your Administration, and Congress will find the new quantitative information and analysis in the report useful and timely for informed thinking and planning on national priorities, policies, and programs in science and technology.

Respectfully yours,

Warren M. Washington
Chairman

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Contents

Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
ACS	American Community Survey
AP	Advanced Placement
ATP	Advanced Technology Program
AUTM	Association of University Technology Managers
BEA	U.S. Bureau of Economic Analysis
BLS	U.S. Bureau of Labor Statistics
CATI-MERIT	Cooperative Agreements and Technology Indicators database, Maastricht Economic Research Institute on Innovation and Technology
CCD	Common Core of Data
CDC	U.S. Centers for Disease Control and Prevention
CORE	Cooperative Research (database)
CPS	Current Population Survey
CRADA	cooperative research and development agreement
DHS	U.S. Department of Homeland Security
DNA	deoxyribonucleic acid
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DVR	digital video recorder
EDP	electronic data processing
ELS	Education Longitudinal Study
EPO	European Patent Office
EPSCoR	Experimental Program to Stimulate Competitive Research
ESP	extrasensory perception
EU	European Union
FASB	Financial Accounting Standards Board
FDA	U.S. Food and Drug Administration
FDI	foreign direct investment
FDIUS	Survey of Foreign Direct Investment in the United States
FFRDC	federally funded research and development center
FS&T	federal science and technology
FY	fiscal year
G-7	Group of Seven
G-8	Group of Eight
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GED	General Educational Development
GM	genetically modified
GPA	grade point average
GSP	gross state product
GSS	General Social Survey
GUF	general university fund
HHS	U.S. Department of Health and Human Services
HS&B	High School and Beyond Study
IB	International Baccalaureate
ICT	information and communications technologies
IOF	involuntary out of the field
IPR	intellectual property right
IRI	Industrial Research Institute
IRS	Internal Revenue Service
ISI	Institute for Scientific Information
ISIC	International Standard Industrial Classification
IT	information technology
MER	market exchange rate
MMR	measles, mumps, and rubella
MNC	multinational corporation
NAEP	National Assessment of Educational Progress
NAGB	National Assessment Governing Board
NAICS	North American Industry Classification System
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASF	net assignable square feet
NCES	National Center for Education Statistics
NCLB	No Child Left Behind Act of 2001
NCRA	National Cooperative Research Act
NCRPA	National Cooperative Research and Production Act
NELS	National Education Longitudinal Study
NIH	National Institutes of Health
NIOEM	National Industry-Occupation Employment Matrix
NIPA	national income and product account
NIST	National Institute for Standards and Technology
NITRD	Networking and Information Technology Research and Development
NNI	National Nanotechnology Initiative
NRC	National Research Council
NS&E	natural sciences and engineering
NSB	National Science Board
NSCG	National Survey of College Graduates
NSF	National Science Foundation
NTU	National Technological University

OECD	Organisation for Economic Co-operation and Development
OMB	U.S. Office of Management and Budget
PBS	Public Broadcasting Service
PCT	Patent Cooperation Treaty
PDA	personal data assistant
PhRMA	Pharmaceutical Research and Manufacturers of America
PISA	Programme for International Student Assessment
PPP	purchasing power parity
PRO	public research organization
PTO	U.S. Patent and Trademark Office
PUMS	Public Use Microdata Sample
R&D	research and development
R&E	research and experimentation
RA	research assistantship
S&E	science and engineering
S&T	science and technology
SBIR	Small Business Innovation Research
SCI	Science Citation Index
SESTAT	Scientists and Engineers Statistical Data System
SFAS	Statement of Financial Accounting Standards
SNA	System of National Accounts
SRS	Division of Science Resources Statistics
SSCI	Social Sciences Citation Index
STEP	Science, Technology and Economic Policy Board
STTR	Small Business Technology Transfer Program
TA	teaching assistantship
TIMMS	Trends in International Math and Science Study
UFO	unidentified flying object
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	U.S. Department of Agriculture
USDIA	Survey of U.S. Direct Investment Abroad
VCU	Virginia Commonwealth University
WebCASPAR	Integrated Science and Engineering Resources Data System
YSD	years since highest degree

About Science and Engineering Indicators

Science and Engineering Indicators (SEI) is first and foremost a volume of record comprising the major high quality quantitative data on the U.S. and international science and engineering enterprise. SEI is factual and policy-neutral. It does not offer policy options and it does not make policy recommendations. SEI employs a variety of presentational styles—tables, figures, narrative text, bulleted text, web-based links, highlights, introductions, conclusions, reference lists—to make the data accessible to readers with different information needs and different information processing preferences.

The data are "indicators." Indicators are quantitative representations that might reasonably be thought to provide summary information bearing on the scope, quality, and vitality of the science and engineering enterprise. The indicators reported in SEI are intended to contribute to an understanding of the current environment and inform the development of future policies. SEI does not model the dynamics of the enterprise, and it avoids strong claims about the significance of the indicators it reports. SEI is used by readers who hold a variety of views about which indicators are most significant for different purposes.

SEI is prepared by the National Science Foundation's Division of Science Resources Statistics (SRS) on behalf of the National Science Board. It is subject to extensive review by outside experts, interested federal agencies, NSB members, and SRS internal reviewers for accuracy, coverage, and balance.

SEI includes more information about measurement than many readers unaccustomed to analyzing social and economic data may find easy to absorb. This information is included because readers need a good understanding of what the reported measures mean and how the data were collected in order to use the data appropriately. SEI's data analyses, however, are relatively accessible. The data can be examined in various ways, and SEI generally emphasizes neutral, factual description and avoids unconventional or controversial analysis. As a result, SEI almost exclusively uses simple statistical tools that should be familiar and accessible to most readers. Readers comfortable with numbers and percentages and equipped with a general conceptual understanding of terms such as "statistical significance" and "margin of error" will readily understand the statistical material in SEI.

SEI's Different Parts

SEI consists of seven chapters that follow a generally consistent pattern; an eighth chapter, on state indicators, presented in a unique format; and an overview that precedes these eight chapters. The chapter topics are

- Elementary and Secondary Education
- Higher Education in Science and Engineering
- Science and Engineering Labor Force
- Research and Development: Funds and Technology Linkages
- Academic Research and Development
- Industry, Technology, and the Global Marketplace
- Science and Technology: Public Attitudes and Understanding
- State Indicators

An appendix volume contains tables keyed to the first seven chapters. SEI is available on the NSF website (http://www.nsf.gov/statistics/seind06/), and the paper volume is accompanied by a CD-ROM version and pocket size Information Cards. The web version includes presentation graphics. A policy-oriented "companion piece," authored by the National Science Board (NSB) and providing NSB analyses and recommendations, often accompanies SEI and draws on its data.

The Seven Core Chapters

Each chapter consists of front matter (table of contents and lists of sidebars, text tables, and figures), highlights, an introduction (chapter overview and chapter organization), a narrative synthesis of data and related contextual information, a conclusion, notes, a glossary, and references.

Highlights. The highlights provide an outline of major dimensions of a chapter topic. They are intended to be suitable as the basis for a presentation that would capture the essential facts about a chapter topic. As such, they are prepared for a knowledgeable generalist who seeks an organized generic presentation on a topic and does not wish to develop a distinctive perspective on the topic, though s/he may wish to flavor a standard presentation with some distinctive insights. They also provide a brief version of the "meat" of the chapter.

Introduction. The chapter overview provides a brief explanation of why the topic of the chapter is important. It situates the topic in the context of major concepts, terms, and developments relevant to the data that the chapter reports. The introduction includes a brief narrative account of the logical flow of topics within the chapter.

Narrative. The chapter narrative is a descriptive synthesis that brings together significant findings. It is also a balanced presentation of contextual information that is useful for interpreting the findings. As a descriptive synthesis, the narrative aims to (1) enable the reader to comfortably assimilate a large amount of information by putting it in an order that facilitates comprehension and retention and (2) order the

material so that major points readily come to the reader's attention. As a balanced presentation, the narrative aims to include appropriate caveats and context information such that (3) a non-expert reader will understand what uses of the data may or may not be appropriate, and (4) an expert reader will be satisfied that the presentation reflects a good understanding of the policy and fact context in which the data are interpreted by users with a range of science policy views.

Figures. Figures provide visually compelling representations of major findings discussed in the text. Figures also enable readers to test narrative interpretations offered in the text by examining the data themselves.

Text Tables. Text tables help illustrate points made in the text.

Sidebars. Sidebars discuss interesting recent developments in the field, more speculative information than is presented in the regular chapter text, or other special topics. Sidebars can also present definitions or highlight crosscutting themes.

Appendix Tables. Appendix tables, which appear in Volume 2 of SEI, provide the most complete and neutral presentation of quantitative data, without contextual information or interpretive aids. According to past surveys of SEI users, even experienced expert readers find it helpful to consult the chapter text in conjunction with the appendix tables.

Conclusion. The conclusion summarizes important findings. It offers a perspective on important trends, but stops short of definitive pronouncements about either likely futures or policy implications. Conclusions tend to avoid factual syntheses that suggest a distinctive or controversial viewpoint.

References. SEI includes references to data sources cited in the text, stressing national or internationally comparable data. SEI does not review the analytic literature on a topic or summarize the social science or policy perspectives that might be brought to bear on it. References to that literature are included only where they are necessary to explain the basis for statements in the text. SEI does not reference many suggestive analyses of national and international patterns and trends that use more limited or less reliable data sources than those in SEI.

The State Indicators Chapter

This chapter consists of data that can be used by people involved in state-level policy-making, including journalists and interested citizens, to assess trends in S&T-related activities in their states. Indicators are drawn from a range of variables, most of which are part of the subject matter of the seven core chapters. The text explains the meaning of each indicator and provides important caveats about how to interpret it. Approximately 3 to 5 bullets highlight significant findings. The presentation is overwhelmingly graphic and tabular. It is dominated by a United States map that color codes states into quartiles and a table with state by state data.

There is no interpretive narrative to synthesize overall patterns and trends. SEI includes state level indicators to call attention to state performance in S&T and foster consideration of state level activities in this area.

Overview

The overview is a selective interpretive synthesis that brings together patterns and trends that unite data in several of the substantive chapters. The overview helps readers synthesize the findings in SEI as a whole and draws connections among separately prepared chapters that deal with related topics. It is intended to serve readers with varying levels of expertise. Because the overview relies heavily on figures, it is well adapted for use in developing presentations, and presentation graphics for the figures in the overview are available on the Web.

Like the core chapters, the overview strives for a descriptive synthesis and a balanced tone, and it does not take or suggest policy positions. But, whereas the priority for the core chapters is a comprehensive and neutral presentation of data, even at the cost of some internal coherence, the overview strives for greater coherence and permits more selectivity.

Presentation

SEI is released in printed and electronic formats. The printed version is published in 2 volumes: Volume 1 provides the main text content and Volume 2 provides the detailed tabular data. The complete content of the printed volumes is posted on the NSF website in html and pdf formats, with tables available in spreadsheet (MS Excel) format and source data associated with every figure. In addition, selected figures are also available in presentation format in MS PowerPoint and JPEG formats. Source data are also included.

The printed version of SEI includes a CD-ROM in PDF format and a packaged set of Information Cards in a pocket attached to the inside back cover. The CD-ROM is a complete version of SEI. As with the online version, appendix tables are presented in MS Excel format and the set of presentation graphics is included. The Information Cards highlight important patterns and trends. Each card presents a selection of figures with captions stating the major point the figure is meant to illustrate. A mini-CD-ROM containing the full volume is included with each card set.

SEI includes a list of abbreviations/acronyms and an index.

Overview

List of Figures

Introduction

This overview of the National Science Board's *Science and Engineering Indicators 2006* describes some major U.S. and international science and technology (S&T) developments. It focuses on trends since about 1990, although it occasionally takes a longer view. The overview synthesizes selected major findings in a meaningful way and is not intended to be comprehensive. The reader will find many important findings in the report that are not covered in the overview, e.g., public support for science is strong even though public knowledge is limited; S&T activities in different states vary substantially in size and scope; and some of those who are employed in S&T occupations lack S&T degrees, although many people with S&T degrees work in other types of jobs. The interested reader will find more extensive data in the body of the report; major findings on particular topics appear in the Highlights sections that precede chapters 1–7.

The reader should note the indicators included in *S&E Indicators 2006*, which derive from a variety of national, international, and private sources, may not be comparable in a strict statistical sense, especially for international data. In addition, some metrics and data are somewhat weak, and models relating them to each other and to economic and social outcomes are not well developed. Thus, even though many data series conform generally to international standards, the focus is on broad trends that should be interpreted cautiously.

The overview begins with a broad picture of major developments that are changing the location and conduct of international research and development and are recasting international high-technology markets. It then discusses changes in scientific research that, although less pronounced, show paths similar to earlier technology trends. Next it reviews evidence of widespread international upgrading of education levels and the increasing international mobility of highly educated individuals, especially since the 1990s. The analysis then examines relevant S&T patterns and trends in the United States on which these external changes have a bearing. To the extent possible, the overview presents comparative data for the United States, the European Union (EU) before enlargement,[1] Japan, China, and eight other selected Asian economies (Asia-8).[2]

S&T: The Global Picture

For S&T, it is a changed world.

Since the early 1990s, the globalization of S&T has proceeded apace. The demise of the Cold War political order precipitated more open borders just as the Internet became a tool for unfettered worldwide information dissemination and communication. Dense and relatively inexpensive airline links developed in response to a growing demand for both business and leisure travel. A more integrated trade regimen stimulated a vast expansion of international trade in goods and services. Governments increasingly looked to the development of knowledge-intensive economies—those in which research, its commercial exploitation, and other intellectual work have a major role—for economic competitiveness and growth. Companies seeking new markets set up operations in new locations, bringing with them technological know-how and management expertise. Governments anticipated and stimulated such moves with incentives, decreased regulatory barriers, development of infrastructure, and expanded access to higher education.

Asian countries outside Japan are increasingly important in the global S&T community.

The major development since the mid-1990s was the rapid emergence of Asian economies outside of Japan as increasingly strong players in the world's S&T system. South Korea and Taiwan were already well established in particular markets, and Singapore, Malaysia, Thailand, and others boosted their market strength and showed potential for further increases in competitiveness. China is growing at the most rapid pace, and its government has declared education and S&T to be the strategic engines of sustainable economic development. China has already become an important player in high-technology markets, has attracted the world's major corporations, and in 2004 was the world's largest recipient of foreign direct investment. In the area of scientific research, China does not yet approach parity with major science-producing nations, but its scientists and engineers are collaborating broadly with their counterparts in Asia and across the globe. In addition, China's international patenting and publishing activities, although still modest, are fast increasing. Fragmentary data on India suggest that it is also seeking rapid technological development focusing on knowledge-intensive service sectors and biotechnology.

Ubiquitous growth is coupled with share losses for traditional S&T locations.

The developments stated above are recasting the international S&T scene. In an absolute sense, growth is ubiquitous in both funding and personnel devoted to S&T activities and in outputs from these activities, including scientific articles, patents, and high-technology products. In a relative sense, the major European nations and the EU countries as a group are losing ground, as is Japan, whereas the United States is maintaining its position across a variety of measures. China is making large relative gains as are, to a lesser degree, other Asian economies. Other areas of the world such as Eastern Europe, central Asia, the Middle East, Latin America, and Africa, are slowly and selectively entering the international S&T scene but do not yet play a major role in the world's S&T system.

International R&D Performance

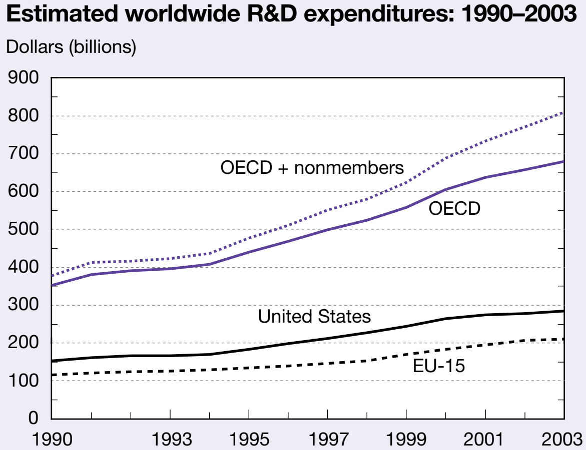
International R&D spending has seen robust increases.

Rising R&D expenditures are no longer limited to the member countries of the Organisation for Economic Co-operation and Development (OECD).[3] Based on OECD and nonmember economies,[4] the (underestimated) worldwide R&D expenditures, unadjusted for inflation, rose from $377 billion in 1990 to $810 billion in 2003, the last year of available data. The OECD countries' share dropped from an estimated 93% to 84% of the total over the period, based on the reported R&D expenditures of eight non-OECD members whose 1995–2003 average annual growth rate of 17.1% compared with 5.6% annual growth for OECD members (figure O-1).

Industrial R&D investments outpace those of governments.

Governments around the world are increasing their R&D funding in support of the development of high-technology industries. However, industry R&D support has often expanded more rapidly, leading to a declining share of government support in total R&D in many countries. The relative decline in the United States had been very steep—the federal government share fell from 48% in 1990 to a low of 26% in 2001. Changes after September 11, 2001, largely in defense and national security R&D, brought it back up to 31% in 2004. In the EU, the government share diminished from 41% in 1990 to 34% in 2001 (more current data are unavailable). Germany's 32% rate in 2003 was close to its 1990 level of 34%, after rising as high as 38%. Japan's rate, by far the lowest among OECD countries, has fluctuated between 18% and 23% over the period (figure O-2).

Figure O-1
Estimated worldwide R&D expenditures: 1990–2003



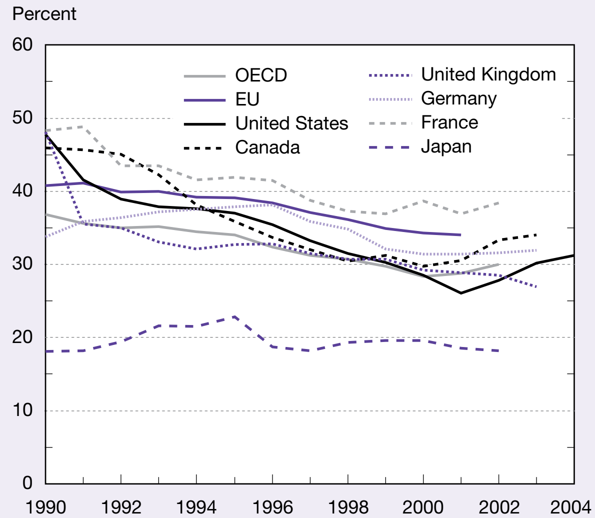
EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTE: Current dollars converted with purchasing power parities.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

Figure O-2
Government funds as share of gross expenditures for R&D: 1990–2004



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTE: Current dollars converted with purchasing power parities.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

Firms' cross-border R&D investments are increasing, as are cross-border alliances.

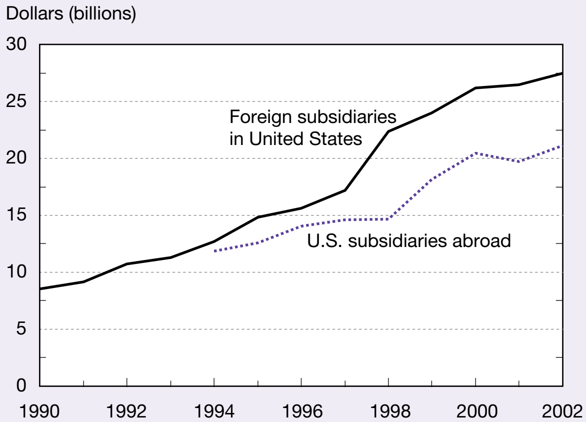
Industry is increasingly looking beyond national borders in the location of R&D activities, and the United States remains an attractive venue for foreign companies seeking to conduct R&D. From 1990 to 2002, R&D expenditures in the United States by majority-owned affiliates of foreign-based multinationals rose from 8% to 14% of total U.S. industrial R&D performance. R&D expenditures by U.S.-owned companies abroad rose from about $12 billion in 1994 to $21 billion in 2002 (figure O-3). In the United Kingdom, more than a quarter of its industrial R&D was supported by foreign sources in 2002, while Canada's foreign support rose to 21% and the EU-15's rose to 10%, including within-EU funds flows.

The global nature of S&T markets is also reflected in the rising number of companies' international alliances devoted to joint R&D or technology development. Industrial innovation increasingly involves external partners to complement internal capabilities, share costs, spread market risk, expedite projects, and increase sensitivities to geographic variations in product markets. To accomplish these ends, companies have resorted to a variety of technology alliances, often crossing national boundaries. The number of new international alliances rose from under 100 in 1980 to 183 in 1990 and 342 early in the new century. Historically, U.S. companies have been involved in 75% to 86% of these alliances (figure O-4).

Overseas, R&D spending by U.S.-based multinationals is increasing in Asia. Although Europe remains the single largest location of these R&D expenditures, accounting for

just over 60% of the total, its share has slipped by about 10 percentage points since 1994. Over the period, the combined share of Europe, Canada, and Japan declined from 90% to 80% of the total. The share of other Asian economies rose from 5% to 12% as R&D expenditures by U.S.-based multinationals more than doubled in the region starting in 1999, to about $3.5 billion, compared with $1.5 billion during the 1994–98 period. This increase was fueled primarily by steep investment growth in China (more than $1 billion in 2002 and rising) and the Asia-8 economies. U.S. R&D expenditures in Japan increased only moderately (figure O-5).

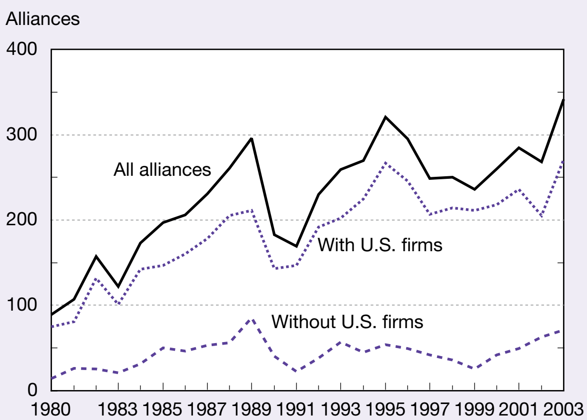
Figure O-3
R&D expenditures of foreign-owned firms in United States and of U.S.-owned firms abroad: 1990–2002



SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/bea/di/di1fdiop.htm; and Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm. See appendix tables 4-49 and 4-51.

Science and Engineering Indicators 2006

Figure O-4
New international technology alliances by membership: 1980–2003



NOTE: Includes business alliances with joint R&D or technology development agreements, contracts, or equity joint ventures.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

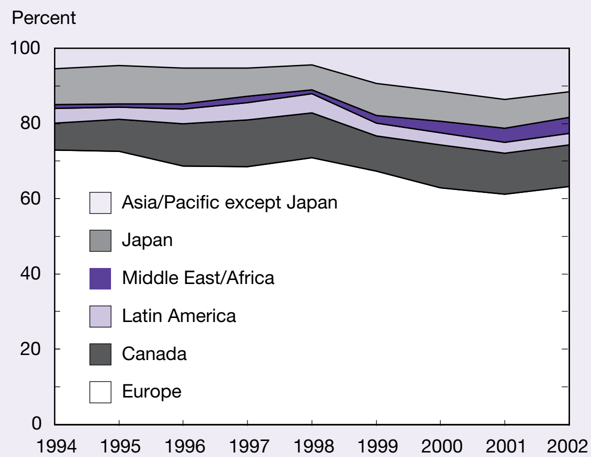
Science and Engineering Indicators 2006

China has become the world's third-largest R&D performer.

According to data compiled by OECD, Chinese R&D spending reached $84.6 billion in 2003, up from $12.4 billion in 1991. Although a question remains about the precise international comparability of the data, this would put China in third place, behind only the United States and Japan and ahead of Germany. Average annual increases in R&D investment over the 12-year period ranged from 4% to 5% for the United States, EU-25,[5] and Japan. These contrasted sharply with the 17% average annual growth for China, which is accelerating: for the past 5 years, China's R&D expenditures have registered 24% average annual increases. Over the period, China's R&D/gross domestic product ratio, indicative of the relative prominence of R&D in China's rapidly growing economy, rose from 0.6% to 1.3%, compared with about 1.8% for the EU-15 and 2.6% for the United States (figure O-6).

China's R&D expenditures are rapidly approaching those of Japan, the second largest R&D-performing nation. OECD data show China's investment at 17% of Japan's in 1991 but at 74% of Japan's in 2003. Relative to the EU-25, the comparable Chinese figures were 10% and 40%, and relative to the United States the increase was from 8% to 30% (figure O-7). Even if more fully comparable Chinese figures reduced the growth statistics somewhat, such a rapid advance on the leading R&D-performing countries and regions would still be unprecedented in recent history. It is underscored by the growth of China's industrial research workforce, which expanded from 16% of

Figure O-5
Geographic distribution of U.S. firms' overseas R&D: 1994–2002

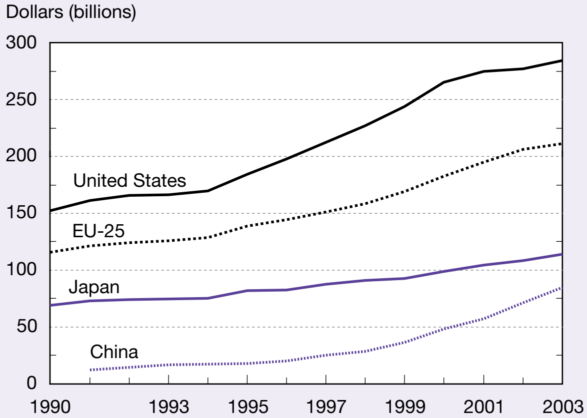


NOTE: R&D performed overseas by majority-owned affiliates of U.S. firms.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm. See appendix table 4-51.

Science and Engineering Indicators 2006

Figure O-6
R&D expenditures of selected region and countries: 1990–2003



EU = European Union

NOTES: All data calculated by Organisation for Economic Co-operation and Development (OECD) with purchasing power parities. Data differ somewhat from U.S. dollar figures. EU-25 is EU-15 plus 10 new member states.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

the size of its U.S. counterpart in 1991 to 42% in little more than a decade.

Growth in industrial R&D creates rising numbers of researchers around the world.

The number of industrial researchers has grown along with rapidly increasing industrial R&D expenditures. Across OECD member nations, employment of researchers by industry has grown at about twice the rate of total industrial employment. For the OECD as a whole, the full-time equivalent number of researchers more than doubled, from just below 1 million in 1981 to almost 2.3 million in 2002. Over the same period, the number of researchers in the United States rose from 0.5 million to nearly 1.1 million. Non-OECD members also show increasing researcher employment (figure O-8).

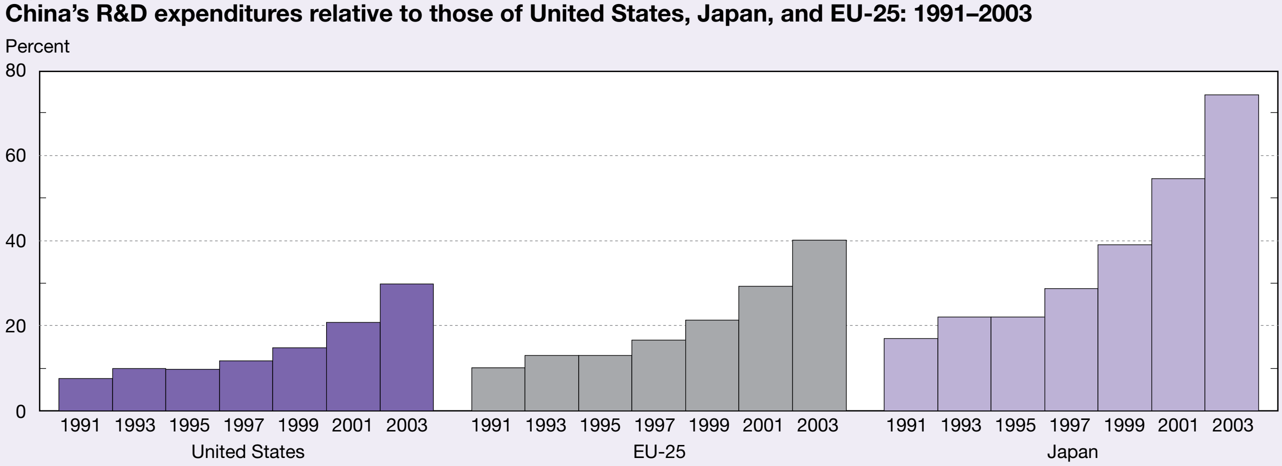
High-Technology Markets

Europe and Japan are losing market share in high-technology manufacturing

High-technology manufacturing industries embody the fruits of innovation. High-technology industry output has grown rapidly since 1990 and now comprises about one-fifth of the world's total manufacturing output. The United States, China, and other Asian economies have shifted into high-technology manufacturing sectors more rapidly than the EU-15 or Japan.

Overall world manufacturing output grew from $13.9 trillion in 1990 to $19.6 trillion in 2003 after adjusting for inflation. However, the manufacturing output of five high-technology industries (aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific instruments) grew faster, from $1.5 trillion to $3.5 trillion. The United States and developing Asian economies largely drove the worldwide growth in high-technology manufacturing. The resulting shifts in its geographical distribution were pronounced. Shares for the United States, the EU-15, and Japan were about 25% each in 1990, but by 2003 the U.S. share had risen to nearly 40%, while those of the EU-15 and Japan had declined to 18% and 11%, respectively. In 2003, China had surpassed Japan as a producer of high-technology

Figure O-7
China's R&D expenditures relative to those of United States, Japan, and EU-25: 1991–2003



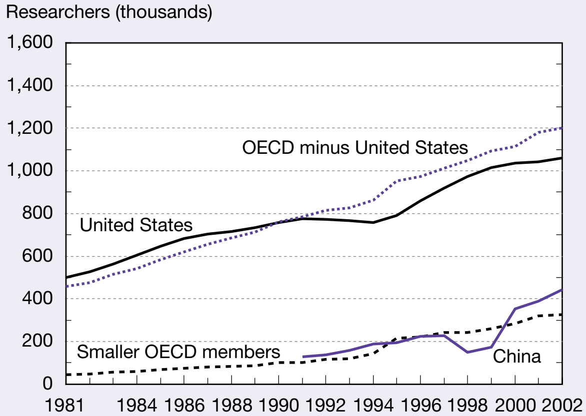
EU = European Union

NOTE: All data calculated by Organisation for Economic Co-operation and Development (OECD) with purchasing power parities.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

Figure O-8
Estimated number of industrial researchers, by country/region: 1981–2002



OECD = Organisation for Economic Co-operation and Development

NOTE: "Smaller OECD members" is OECD minus United States, Japan, United Kingdom, Germany, France, Italy, and Canada.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

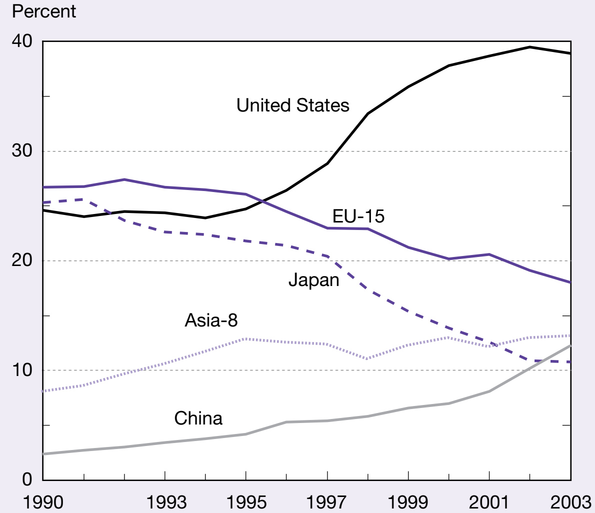
goods and accounted for 12% of the world market share, about the same as that of the Asia-8 (figure O-9).

The United States has rapidly developed the most high-technology-intensive manufacturing sector among major nations. Since 1990, U.S. high-technology manufacturing output has risen from 12% to 30% of total domestic manufacturing. The EU-15 shift was less pronounced, from 9% to 12%, and Japan's was minimal, from 14% to 15% (automobiles are excluded from the high-technology definition used here). China's fast-growing manufacturing sector (about the same size as Japan's by 2003) shifted rapidly toward high-technology production, boosting this component from 6% in 1990 to 18% in 2003. For the Asia-8, the high-techno logy manufacturing component expanded from 13% to 23% (figure O-10).

High-technology shares of Asian exporters are expanding.

Exports of all manufactured goods more than doubled from 1990 to 2003, but high-technology exports had greater increases and reached $1.9 trillion in 2003. The single largest volume was that of the EU-15, at almost one-third of the total since the mid-1990s; the combined Asia-8 exports were the second highest (figure O-11). The shares of China and the Asia-8 economies rose at the expense of the United States and Japan. U.S. high-technology exports stood at $305 billion in 2003, essentially the same level as in 2000, and the U.S. share declined from 23% to 16% during this period. The Japanese share dropped from 17% to 9%. China's rise from a mere $23 billion in 1990 to $224 billion in 2003, remarkable both for its speed and consistency, moved its share of world high-technology exports to 12%, beyond Japan's share.

Figure O-9
Location of world's high-technology manufacturing output: 1990–2003



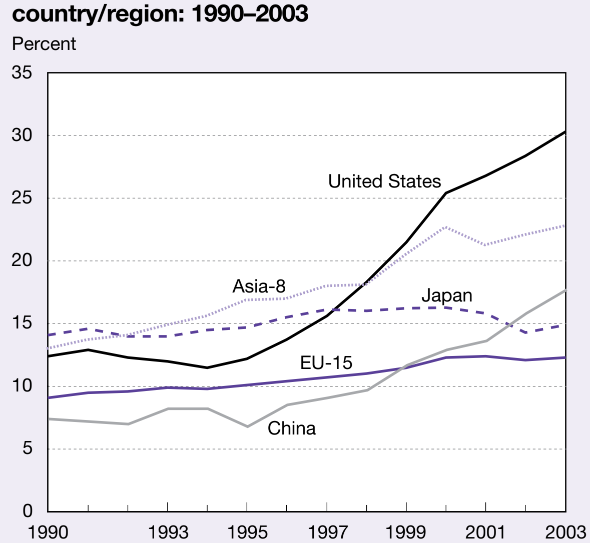
EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development, and country sources. See appendix table 6-2.

Science and Engineering Indicators 2006

Figure O-10
High-technology share of total manufacturing, by country/region: 1990–2003



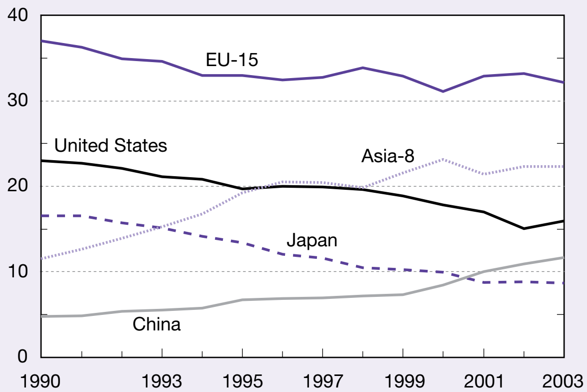
EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development, and country sources. See appendix table 6-2.

Science and Engineering Indicators 2006

Figure O-11
Export market shares in high-technology goods, by country/region: 1990-2003



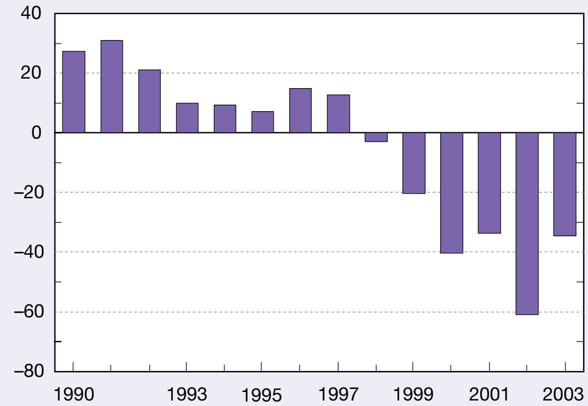
EU = European Union

NOTES: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand. These countries/regions account for 91%–93% of world total.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development, and country sources. See appendix table 6-4.

Science and Engineering Indicators 2006

Figure O-12
U.S. trade balance for five high-technology industries: 1990–2003



NOTE: Includes aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific instruments.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development; and country sources. See appendix table 6-4.

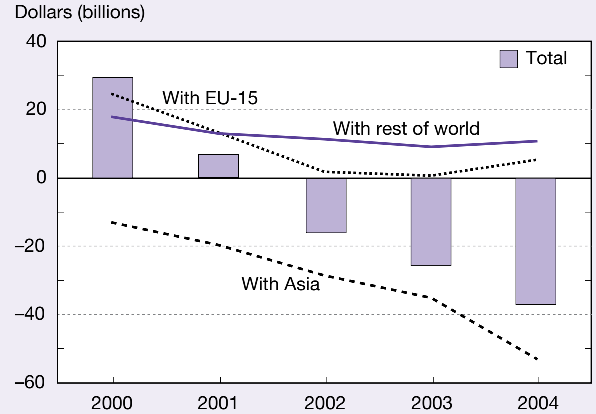
Science and Engineering Indicators 2006

The U.S. high-technology trade balance is negative.

The U.S. high-technology trade balance, which broadly reflects relative economic strengths and foreign exchange rate movements, has been closely watched as an indication of the international competitiveness of the nation's high-technology industries. For the first time in recent memory, the U.S. high-technology trade balance turned negative in the past several years (figure O-12). Trade data for five high-technology manufacturing industries (aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific instruments) show that, beginning in 1998, U.S. high-technology industries' imports exceed exports.

U.S. trade in goods with high-technology content yields a similar picture. For 10 high-technology product categories (biotechnology, life sciences, optoelectronics, information and communications equipment, electronics, flexible manufacturing, advanced materials, aerospace, weapons, and nuclear technology), U.S. trade turned negative in 2002 and stayed that way through 2004, the latest year for which data are available (figure O-13). A negative balance with the Asian region is partially offset by positive balances with the EU-15 and the rest of the world.

Figure O-13
U.S. trade balance in high-technology goods: 2000–04



EU = European Union

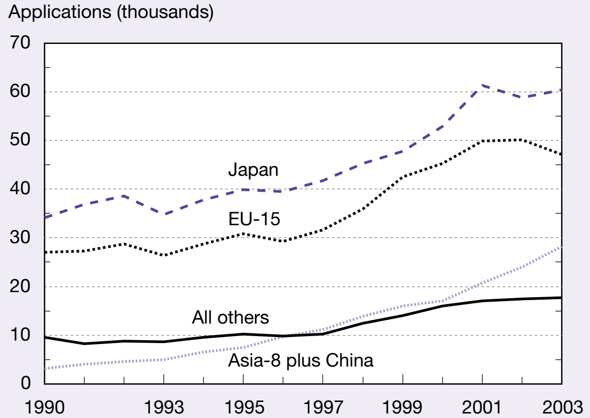
SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations (March 2005). See appendix table 6-6.

Science and Engineering Indicators 2006

Increasing Asian patent filings show growing technological sophistication.

Strong growth in the number of applications for U.S. patents by foreign-resident inventors, particularly from Asia, attests to the increase in technological sophistication in other parts of the world. The number of such filings has historically been just under half of the growing number of U.S. Patent and Trademark Office filings. Applications from Japanese inventors, traditionally the largest group of foreign filers, rose by about 75%, as did those from filers in Europe and other areas. However, as with many economic statistics, other Asian economies are an exception. Applications from China and the Asia-8 rose by 800% and, by 2003, constituted nearly one-fifth of all foreign-resident inventor filings (figure O-14). South Korea and Taiwan have now joined Japan among the top five inventor locations.

Figure O-14
U.S. patent applications by foreign-resident inventors: 1990–2003



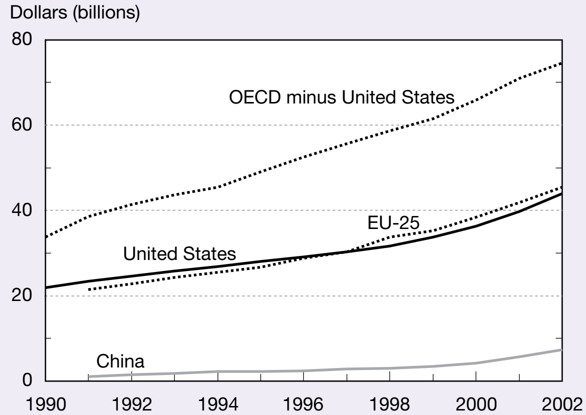
EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (December 2004). See appendix table 6-13.

Science and Engineering Indicators 2006

Figure O-15
Academic R&D expenditures: 1990–2003



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTES: All data calculated by OECD with purchasing power parities. EU-25 is EU-15 plus 10 new member states.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

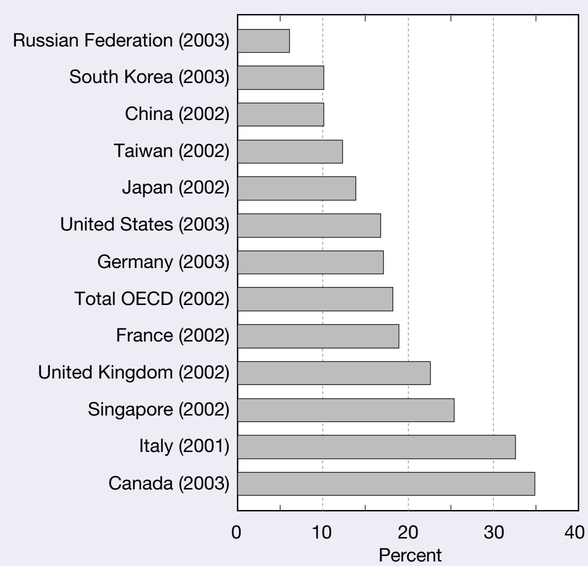
Scientific Research

Academic R&D has grown robustly but remains less prominent in Asia.

Academic R&D has seen robust growth in many countries as governments try to stimulate basic research capability and to connect universities with industry for the efficient exploitation of research results. The United States and the EU-25 (including 10 new member countries) have been spending similar amounts for academic R&D, $41 to $44 billion in 2003, about double their expenditures in 1990. OECD nations other than the United States spent $74 billion, an increase of 120% over 1990. However, China has experienced the most rapid growth in its spending for academic R&D, from $1.1 billion in 1991 to $7.3 billion in 2002, with double-digit growth rates since 1999 (figure O-15).

Nevertheless, the academic sector, where basic research is conducted in many countries, plays a relatively small role (about 10%) in China's R&D system. This is also the case in some other Asian countries, where R&D tends to focus more on applied research and especially on development. In other major OECD nations, the share of academic R&D was at least 14% (figure O-16).

Figure O-16
Academic R&D as share of total R&D, by country/economy: Most recent year



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

Scientific expertise is expanding, which diminishes the U.S. quality advantage.

Scientific expertise is developing rapidly outside the established scientific centers of the United States, the EU, and Japan, as shown by research articles published in the world's major peer-reviewed scientific and technical journals. The total number of articles rose from 466,000 in 1988 to 699,000 in 2003. Over the period, the combined share of the United States, Japan, and the EU-15 declined from 75% to 70% of the total, with flat U.S. article output from 1992 to 2002, leading to a drop of the U.S. share from 38% to 30%. Meanwhile, EU-15 output rose steadily to surpass that of the United States in 1998, and Japan's output also continued to rise. Output from China and the Asia-8 expanded rapidly

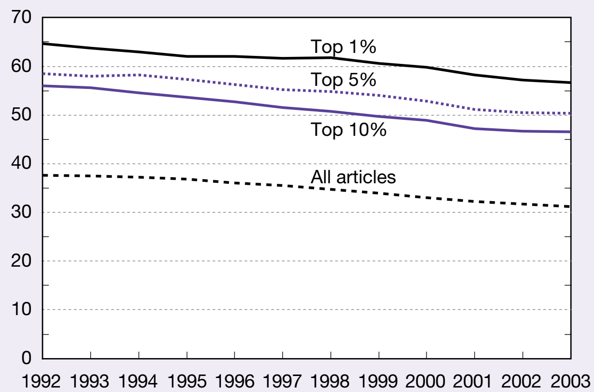
over the period, by 530% and 235%, respectively, boosting their combined share of the world total from less than 4% in 1988 to 10% in 2003. By 2003, South Korea ranked 6th and China ranked 12th in world article output. Increases in other parts of the world tended to be more modest (figure O-17).

Scientists acknowledge their colleagues' relevant work by citing it, and the aggregate of these citations provides an approximate measure of quality. Relative to its publications volume, U.S. scientific literature continues to receive a disproportionate share of all international citations. However, a closer look reveals that the quality of scientific output produced outside the United States is rising. An examination of articles published in the most prestigious journals included in the Science Citation Index[6] reveals that, in almost every field, the U.S. share of citations, while high, has declined significantly since 1990. The U.S. share of citations in the highest-cited articles has declined as well (figure O-18). In both cases, the declines are broadly proportional to the progressively lower share of U.S. articles.

International collaboration is commonplace.

The manner in which science and engineering is conducted is becoming increasingly international in response to the growing complexity of science, ease of face-to-face contact, the Internet, and government incentives. Overall, about 20% of the world's scientific and technical articles in 2003 had authors from two or more countries, compared with 8% in 1988. One-quarter of articles with U.S. authors have one or more international coauthors, which is similar to the percentages for Japan, China, and the Asia-8 (figure O-19). The higher EU level partially reflects the EU's emphasis on collaboration among the member countries as well as the relatively small science establishments of some members. Other countries'

Figure O-18
Share of U.S. articles among most-cited articles, total S&E: 1992–2003

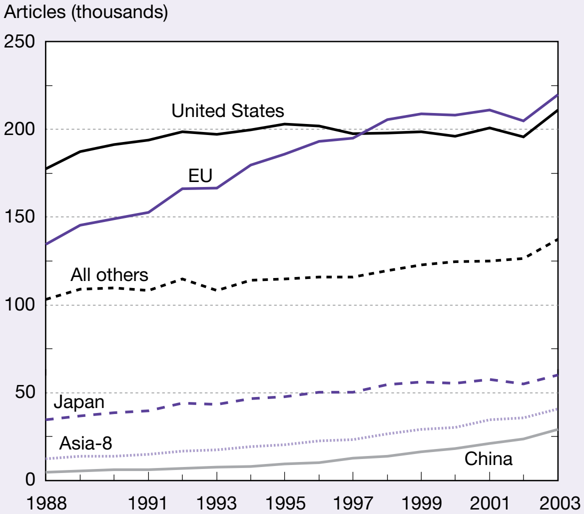


NOTE: Three years of article citations, lagged by 2 years.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Figure O-17
Scientific and technical articles, by country/region: 1988–2003



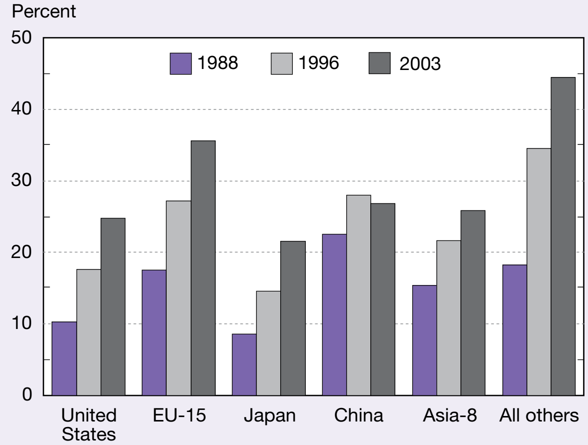
EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-41.

Science and Engineering Indicators 2006

Figure O-19
Share of scientific and technical articles with international coauthorship, by country/region: 1988, 1996, and 2003



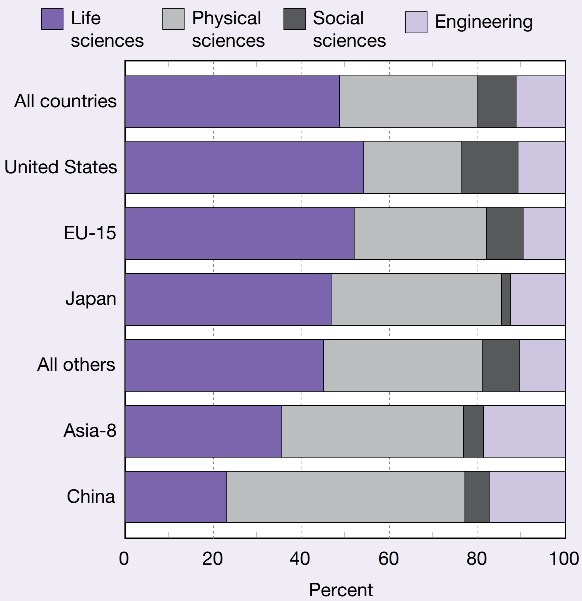
EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-47, 5-48, and 5-49.

Science and Engineering Indicators 2006

Figure O-20
Portfolio of scientific and technical articles, by field and country/region: 2003



EU = European Union

NOTES: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand. Countries/regions ordered by percentage of life sciences.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-45.

Science and Engineering Indicators 2006

high levels of collaboration reflect science establishments that may be small (e.g., in developing nations) or that may be in the process of rebuilding (e.g., in Eastern European countries). Generally, international collaboration is lower in the social sciences than in other fields.

By choice or by legacy, international science portfolios vary greatly.

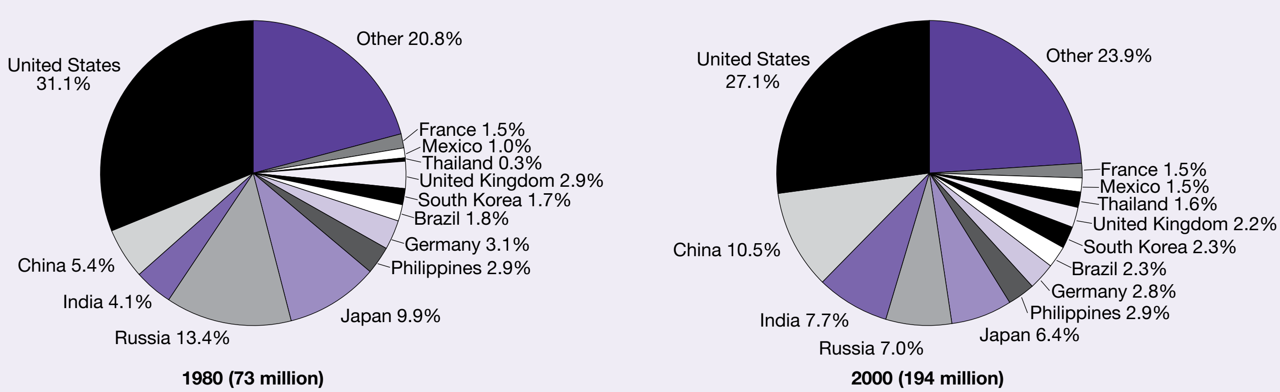
The scientific portfolios of the emerging Asian countries suggest a relatively greater specialization in the physical sciences and engineering than that of the traditional scientific centers. In 2003, more than half of China's publications concentrated on the physical sciences and nearly another fifth concentrated on engineering; in comparison with the rest of the world, the life sciences and social sciences constituted a very small share. The sum of eight other Asian portfolios showed a similar pattern. In contrast, the literature from both the United States and the EU-15 showed a fairly heavy emphasis on the life sciences (45%–54%) and a relatively lighter share in engineering (10%–13%) and the physical sciences (22%–39%) (figure O-20). The literature from Japan falls in between these two ranges. These portfolio patterns have changed little since the mid-1990s.

International Labor Forces, Students, and Degrees

International S&E labor force data can only be estimated.

International S&E labor force data are unavailable; however, the number of people with a postsecondary education can serve as an approximate measure of a highly educated S&E workforce. It shows enormous growth over two decades, from about 73 million in 1980 to 194 million in 2000. This broad measure of those who are highly skilled includes persons with at least a technical school or associate's degree and all advanced degrees (including doctorates and professional degrees). Over the period, the U.S. share of the total, which was the largest share, fell from 31% to 27%. China's and India's shares doubled to 10% and 8%, respectively, while Russia's share decreased by nearly half but remained the fourth largest. None of these three large countries are OECD members. A number of developing nations increased their share, indicating a broader provision of higher education (figure O-21).

Figure O-21
Population 15 years old or older with tertiary education by country/region: 1980 and 2000



SOURCE: Adapted from R.J. Barro and J.W. Lee, Center for International Development, *International Data on Educational Attainment* (2000).

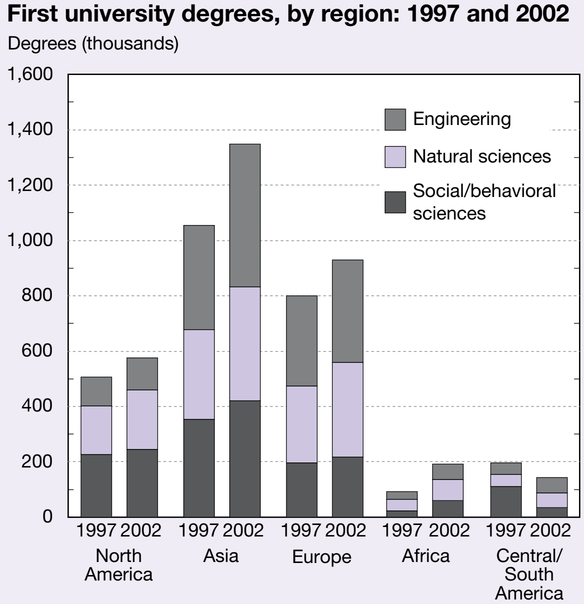
Science and Engineering Indicators 2006

International degree production is rising and is focused on S&E.

The number of first university degrees awarded around the world is rising rapidly, from about 6.4 million in 1997 to 8.7 million in 2002. Particularly strong increases occurred in Asia and Europe, with large numbers and strong gains in engineering and the natural sciences. In 2002, engineering degrees awarded in Asia were more than four times the amount of those awarded in North America, and the number of natural science degrees was nearly double. Europe graduated three times as many engineers as North America in 2002 (figure O-22).

The share of S&E degrees among first university degrees in the United States is lower than in other countries, as is the share of U.S. degrees in natural sciences and engineering (NS&E) (i.e., S&E degrees without the social sciences and psychology). Just under one-third of all U.S. degrees are awarded in S&E. This statistic has held steady over the years, along with the 19% share of NS&E degrees. However, world trends seem to be converging. In 1997, an average of 44% of all degrees awarded in other countries were in S&E, but that number fell to 38% in 2002. Similarly, the share of NS&E degrees declined from 30% to 27%, indicating that the worldwide expansion of higher education degrees was stronger in the non-S&E fields than in S&E (figure O-23). In light of these statistics, OECD ministers have expressed concern that young people lack interest in S&E.

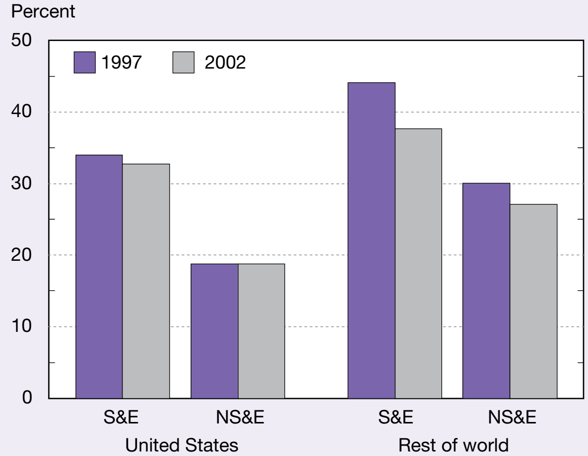
Figure O-22
First university degrees, by region: 1997 and 2002



SOURCES: Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics, special tabulations; Iberoamerican Network of Science and Technology Indicators (RICYT), Principales Indicadores de Ciencia y Tecnología (1999); and country sources. See appendix table 2-37.

Science and Engineering Indicators 2006

Figure O-23
First university degrees in NS&E as share of total first university degrees: 1997 and 2002



NS&E = natural sciences and engineering

SOURCES: China—National Research Center for Science and Technology for Development, unpublished tabulations; Japan—Government of Japan, Ministry of Education, Culture and Science, Monbusho Survey of Education (annual series, 2005); South Korea—Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp; Taiwan—Ministry of Education, Educational Statistics of the Republic of China (annual series, 2004); Germany—Federal Statistical Office, Prüfungen an Hochschulen 2003 (annual series, 2004); United Kingdom—Higher Education Statistics Agency, special tabulations (2005); and United States—U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-38.

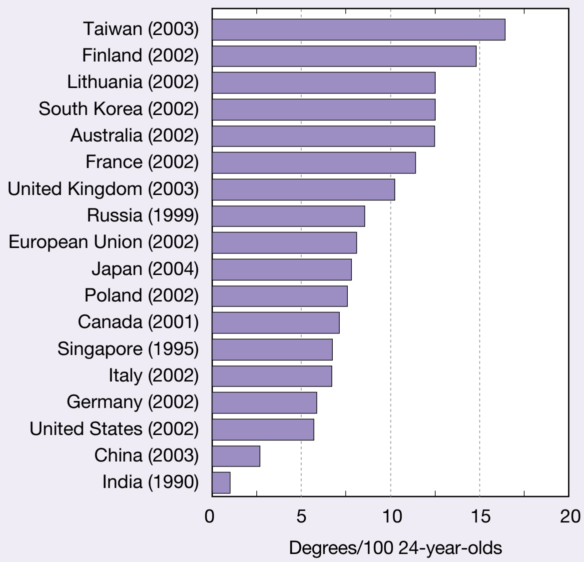
Science and Engineering Indicators 2006

Europe and Asia have made great strides in natural science and engineering degree production.

In the context of building knowledge-intensive economies, the education of young people in NS&E has become increasingly important for many governments. Results vary widely for first university degrees in the NS&E from about 16 per 100 24-year-olds in Taiwan to 12–13 in Australia and South Korea, and 10 in the United Kingdom. The United States ranks 32nd out of 90 countries for which such data are available at just under 6 per 100. China and India have low ratios (1.6 and 1.0, respectively), reflecting low overall rates of access to higher education in those countries (figure O-24). However, this trend appears to be changing: S&E degree production in China doubled and engineering degrees tripled over the past two decades.

The international production of S&E doctorate holders has also accelerated; in recent years most of these degrees (78% in 2002) have been granted outside the United States. The EU graduated one-third of the new S&E doctorates and also one-third of those with doctorates in the natural sciences. One-third of the engineering doctorates were awarded in Asia, where numbers are understated because of incomplete

Figure O-24
NS&E degrees per 100 24-year-olds, by country/economy: Most recent year

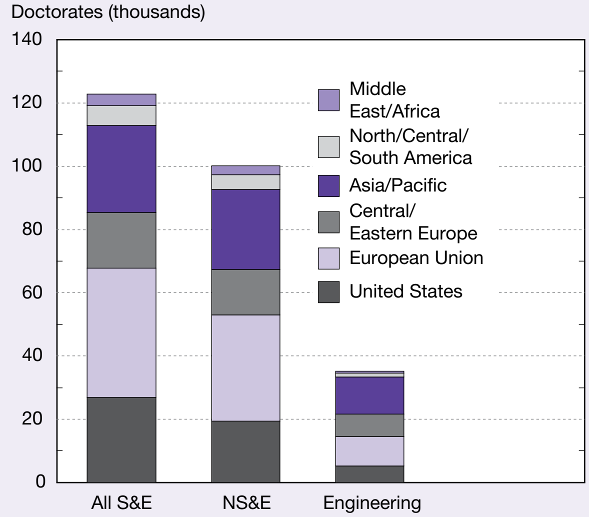


NS&E = natural sciences and engineering

SOURCES: Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, www1.oecd.org/scripts/cde/members/edu_uoeauthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics database, http://www.unesco.org/statistics, and national sources. See appendix table 2-37.

Science and Engineering Indicators 2006

Figure O-25
S&E doctorates awarded, by country/region: Most recent year



NS&E = natural sciences and engineering

SOURCES: Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, www1.oecd.org/scripts/cde/members/edu_uoeauthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics database, http://www.unesco.org/statistics. See appendix table 2-41.

Science and Engineering Indicators 2006

reporting. The United States produced 15% of the world's engineering doctorates in 2002 (figure O-25); students on temporary visas earned more than half of these degrees.

International Mobility

Large numbers of highly educated persons live outside their home countries.

In 2002,[7] close to 2 million students were enrolled in higher education institutions outside their home country, nearly one-third of them in the United States. A few countries continue to dominate the international student market. In 2002, the United States, United Kingdom, and Germany accounted for 54% of the total; three-quarters of all foreign students were enrolled in these three countries plus Australia, France, and Japan (figure O-26). However, this pattern shows signs of changing. The U.S. share has declined for several years, while those of the United Kingdom, Australia, and Japan have increased. Recently, a number of countries have expanded their efforts to attract foreign students.

The number of individuals with higher education degrees who lived outside their home countries grew by 9.5 million from 1990 to 2000. Individuals from Eastern Europe, Central and South America, and smaller Asian countries account for most of the increase, followed by Western Europe, China, India, and Africa. The number of expatriates from China, India, and Africa more than doubled. However, by 2000, home countries were absorbing relatively more of their highly educated citizens than in the past. In 1990, 1 in 6 resided abroad; by 2000 that number had dropped to 1 in 9, indicating that much of the world had developed an infrastructure capable of using these highly educated people productively (figure O-27). Among developed countries, the United Kingdom has the largest group of citizens with formal education beyond high school residing abroad, with Germany in second place. China, India, and the Philippines each have 1.0–1.2 million highly educated expatriates.

S&E Trends in the United States

The U.S. S&E Labor Force

S&E jobs play a growing role in the U.S. economy, but U.S. S&E degree production lagged growth in S&E occupations.

In 2003, the number of people working in S&E occupations reached 4.6 million, up from 3.3 million a decade earlier. The past decade's growth in S&E jobs continues a longer trend. In each of the past five decades, S&E jobs in the U.S. economy grew more rapidly than the overall civilian labor force. After unusually rapid increases in the 1950s (averaging about 17%), S&E employment through the 1990s rose at an annual average of 3.5%, more than three times as fast as the growth in overall civilian employment (figure O-28). In 2003, another 8.6 million holders of S&E degrees worked

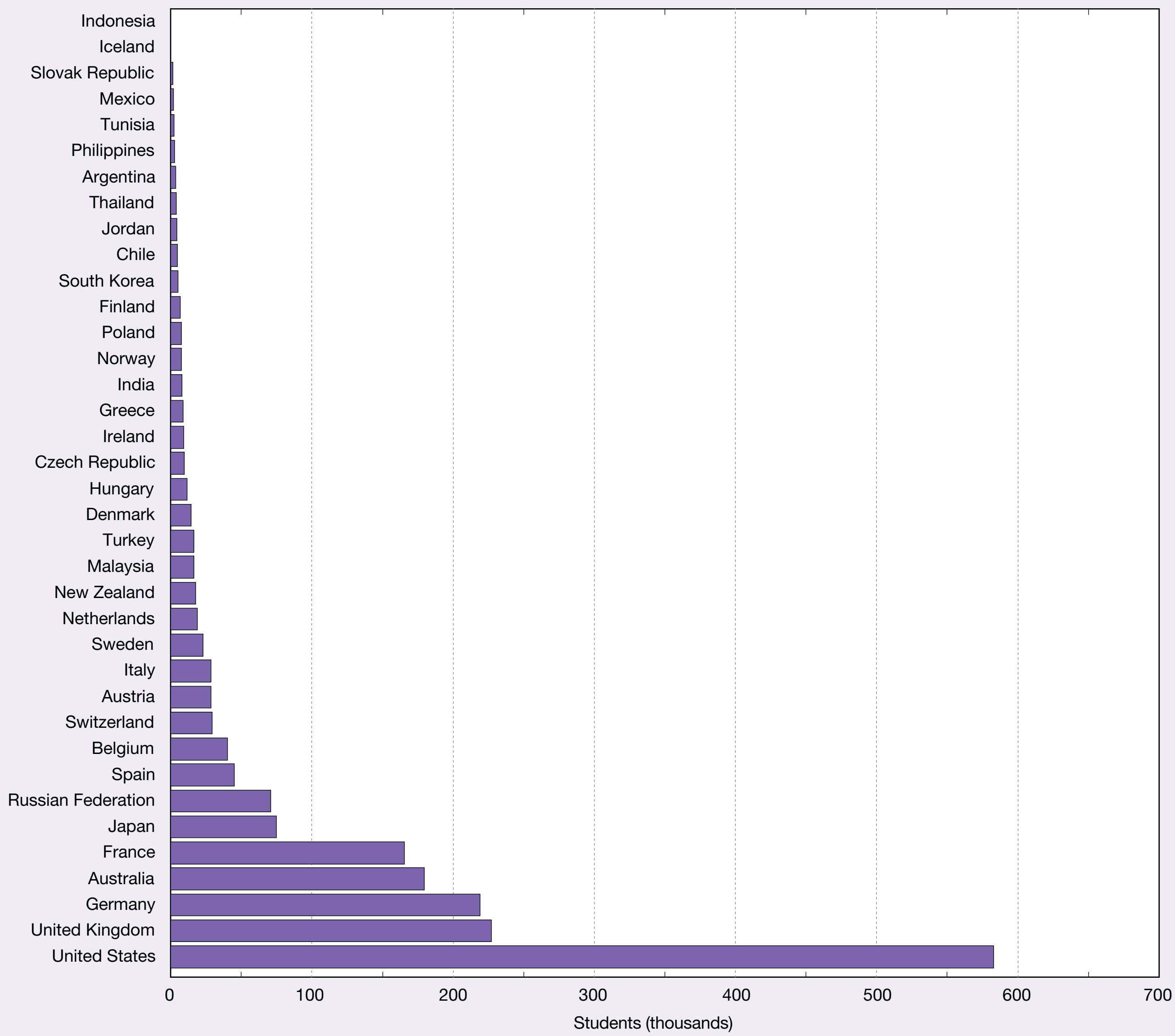
in jobs not classified as S&E, up from 6.5 million a decade earlier. Many of these other jobs required some S&E knowledge, indicating an increase in these jobs' technical content.

S&E degree production increased but was less than the 4% average annual growth rate of S&E employment from 1980 to 2000. The more rapid expansion of S&E jobs was made possible by the growing numbers of foreigners who earned U.S. degrees and subsequently stayed in the country, those with foreign S&E degrees who migrated to the United States for a limited period or permanently, and low retirement rates of scientists and engineers who, as a group, were younger than the overall labor force.

The influx of scientists and engineers from Asia and elsewhere accelerated in the 1990s.

The 1990s showed strong increases in the number of foreign-born individuals holding U.S. S&E jobs; by 2000, this share had increased from 14% to 22% (figure O-29). The largest increases were for doctorate holders, from 24% to 38%, and for certain job specialties. More than half of the engineers holding doctorates and 45% of doctorate holders in the physical sciences, computer sciences, and life sciences were foreign born. One-third of these foreign-born scientists and engineers came from India, China, and the Philippines; among doctorate holders, those from China and India alone comprised one-third of the total.

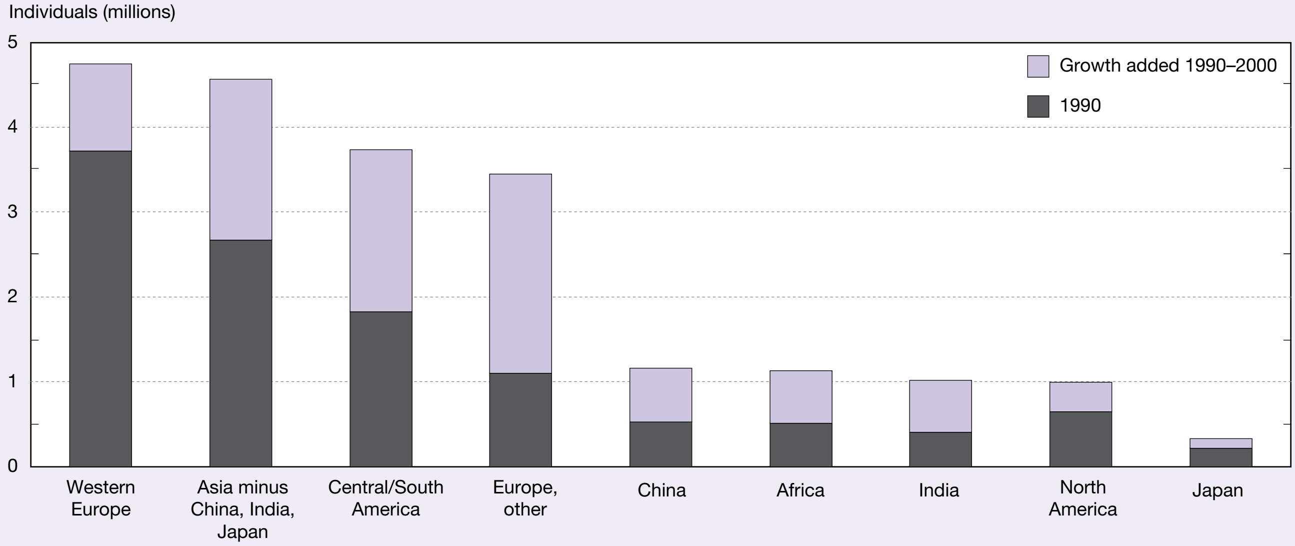
Figure O-26
Foreign higher education students in all fields, by country: 2002



SOURCE: Organisation for Economic Co-operation and Development, *Education at a Glance 2002* (2002).

Science and Engineering Indicators 2006

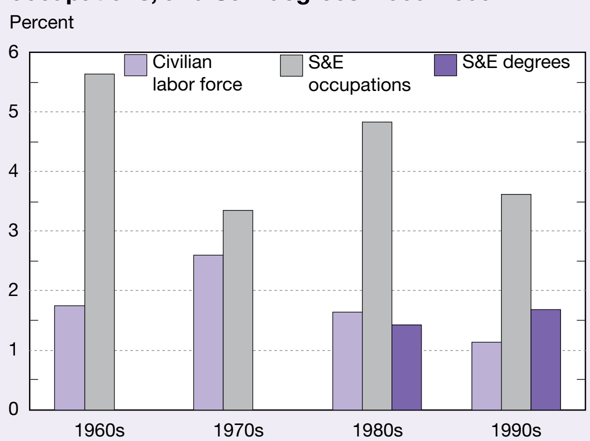
Figure O-27
Individuals with higher education living abroad, by country/region of origin: 1990 and 2000



SOURCE: F. Docquier and A. Marfouk, *Measuring the International Mobility of Skilled Workers (1990–2000)* (2004).

Science and Engineering Indicators 2006

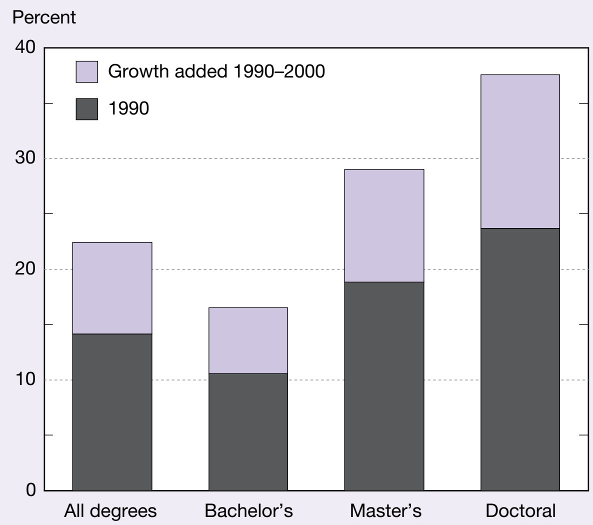
Figure O-28
Average annual growth of U.S. labor force, S&E occupations, and S&E degrees: 1960–2000



SOURCES: B.L. Lowell, Estimates of the Growth of the Science and Technology Workforce, Commission on Professionals in Science and Technology (forthcoming); *Economic Report of the President* (2002); and U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey (various years).

Science and Engineering Indicators 2006

Figure O-29
Share of foreign-born scientists and engineers in U.S. S&E occupations, by degree level: 1990 and 2000



NOTE: Data exclude postsecondary teachers because of Census occupation coding.

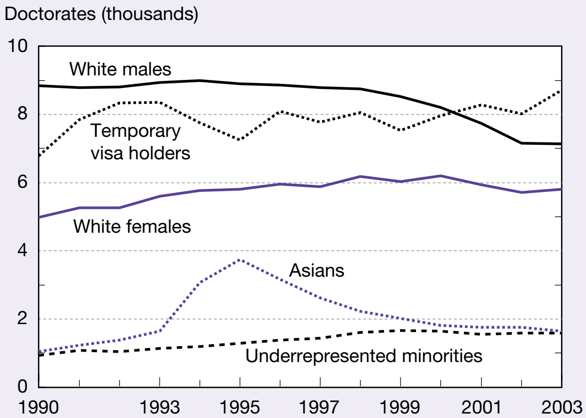
SOURCE: U.S. Census Bureau, 5-Percent Public-Use Microdata Sample, www.census.gov/main/www/pums.html.

Science and Engineering Indicators 2006

Foreign students earned one-third of U.S. S&E doctorates and 55% of engineering doctorates, whereas doctorates earned by U.S. white males dropped sharply.

The production of U.S. S&E doctorates since 1990 has been robust, rising from 23,800 to a record 28,800 in 1998 before dropping to 26,900 in 2003. The overall number depended heavily on foreign students. Students holding temporary visas earned between 6,800 and 8,700 doctorates a year (figure O-30)—in 2003 they earned one-third of the total number of doctorates, more than half of those in engineering, 44% of those in mathematics and computer science, and 35% of those in the physical sciences. The number of U.S. Asian students is inflated by the conversion of large numbers of

Figure O-30
S&E doctorates conferred by citizenship status and race/ethnicity: 1990–2003

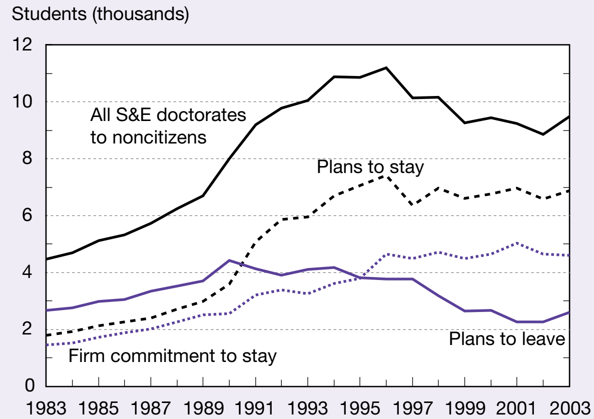


NOTES: Physical sciences include earth, ocean, and atmospheric sciences. Social sciences include psychology. Whites, underrepresented minorities, and Asians include U.S. citizens and permanent visa holders only. Excludes unknown citizenship or race/ethnicity.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-30 and 2-31.

Science and Engineering Indicators 2006

Figure O-31
Foreign student plans to stay in United States after receipt of U.S. S&E doctorate: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005). See appendix table 2-33.

Science and Engineering Indicators 2006

Chinese students with temporary visas to permanent status under the 1992 Chinese Student Protection Act.

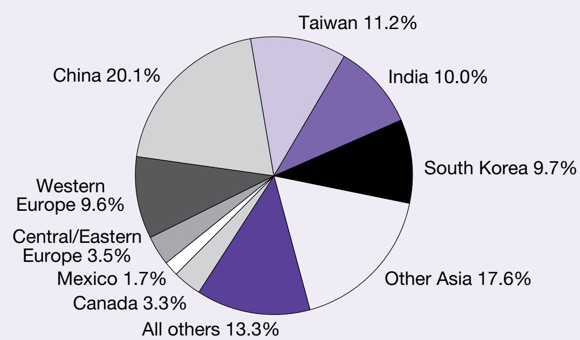
Large numbers of foreign doctorate holders continue to stay in the U.S. after receiving their degree.

Recent downturns in foreign enrollment notwithstanding, many foreign students pursue advanced study in S&E fields at U.S. universities. These students frequently choose to stay in the United States after earning their S&E degree. Beginning in the 1990s, a growing number of graduate students, doctorate holders, and postdoctoral fellows chose to remain in the country for further study or work. Since the mid-1990s, every year about 6,500–7,000 foreign students who earned a U.S. S&E doctorate planned to stay in the United States after receiving their degree (figure O-31). Through 2003, many of these students remained in the country for years after graduation: 53% of the 1993 doctorate recipients were working in the United States in 1997 and 61% of the 1998 cohort remained in the country in 2003. However, increasing international competition for foreign students raises questions about the continued viability of these high rates.

Asian locations that have been the source of two-thirds of foreign doctoral candidates in the United States are developing their own S&T infrastructures.

During the past two decades, two-thirds of foreign students earning a U.S. S&E doctorate were from Asia: about 20% from China and 10%–11% each from Taiwan, India, and South Korea (figure O-32). However, Asia is investing heavily in the development of knowledge-based economies

Figure O-32
Origin of foreigners earning U.S. S&E doctorates: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

Science and Engineering Indicators 2006

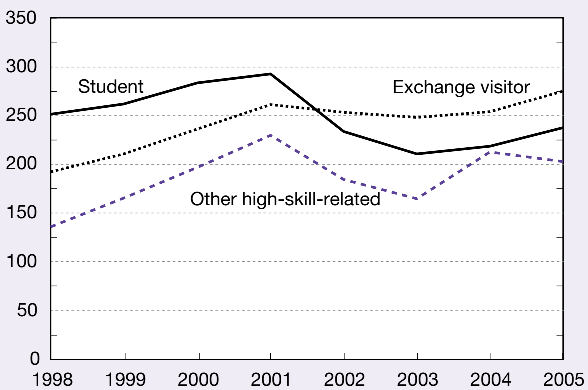
and higher education systems, and countries such as Japan are starting to import large numbers of Asian scientists and engineers. Thus, there is no assurance of a continued influx of students from this region to the United States, especially since other countries are creating immigrant-friendly policies for those with advanced S&E degrees.

Foreign student visas are recovering but remain down by one-fifth since 2001, and other high-skill visa categories are trending upward.

The U.S. reaction to the events of September 11, 2001, affected the flow of foreign-born scientists and engineers into the United States. The number of student, exchange visitor, and other high-skill-related visas issued annually grew rapidly during the 1990s but decreased sharply after September 11.

The number of applications declined because of increased difficulty in processing, higher cost, and heightened scrutiny of applicants. The number of visas issued reached a low point in 2003 and has since recovered. By 2005, the number of student visas issued had risen to their 2002 level, as the length of time for processing along with the difficulty in processing had decreased. The number of student visas issued remained below the 2001 level, while that for exchange visitors exceeded it. (figure O-33).

Figure O-33
Student, exchange visitor, and other high-skill-related temporary visas issued: 1998–2005



SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division (1998–2005).

Science and Engineering Indicators 2006

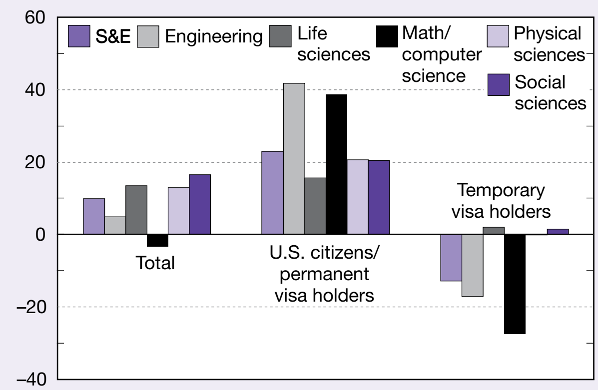
A leading indicator suggests declining foreign enrollments in advanced S&E study.

First-time, full-time enrollment in graduate study, a leading indicator, shows significant changes since 2001. The number of foreign students enrolling for the first time dropped sharply in 2003 compared with the 2001 level (figure O-34). The 2-year decline was most pronounced in mathematics and computer science (–28%) and engineering (–17%), fields heavily favored by foreign students. Gains by U.S. citizens and permanent visa holders more than offset these losses, with both engineering and mathematics and computer science rising by about 40%. However, these trends may be about to change again; data compiled by the Institute of International Education show an increase of about 2.4% in foreign graduate enrollment from 2003 to 2004.

Many retirements from the U.S. S&E labor force are impending.

Barring major changes in current trends, many individuals in the S&E labor force will retire in the coming decades. In 2003, 13% of S&E bachelor's degree holders, 20% of master's degree holders, and 28% of doctorate holders were 55 years old or older (figure O-35). Historically, by age 61 about half of the bachelor's degree holders no longer work full time; the same is true at age 62 for those with master's degrees and at age 64 for doctorate holders.

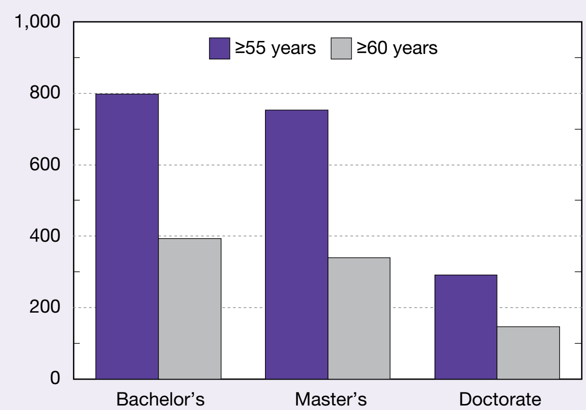
Figure O-34
Change in first-time full-time graduate enrollment in S&E, by citizenship status: 2001–03



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-16.

Science and Engineering Indicators 2006

Figure O-35
Individuals in U.S. S&E labor force nearing retirement age, by degree level: 2003



NOTE: Preliminary estimates made in 2005 based on 2003 data

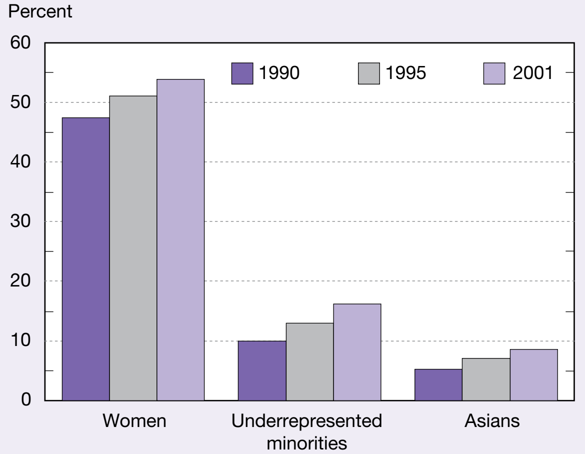
SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates, preliminary estimates (2005).

Science and Engineering Indicators 2006

Women and minorities earned increased shares of S&E degrees, including advanced degrees.

Among U.S. citizens and those who hold permanent visas, women and members of minority groups increased their share of S&E degrees at the bachelor's and higher degree levels. Beginning in 2000, women received half of these degrees, Asians received 10%, and other minorities received 18% (figure O-36). The number of S&E undergraduate degrees was 416,000 in 2002, the last year for which data are available. Three major trends since 1990 are a strong increase in the

Figure O-36
U.S. S&E bachelor's degrees earned by women and minorities: 1990, 1995, and 2001

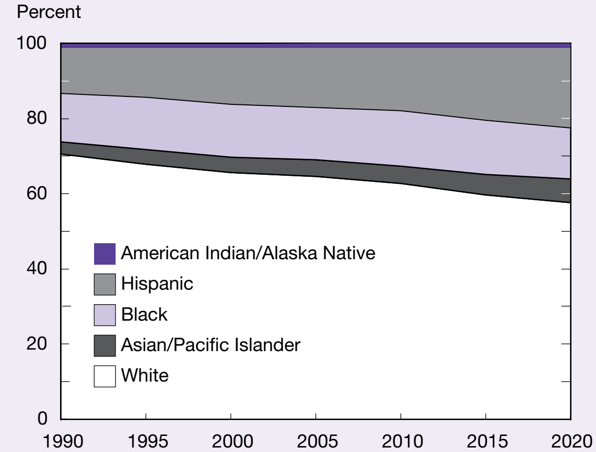


NOTE: U.S. citizens and permanent visa holders only.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-26 and 2-27.

Science and Engineering Indicators 2006

Figure O-37
Composition of U.S. college-age cohort: 1990–2020



SOURCES: U.S. Census Bureau, Population Division, 1990 Census, http://www.census.gov/population/estimates/nation; and Population Projections Program, Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100 (2000), http://www.census.gov/population/projections/nation/detail/d2001_10.pdf. See appendix table 2-4.

Science and Engineering Indicators 2006

social sciences and psychology, a sustained rise in life sciences followed by a gradual decline, and steep growth in computer science degrees beginning in the late 1990s.

Continuing demographic changes in college-age cohorts pose challenges to raising domestic S&E degree output.

Projected changes in the composition of successive U.S. college-age cohorts will present challenges to increasing the number of S&E degrees earned by U.S. citizens. The share of whites is projected to decline from 71% in 1990 to 58% by 2020; historically whites have been more likely than other groups (except Asians) to earn S&E degrees. The share of Asians is projected to increase to 6%. The Hispanic share will nearly double (from 12% to 22%), while the shares of blacks and other minorities will remain flat, at a combined total of about 15% (figure O-37).

The performance of U.S. students in elementary and secondary schools may raise concerns.

International and domestic assessments of the performance of American students present a mixed picture. Both U.S. fourth and eighth grade students scored above the international average on the 2003 Trends in International Math and Science Study (TIMSS), which measures mastery of curriculum-based knowledge and skills. TIMSS calculated the average of all participating countries, both developed and developing. However, U.S. 15-year-olds scored below the international average on the 2003 Programme for International Student Assessment (PISA), which measures students' ability to apply scientific and mathematical concepts and skills (figure O-38). OECD administers PISA, and PISA's average was based on scores from industrialized OECD countries only. In the United States, only about one-third of 4th and 8th grade students and less than 20% of 12th graders reached proficiency in mathematics and science tests administered by the National Assessment of Educational Progress; scores for underrepresented minorities were significantly lower. Proficiency in these tests denotes solid performance for the students' grade based on judgments of what students should know and be able to do in the subject assessed.

In sum, prospects for the U.S. S&E workforce are for slower growth, rising retirements, and increasing average age.

Taken together, and barring significant changes, current trends in degree production, retirement, and immigration suggest that the number of trained scientists and engineers in the labor force will continue to increase, but at a slower rate; the average age of S&E workers will rise; and the number of retirements will increase sharply over the next two decades. Declining degree production or immigration would accentuate these trends.

U.S. Academic R&D

Since 1990, inflation-adjusted academic R&D expenditures have almost doubled, driven by federal and institutional funds.

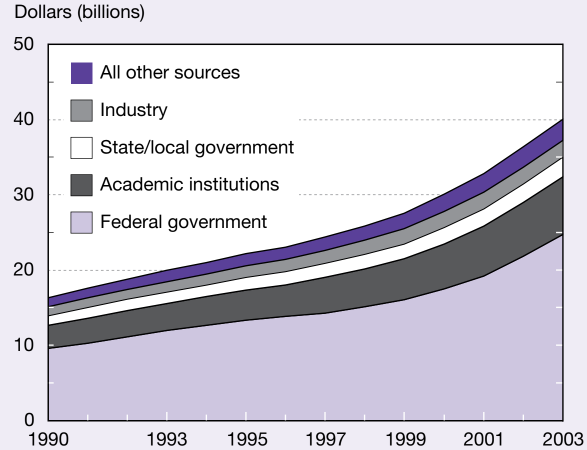
Expenditures for academic R&D reached $40 billion in 2003, the second-fastest growth of any U.S. R&D sector. The federal government supplied 62% of these funds,

Figure O-38
Average science literacy score of 15-year-old students, by country: 2003

SOURCE: Organisation for Economic Co-operation and Development, Programme for International Student Assessment (2003). See appendix table 1-14.

Science and Engineering Indicators 2006

Figure O-39
Expenditures for academic R&D by source of funds: 1990–2003



NOTE: Current dollars; excludes capital expenditures.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2003 (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-2.

Science and Engineering Indicators 2006

up from 59% in 1990, reversing the long-declining share of federal dollars. The universities themselves provided an additional 19%. State government and industry support grew slowly, state government funding because of unfavorable budget conditions, industry funding because of retrenchment after the collapse of the dot.com industry (figure O-39). The life sciences share of academic research expenditures rose to 59%, whereas the shares of engineering and the physical sciences declined because their funding grew more slowly.

Academic laboratory construction is booming, but equipment spending is at a long-term low.

Extensive laboratory construction activities are currently under way; in 2002–03, almost half of all universities began construction projects. Investment for new laboratory space stood at $7.6 billion in 2003, with another $9.1 billion in projects scheduled to start in 2004 or 2005. Most of these expenditures were for the biological and life sciences (58%–60%) and engineering (14%). During most of the period, state and local governments supplied about one-third of the funds (and more in the mid-1990s); the federal government's share was 5% in 2002–03, reflecting the growing prominence of institutional sources, private donations, and forms of debt funding. Cutting-edge research also requires state-of-the-art research equipment. However, equipment spending, generally from operating funds, grew more slowly than overall research funds and reached a long-term low of 4.5% of academic R&D expenditures in 2003 (figure O-40).

Doctoral Scientists and Engineers in Academia

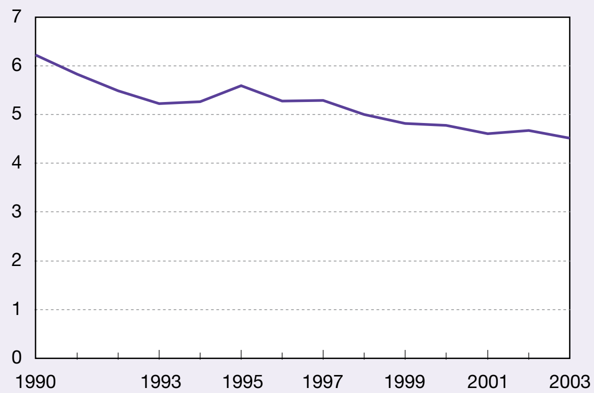
Fewer S&E doctorate holders are employed in academia, and fewer have traditional faculty positions, especially among young doctorate holders.

The academic doctoral labor force grew from 211,000 in 1991 to 258,000 in 2003, representing fewer than half of all employed S&E doctorate holders. In academia, the share of those with full-time faculty appointments declined from 82% to 75%. The share of full-time senior faculty fell below 55% in 2003, and the share of junior faculty was about 20%. These trends were accentuated for those with recent doctorates (figure O-41).

The academic doctoral labor force has become more diverse with the employment of more women, minority group members, and those born in other countries.

Increased conferral of S&E degrees to women and minority group members has been accompanied by rising academic employment among these groups. In 2003, women constituted 30% of all academic positions and 28% of full-time faculty. At a level of 8% in 2003, blacks, Hispanics, and American Indian/Alaska Natives remained a small proportion of total

Figure O-40
Expenditures for academic research equipment as share of total academic R&D expenditures: 1990–2003

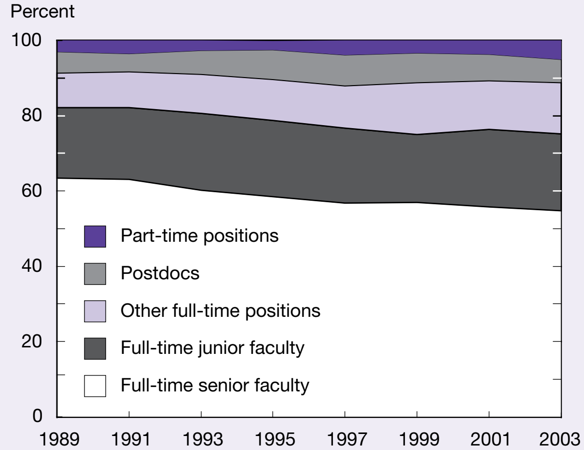


NOTE: Excludes capital expenditures.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2003 (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-15.

Science and Engineering Indicators 2006

Figure O-41
Faculty and tenure-track status of academic S&E doctorate holders 4–7 years after receipt of doctorate: 1989–2003

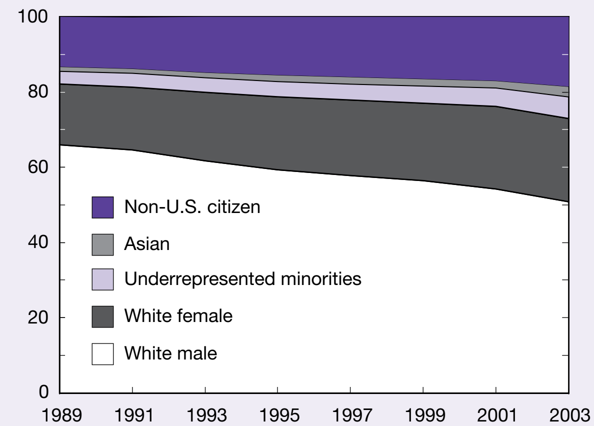


SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-25.

Science and Engineering Indicators 2006

academic employment. The growing number of foreign-born doctorate holders in the academic labor force cannot be accurately determined from available data. Of those with U.S. degrees who are employed in academia, increasing proportions have been foreign born, rising from 17% in 1989 to 23% in 2003 (figure O-42).

Figure O-42
Composition of academic doctoral S&E workforce by race/ethnicity, sex, and citizenship at degree conferral: 1989–2003



NOTES: Non-U.S. citizens include both permanent and temporary visa holders. Other categories include only U.S. citizens.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-25.

Science and Engineering Indicators 2006

The number of academic researchers is growing, but government support, despite strong growth, reaches fewer of them, especially those at the start of their careers.

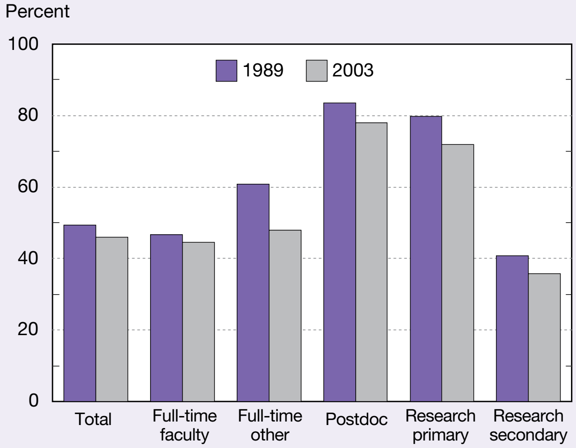
The numbers of individuals with primary work responsibility for R&D increased more rapidly than those with primary teaching responsibility. Academic researchers rely on the federal government for a significant share of their support. In 2003, 46% of all academic doctoral scientists and engineers and 72% of those for whom research was their primary work activity received federal support. These figures are less than those for the late 1980s and early 1990s for all fields except engineering, and the differences over time are especially pronounced for those with recent doctorates who are trying to establish a career (figure O-43).

Broader U.S. R&D Trends

Total U.S. R&D performance rebounded robustly after declining in 2002.

Total U.S. R&D expenditures more than doubled since 1990 and are projected to reach $313 billion in 2004. This strong rebound follows the first-ever reduction in 2002 that was caused by industry's retrenchment after the collapse of the dot.com industry. Adjusting for inflation, the 1990–2004 increase was 55%, with strong post-2002 gains in both federal and industry support. However, industry's share of total R&D support dropped from 70% in 2000 to 64% in 2004 as federal R&D investment rose, especially in security-related areas (figure O-44).

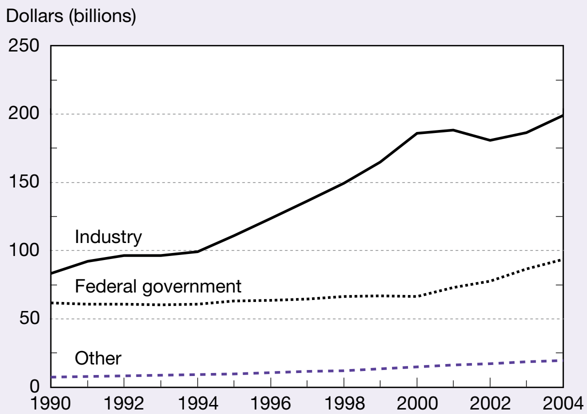
Figure O-43
Academic S&E doctorate holders receiving federal support for research: 1989 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-37.

Science and Engineering Indicators 2006

Figure O-44
R&D expenditures by source of funds: 1990–2004



NOTE: Current dollars; 2004 data are preliminary. Other includes $8 billion from universities' own funds.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-3.

Science and Engineering Indicators 2006

R&D performance in concert with external partners is increasing.

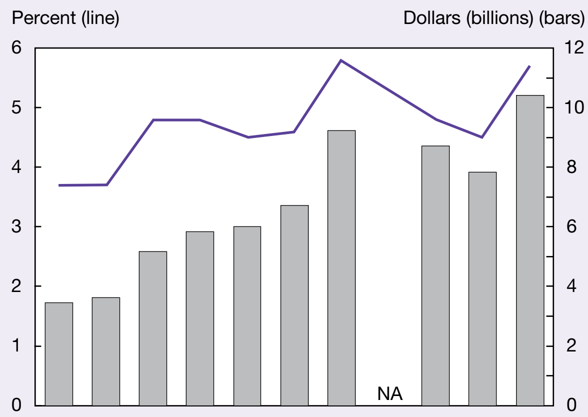
Firms are increasingly collaborating with external partners to conduct R&D in response to the growing complexity of R&D activities and the desire to reduce risks, share costs, expedite projects, complement internal capabilities, and enter new markets. This collaboration takes many forms, e.g., contracting out R&D and forming formal strategic alliances. In 2003, U.S. firms contracted $10.4 billion worth of R&D to other performers, up from less than $2 billion a decade earlier. This amounted to nearly 6% of internally performed R&D, up from less than 4% in 1993 (figure O-45). From 1993 to 2003, contracted R&D grew twice as fast as in-house R&D, and for manufacturing companies it grew nearly three times as fast.

Every year, many U.S. companies enter into formal strategic technology alliances domestically or with companies in other countries. With some year-to-year variation, about half of these alliances tend to be among U.S. partners only, with the other half primarily focusing on Europe. Formation of alliances increased rapidly during the early 1990s, peaked in 1995, and recently started increasing again. In 2003, U.S. companies announced nearly 500 new strategic alliances; 220 of them were among U.S. firms (figure O-46).

Federal stimulation of small business innovation is increasing.

A fixed portion of federal agencies' extramural R&D funds is set aside for competitive awards to small businesses to commercialize the results of federally funded projects. Small (Phase I) awards of short duration are designed to assess the scientific and technical feasibility of ideas with commercial potential; Phase II awards are intended for further development. Subsequently, the innovation must be brought to market with private-sector investment but without further federal support. Total funds awarded under this program have increased from about $500 million in the early 1990s to just under $1.7 billion in 2003 (figure O-47). The number of awards has nearly doubled, to just under 6,000.

Figure O-45
Contracted-out U.S. industrial R&D: 1993–2003



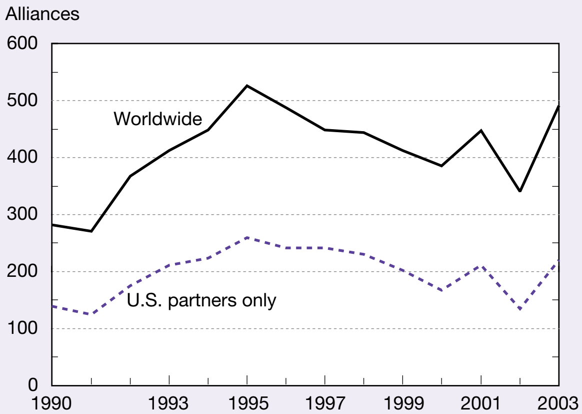
NA = not available

NOTE: Percent is ratio of contracted-out R&D to R&D performed internally.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series), http://www.nsf.gov/sbe/srs/indus/start.htm. See appendix table 4-34.

Science and Engineering Indicators 2006

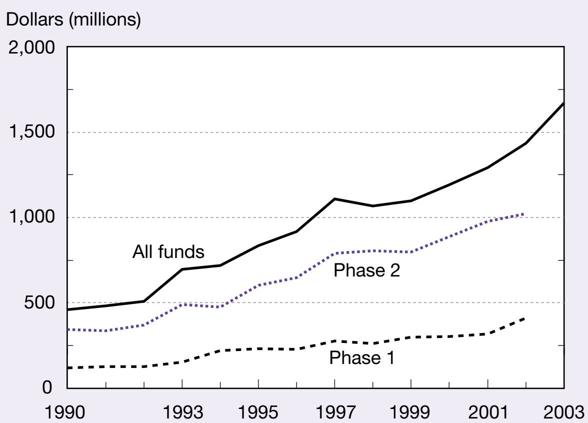
Figure O-46
New strategic technology alliances involving U.S. firms: 1990–2003



SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

Science and Engineering Indicators 2006

Figure O-47
Federal Small Business Innovation Research funds, by phase: 1990–2003

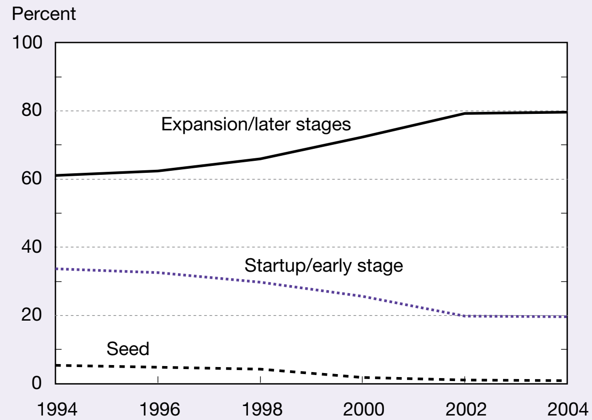


NOTE: Phase 1 awards are for feasibility assessment; phase 2 awards are for further development.

SOURCE: U.S. Small Business Administration, *Small Business Innovation Research Program Annual Report* (annual series). See appendix table 4-39.

Science and Engineering Indicators 2006

Figure O-48
Venture capital disbursements, by stage of financing: 1994–2004



SOURCE: Thomson/Venture Economics, special tabulations (May 2005). See appendix table 6-19.

Science and Engineering Indicators 2006

U.S. venture capital, the seedbed of startup companies, grows risk-averse.

At $21 billion, U.S. venture capital disbursements have again reached the level of the late 1990s after the collapse of the dot.com industry, but startup capital is scarcer than ever. The focus has shifted to expansion and later-stages funding, which consumed 80% of the funds disbursed in 2004. Startup and other early-stage funding dropped from 34% of funds in the early 1990s to 20%. Seed funding, the earliest stage with the most risk, received only $158 million, its lowest level since the early 1990s; this figure represented 0.8% of disbursed funds in 2004 compared with 5% through the mid-1990s (figure O-48). With the end of the surge in the dot.com industry, funds have shifted from Internet-specific firms to software and medical and health companies.

Conclusion

The globalization of R&D, S&T, and S&E labor markets continues. Countries seek competitive advantage by building indigenous S&T infrastructure, attracting foreign investments, and importing foreign talent. The location of S&E employment is becoming more internationally diverse and those who are employed in S&E have become more internationally mobile.

These trends affect every area of S&T. They reinforce each other, as R&D spending and business investment cross national borders in search of available talent, as talented people cross borders in search of interesting and lucrative work, and as employers recruit and relocate employees internationally.

Human capital is a key ingredient in these developments. Three factors affect the size of the U.S. S&E labor force that is available to compete for and create high-quality jobs in the worldwide knowledge economy: (1) retirements, because the number of individuals with S&E degrees who are reaching traditional retirement ages is expected to triple; (2) S&E degree production, because current trends will sustain growth but at a lower rate than before; and (3) potentially diminished U.S. success in the increasing international competition for foreign scientists and engineers, because many countries are actively reducing barriers to high-skilled immigrants while entry into the United States has become somewhat more difficult.

A prolonged slowdown in the growth of the U.S. S&E workforce would produce wage growth adjustments whose

net effects in a mobile and integrated S&T marketplace are currently hard to assess. Better data, metrics, and models are needed to capture the evolving dynamics of international S&E labor markets and other aspects of S&T systems.

Notes

1. European Union (EU-15) includes Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, and the United Kingdom.

2. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

3. Organisation for Economic Co-operation and Development (OECD) includes Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

4. Eight OECD nonmembers are Argentina, China, Israel, Romania, the Russian Federation, Singapore, Slovenia, and Taiwan.

5. EU-25 includes the EU-15 plus recent new members Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia.

6. The database is the combined ISI Thompson's *Science Citation Index and Social Sciences Citation Index.* The top journals are those within the top 1%, 5%, and 10% of journals with the highest ratios of citations to articles. Top articles are similarly defined as those with the top 1%, 5%, and 10% of citations in a given field.

7. Or closest year for which data are available.

Chapter 1
Elementary and Secondary Education

List of Sidebars

List of Tables

List of Figures

Highlights

Student Learning in Mathematics and Science

Improvements in U.S. student performance in mathematics and science have been uneven.

- In mathematics, average scores on national assessments rose from 1990 to 2003 and gains occurred in many demographic subgroups.
- In contrast, performance in science has not improved recently. Between 1996 and 2000, average science scores declined at grade 12 and remained the same at grades 4 and 8.
- In both mathematics and science, most students did not reach the proficient performance level, a level denoting solid performance for their grade based on judgments of what students should know and be able to do in the subject assessed. In both subjects, only about one-third of 4th and 8th grade students, and even fewer 12th grade students, reached the proficient level.

Performance disparities in mathematics and science are evident among many student subgroups.

- Students from disadvantaged backgrounds lagged behind, with these disparities starting as early as kindergarten, persisting across grades, and in some cases, widening over time.
- Substantial performance differences were also found between racial/ethnic groups, and those gaps generally remained stable from 1990 to 2003 in mathematics and from 1996 to 2000 in science.
- Sex differences were small but favored males in most cases.

International comparisons of mathematics and science performance present a mixed picture.

- Between 1995 and 2003, U.S. eighth grade students improved their performance on the Trends in International Math and Science Study (TIMSS) assessment, which measures mastery of curriculum-based knowledge and skills. However, scores of fourth graders generally remained flat over the same period. Both U.S. fourth and eighth grade students scored above the international average on the 2003 TIMSS, in which both developed and developing countries participated.
- On the 2003 Programme for International Student Assessment (PISA) tests, which measure students' ability to apply scientific and mathematical concepts and skills, U.S. 15-year-olds scored below the international average. It is important to note that TIMSS and PISA differ in age of participating students, extent to which test questions are aligned with curriculum, and number and type of participating countries. Although countries participating in TIMSS included both developed and developing nations, the international averages for PISA are based on scores from the 30 Organisation for Economic Co-operation and Development (OECD) countries that participated, all of which are industrialized.

Student Coursetaking in Mathematics and Science

Most 2000 U.S. high school graduates attended schools that offered advanced mathematics courses and nearly all had advanced science courses available at their schools.

- However, students attending rural or small schools were less likely to have access to some of the advanced courses than those enrolled in urban/suburban or large schools, particularly in mathematics. (Students are described herein as having access to courses if the school from which they graduated offered the course, but in practice, students usually have access only to those courses for which they have prepared.)

The proportions of students completing courses in many advanced mathematics and science subjects have increased since 1990 but remain relatively modest except in chemistry.

- The percentage of 2000 graduates who earned credits in advanced mathematics ranged from 6% for statistics/probability to 27% for precalculus.
- In science, the proportions earning any credits in chemistry, advanced biology, and physics in high school were 63%, 36%, and 33%, respectively. These figures may still overstate participation in advanced coursetaking because the definition of advanced used for this chapter sets a minimal bar: courses that not all students complete and that are not widely required for graduation. Some of these courses (e.g., certain chemistry and physics courses) may not meet other definitions of advanced that are based on content and skills.

Coursetaking varies by sex and race/ethnicity.

- In 2000, sex differences occurred in science coursetaking but not in mathematics. More females than males completed courses in advanced biology, Advanced Placement (AP) or International Baccalaureate (IB) biology, and chemistry. Males completed physics and AP/IB physics courses at higher rates than females.
- Racial/ethnic differences existed in both mathematics and science coursetaking. Asians/Pacific Islanders were generally more likely than students from other racial/ethnic groups to complete advanced mathematics and science courses, and whites were more likely than blacks and Hispanics to complete some courses.

Since 1990, the number of students taking AP tests has grown rapidly in mathematics and science subjects.

- ♦ Between 1990 and 2004, the number of students taking the Calculus AB Exam nearly tripled and the number taking Calculus BC increased nearly fourfold. In science, the number of students taking Physics C and Biology more than tripled, and those taking Physics B increased almost fivefold.

The majority of students who took AP tests received a passing score that would earn college credit, but gaps existed by sex and race/ethnicity.

- ♦ Male test takers were more likely than their female counterparts to earn passing scores, as were Asians/Pacific Islanders and whites compared with their black and Hispanic peers.

Mathematics and Science Teachers

College graduates who become teachers have somewhat lower academic skills on average than those who do not go into teaching.

- ♦ College graduates who became teachers took fewer rigorous academic courses in high school, had lower scores on 12th grade achievement tests, scored lower on college entrance examinations, and graduated from less-selective colleges.

Out-of-field teaching (as measured by either lacking a certificate or a college major or minor in the assigned teaching field) is common.

- ♦ Nationally, between 17% and 28% of public high school mathematics and science teachers lacked full certification in their teaching field in academic year 2002 (the school year that began in fall 2002). Proportions for the middle grades were even higher.
- ♦ Certification rates for high school mathematics and science teachers declined from 1990 to 2002. Certification rates for middle-level mathematics and science teachers increased in the mid-1990s but subsequently declined.
- ♦ In academic year 1999, between 23% and 29% of public middle-grade and high school mathematics and science teachers did not have a college major or minor in their teaching field.

Many states have implemented policies to promote participation in teacher professional development and improve its quality.

- ♦ By 2002, 48 states had required professional development for teacher license renewal, and 24 had adopted professional development policies aligned with state content standards. As of 2004, 37 states financed some professional development programs, 35 had standards in place for professional development, 27 provided professional development funds for all districts in the state, 16 required and financed mentoring programs for all novice teachers, and 13 required districts or schools to set aside teacher time for professional development
- ♦ However, professional development in many school districts in the late 1990s still consisted mainly of one-time workshops with little followup. Most teachers attended programs for only a few hours over the course of the school year, far below the minimum of 60 to 80 hours that some studies show as needed to bring about meaningful change in teaching behaviors.

Inflation-adjusted U.S. public school teacher salaries increased only slightly between 1972 and 2002.

- ♦ In 2002, the average salary of all public school K−12 teachers was $44,367, just about $2,598 above what it was in 1972 (after adjusting for inflation).

Dissatisfaction with working conditions was among the most common reasons mathematics and science teachers gave for deciding to change schools or leave the profession.

- ♦ Public school mathematics and science teachers who changed schools were less likely than those who stayed to report satisfaction with job security, safety, community support, administrative support, and the amount of autonomy they had, among other factors.
- ♦ Those who left the profession reported they did so to pursue another career, to get a better salary or benefits, or to retire. They also reported more satisfaction with their new nonteaching jobs than with teaching.

Information Technology in Education

Access to computers and the Internet has grown rapidly both at school and at home.

- ♦ The ratio of public school students to online school computers improved from 12:1 in 1998 to 4:1 in 2003.
- ♦ In 2003, 77% of K–12 students lived in a household with a computer and 67% had Internet access at home.

Home computer ownership and Internet access continue to differ by family income, parental education, and race/ethnicity, but rapid growth in access to computers and the Internet in school has helped equalize access for disadvantaged students.

- ♦ Students in high-income families were nearly three times more likely than those from low-income families to have home Internet access, 90% versus 32%.
- ♦ Not only are overall use rates higher at school than at home, these differences are also more pronounced for less advantaged students. Low-income students, for example, were more than twice as likely to use a computer at school than at home in 2003, while high-income students used computers at only slightly different rates at the two locations.

Most third graders frequently use computers at school.

- About 56% of third graders were given computer work at least three times weekly in 2002 and 22% were assigned Internet use at least three times a week.

From 1999 to 2002, the proportion of teachers who feel prepared to use computers in the classroom increased.

- About two-thirds of all public school K–12 teachers surveyed in 1999 indicated that their preparation for using computers in instruction was inadequate. However, in 2002, more than 60% of third grade teachers said they felt prepared to use information technology (IT) in instruction and 75% overall reported being fairly comfortable using computers.

In 2000–01, most public school teachers reported participating in some professional development on using computers for instruction during the previous year.

- Roughly half said they had trained on one or more of three topics: the mechanics of using IT, integrating computers into instructional activities, and using the Internet. However, such training tended to be brief rather than sustained.

Transition to Higher Education

Increasing numbers of students are entering postsecondary education right after high school graduation.

- Between 1973 and 2003, the percentage of high school graduates enrolling in college in the fall following graduation grew from 47% to 64%, with increases occurring at both 2- and 4-year institutions. However, the trend began to flatten in the late 1990s.
- Enrollment rates increased faster for females than for males. Much of the growth in the overall rate was due to increases in the immediate enrollment rate of females at 4-year institutions.
- White high school graduates had consistently higher enrollment rates than their black and Hispanic peers over time, as did students from high-income families compared with those from low-income families.

Many college freshmen lack adequate preparation for higher education and need remedial assistance in their transition to college.

- In 2000, some 76% of postsecondary institutions offered remedial reading, writing, or mathematics courses. At these institutions, 22% of freshmen took remedial mathematics, 14% took remedial writing, and 11% took remedial reading. From 1995 to 2000, more institutions reported that students needed a year or more of remediation.
- Freshmen at public 2-year institutions had higher enrollment rates in remedial courses: 42% of freshmen at these institutions, compared with 12% to 24% of their peers at other types of institutions, enrolled in a remedial course in fall 2000.

Introduction

Chapter Overview

Across the United States, states, schools, and students are now fully immersed in efforts to meet the educational accountability requirements set forth by the federal No Child Left Behind Act of 2001 (NCLB), which took effect in 2002. NCLB requires the development of student performance standards and regular assessment of student learning. Schools that fail to show progress in improving achievement for all students receive assistance first, then sanctions. NCLB also emphasizes the importance of high-quality teaching and contains provisions encouraging states to see that teachers are adequately prepared for their teaching responsibilities.

States have already developed and published standards for mathematics achievement and were required to have standards for science in place by academic year 2005 (the school year that began in fall 2005). Beginning in academic year 2005, school districts must assess student mathematics performance yearly in grades 3 through 8. Beginning in academic year 2007, districts must assess student science performance once in elementary school and once in middle school. Over the next few years, the results of these assessments will provide new and important data about student performance in those crucial subjects.

Concern about the relationship of science and mathematics achievement to American global competitiveness, workforce preparation, and development of an educated citizenry continues to fuel efforts to improve student performance in those areas. This chapter draws on a variety of currently available data (mostly from 2000–04) to examine U.S. students' mathematics and science achievement; compare it with that of their international peers; and highlight developments, trends, and conditions influencing the quality of U.S. elementary and secondary mathematics and science education.

Chapter Organization

The chapter begins by summarizing the most recent available data on U.S. student achievement, including new indicators not available for previous *Science and Engineering Indicators* editions about student performance in mathematics during the first 4 years of schooling and performance in science in third grade. It continues by examining U.S. student performance in mathematics and science in grades 4, 8, and 12, and describes student achievement from an international perspective. The chapter next examines the availability of and participation in mathematics and science courses, including Advanced Placement (AP) testing, and characteristics of schools and students affecting this participation.

Teachers play an important role in helping students meet high standards, so the chapter next devotes attention to data on mathematics and science teachers, including their academic background and experience, the match or mismatch between academic preparation and teaching assignments, participation in professional development activities, and salaries and working conditions. New indicators in this section include transcript data on the academic backgrounds of new college graduates who entered teaching, state policies on teacher professional development, attrition and mobility of mathematics and science teachers, and perceptions of school working conditions by those who change schools or leave the profession.

Information technology (IT) affects all levels of education, and states are increasingly requiring and encouraging teachers to become more proficient in using technology for instruction. The chapter next looks at indicators of student access to and use of IT at school and at home, and the preparation of teachers for using IT in instruction. New indicators in this section include teachers' preparation for using IT in instruction in the early primary grades, and the use of IT among third grade students.

Finally, the chapter examines data on high school students' transition to postsecondary education, first-time entry rates into postsecondary education in the United States relative to rates in other countries, and the extent of remedial education at the college level as an indicator of student preparation for college-level work. A new indicator is information on the length of remedial coursetaking among freshmen.

This chapter focuses primarily on overall patterns, but it also reports variation in access to educational resources by school poverty level and minority concentration, and in student performance by sex, race/ethnicity, and family background characteristics (when data are available). Whenever the report cites a difference, it is statistically significant at the .05 probability level.

Student Learning in Mathematics and Science

The current performance of U.S. elementary and secondary students in mathematics and science is both encouraging and disappointing. Average mathematics scores on national assessments rose during the 1990s and early 2000s, and gains were widespread, with many demographic subgroups registering higher achievement. Performance in science has not improved recently, however. Substantial achievement gaps among some demographic subpopulations of students persist in both mathematics and science, and most 4th, 8th, and 12th grade students do not perform at levels considered proficient for their grade. On international assessments, recent data show that U.S. students performed above international averages that include scores from both developed and developing countries on tests closely aligned to the way mathematics and science are presented to them in the classroom. However, they performed below international averages for the 30 Organisation for Economic Co-operation and Development (OECD) nations in applying mathematical and scientific skills to situations they might encounter outside of a classroom.

This section presents information from recent national and international studies of U.S. student achievement in

mathematics and science and compares them with earlier study results. It begins with a discussion of student performance during the primary grades, followed by a review of assessment results for students in grades 4, 8, and 12. The section ends by placing U.S. student achievement in a broader international context.

Early Formal Learning: Kindergarten Through Third Grade

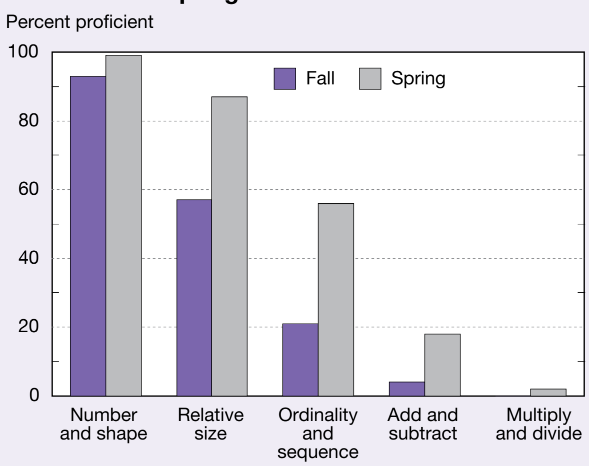
The mathematics and science performance of U.S. students in upper-elementary and secondary grades has been reported since the late 1960s (Campbell, Hombo, and Mazzeo 2000). Much less has been known about student learning in these subjects during the first years of formal education, but this is changing with the release of initial findings from an ongoing study of students who began kindergarten in 1998 (Early Childhood Longitudinal Study, Kindergarten Class of 1998–99, ECLS–K).[1]

Kindergarten: Mathematics Skills and Knowledge

Children begin formal schooling with varying levels of mathematics skills, and over the course of the kindergarten year, the percentage of students proficient in specific skill areas increases (West, Denton, and Germino-Hausken 2000; West, Denton, and Reaney 2000).[2] In 1998, most beginning kindergartners (93%) could recognize single-digit numbers and basic shapes in the fall, and almost all (99%) demonstrated these skills in the spring (figure 1-1). In the fall, just more than half (57%) of the students could count beyond 10, recognize the sequence in basic patterns, and compare the relative size of objects, but by spring, 87% could do so. Increases occurred in other skill areas as well, although gains in more advanced skills such as addition, subtraction, multiplication, and division were relatively small (see sidebar “Mathematics Skills Areas for Primary Grade Students”).

Disparities among subpopulations of students were evident when they started kindergarten. Mathematics performance was related to several student background factors, and the association between social disadvantages and performance was cumulative. Lower proportions of black and Hispanic students were proficient at each skill level compared with their white and Asian/Pacific Islander peers (appendix table 1-1)[3]. Performance was also related to maternal education, with students whose mothers had less formal education demonstrating lower proficiency rates. For the kindergarten assessments, a family risk index was developed consisting of non-English primary home language, single-parent

Figure 1-1
First-time kindergartners demonstrating specific mathematics skills and knowledge: Fall 1998 and spring 1999



SOURCE: J. West, K. Denton, and L. Reaney, *The Kindergarten Year,* U.S. Department of Education, National Center for Education Statistics (2000). See appendix table 1-1.

Science and Engineering Indicators 2006

Mathematics Skills Areas for Primary Grade Students

The Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS–K) mathematics assessment measures core foundational mathematics skills, including conceptual understanding of numbers, shapes, mathematical operations, and processes for problem solving (West, Denton, and Germino-Hausken 2000). The assessment provides information on student performance in the form of an overall achievement score and proficiency in seven specific skill sets. The skill sets represent a progression of mathematics skills and knowledge. Levels 6 and 7 were first assessed in third grade. Each set of skills is labeled by the most sophisticated skill in the set.

Level 1: Number and shape: recognize single-digit numbers and shapes.

Level 2: Relative size: count beyond 10, recognize the sequence in basic patterns, and compare the relative size and dimensional relationship of objects.

Level 3: Ordinality and sequence: recognize two-digit numbers, identify the next number in a sequence, identify the ordinal position of an object, and solve simple word problems.

Level 4: Add and subtract: solve simple addition and subtraction items and identify relationships of numbers in sequence.

Level 5: Multiply and divide: perform basic multiplication and division and recognize more complex number patterns.

Level 6: Place value: demonstrate understanding of place value in integers to the hundredth place.

Level 7: Rate and measurement: use knowledge of measurement and rate to solve word problems.

SOURCE: West, Denton, and Reaney 2000.

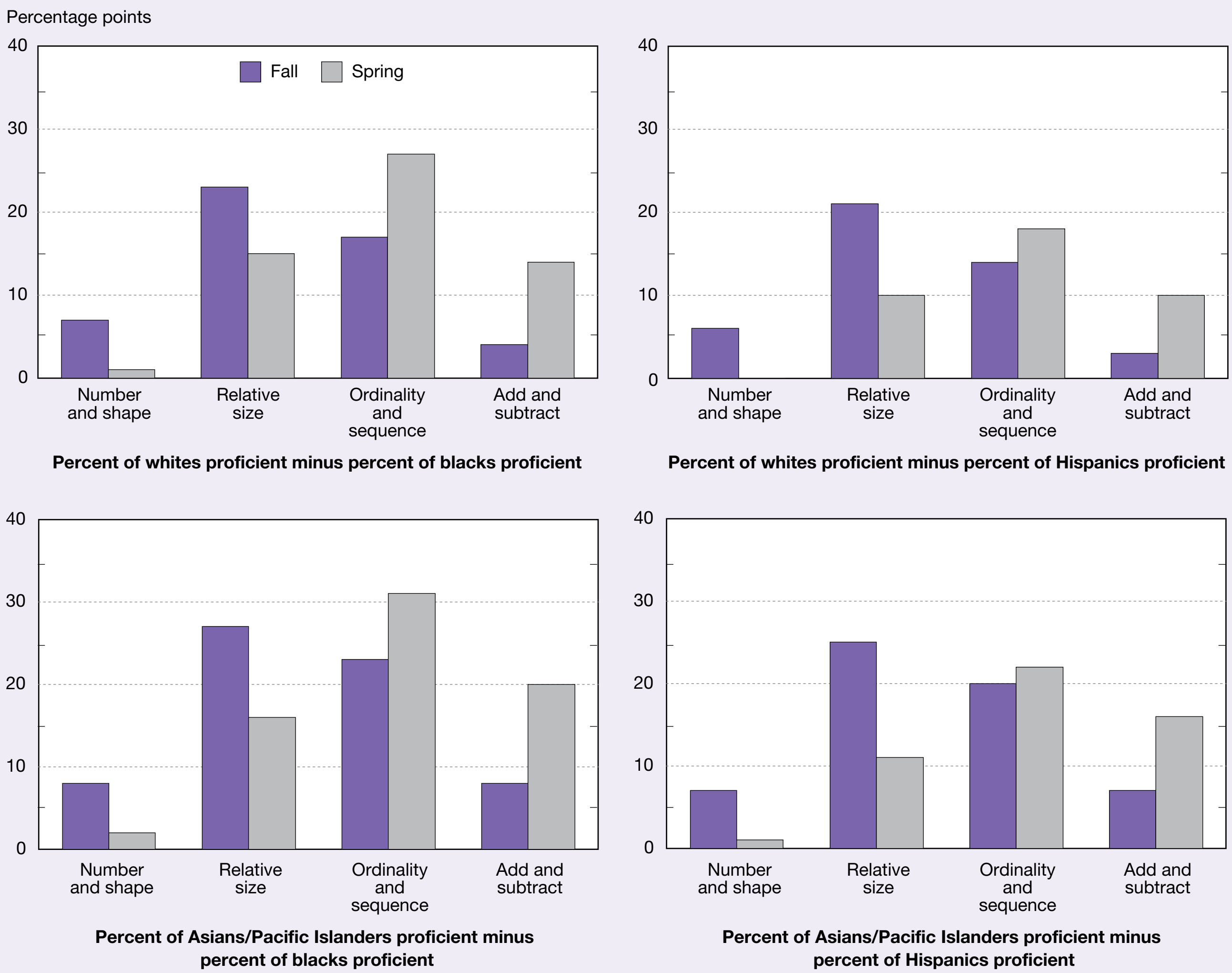
family, less than high school maternal education, and family receiving welfare assistance.[4] Students from families with no risk factors performed better than students from families with one risk factor, and students from families with one risk factor performed better than students from families with two or more risk factors.

As students progressed through kindergarten, gaps in basic mathematics skills decreased, but disparities in the more sophisticated skills increased. For example, by the end of kindergarten, blacks and Hispanics narrowed the proficiency gap with whites and Asians/Pacific Islanders in recognizing single-digit numbers and shapes and in comparing the relative size of objects (figure 1-2; appendix table 1-1). However, they did not acquire more advanced mathematics knowledge and skills, such as addition and subtraction, at the same rate as whites and Asians/Pacific Islanders. This resulted in even larger disparities in the more sophisticated skills by the end of kindergarten.

The First 4 Years of School

Mathematics. After 4 years of formal schooling, when most students were at the end of third grade, some performance gaps had widened (Rathbun and West 2004) (figure 1-3; appendix table 1-2).[5] Black students, who entered kindergarten with lower overall mathematics scores than white and Asian/Pacific Islander students, made smaller gains over the 4 years than did white, Asian/Pacific Islander, and Hispanic students, resulting in larger performance gaps. Students with one or more family risk factors started formal education with lower scores and made less progress than students with no family risk factors, also resulting in larger performance gaps.

Figure 1-2
Mathematics proficiency gaps between whites or Asians/Pacific Islanders and blacks or Hispanics among first-time kindergartners, by skill area: Fall 1998 and spring 1999



SOURCE: J. West, K. Denton, and L. Reaney, *The Kindergarten Year,* U.S. Department of Education, National Center for Education Statistics (2000). See appendix table 1-1.

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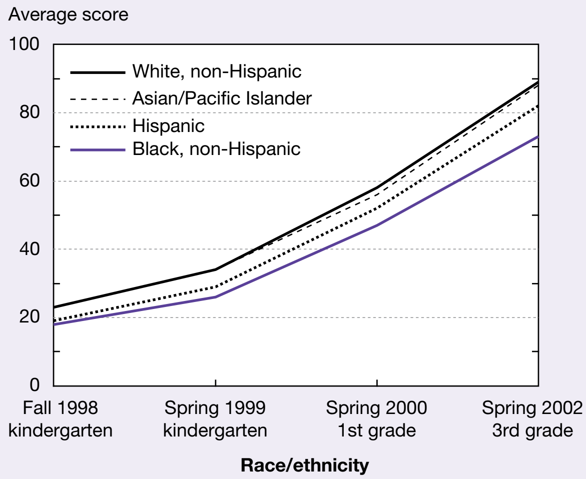
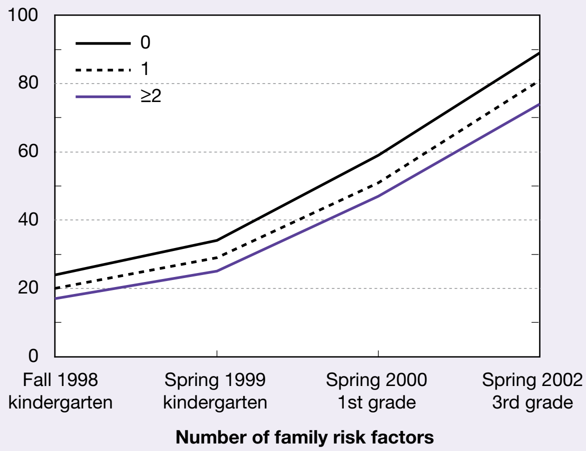
Figure 1-3
Average mathematics scores of fall 1998 first-time kindergartners from fall 1998 to spring 2002, by race/ethnicity and number of family risk factors: 1998–2000, 2002





NOTE: Family risk factors include living below federal poverty level, non-English primary home language, single-parent household, maternal education less than high school diploma or equivalent credential (e.g., General Educational Development certificate).

SOURCE: A. Rathbun and J. West, *From Kindergarten Through Third Grade: Children's Beginning School Experiences,* U.S. Department of Education, National Center for Education Statistics (2004). See appendix table 1-2.

Science and Engineering Indicators 2006

Other research has shown that widening achievement gaps as students progress through school is, at least in part, a result of differential learning growth and loss during the summer (Alexander, Entwisle, and Olson 2001; Borman and Boulay 2004; Cooper et al. 1996). For example, although lower- and upper-income primary grade students made similar gains in mathematics during the school year, lower-income students experienced declines in mathematics skills during summer breaks, whereas higher-income students experienced gains (Alexander, Entwisle, and Olson 2001). These findings have been attributed to greater ability among higher-income parents to provide their children with mathematically stimulating materials and activities during the summer.

Studies of upper-elementary and secondary students dating back to the late 1960s have documented some sex differences in science and mathematics performance (e.g., Campbell, Hombo, and Mazzeo 2000; NCES 2003a and 2003b).[6] The ECLS–K study, the first national study of primary grade students, found no sex differences in average overall mathematics performance during the first 4 years of schooling (Rathbun and West 2004; West, Denton, and Germino-Hausken 2000; West, Denton, and Reaney 2000). However, at the end of third grade, boys were more likely than girls to demonstrate proficiency in the advanced mathematics skills of place value concepts and knowledge of rate and measurement to solve word problems (appendix table 1-3). These advanced math skills were first assessed in the third followup, when most students were in third grade.

The ECLS–K study examined associations between mathematics performance and two aspects of students' early school experiences: whether they attended public or private schools, and whether they attended full- or half-day kindergarten. Performance differences in mathematics by school type were evident as students started formal schooling (West, Denton, and Germino-Hausken 2000). Students beginning kindergarten in private schools had stronger mathematics skills than those at public schools. Although achievement differences persisted through the third grade, the growth rate in mathematics did not differ. Therefore, performance gaps between public and private school students did not increase (Rathbun and West 2004).[7] Students in full-day kindergartens experienced greater gains in mathematics compared with their peers in half-day classes (Watson and West 2004). At the end of third grade, however, the benefit of full-day kindergarten could no longer be detected (Rathbun, West, and Germino-Hausken 2004).

Science. The ECLS–K study began assessing students in science in spring 2002, when most were in third grade. The assessment placed equal emphasis on life science, earth and space science, and physical science and asked students to demonstrate understanding of the physical and natural world, make inferences, and understand relationships (Rathbun and West 2004). Students were also required to interpret scientific data, form hypotheses, and develop plans to investigate scientific questions.[8] Performance gaps observed in mathematics were also generally found in science (appendix table 1-4): white and Asian/Pacific Islander students had higher average science scores than blacks and Hispanics; Hispanic third graders outperformed their black peers; and students with no family risk factors scored higher, on average, than those with one or more risk factors. No sex differences were observed in third grade science performance.

Performance of U.S. Students in Grades 4, 8, and 12

Many of the same performance gaps in mathematics and science achievement found among primary students also exist among upper-elementary and secondary students. Although mathematics performance in particular improved

through the 1990s and early 2000s for many subgroups, substantial achievement gaps persist and, as will be detailed below, in some cases, have grown wider.

The National Assessment of Educational Progress (NAEP), also known as the "Nation's Report Card," has charted the academic performance of U.S. students in the upper-elementary and secondary grades since 1969.[9] This volume reports on recent trends, from 1990 to 2003 for mathematics and from 1996 to 2000 for science.[10] Previous *Science and Engineering Indicators* described long-term trends in mathematics and science results dating back to the first NAEP assessments.[11] Long-term trends in mathematics achievement from the 2004 administration were released too late for the text of this chapter but are reviewed briefly in the sidebar "Long-term Trends in Student Mathematics Achievement" at the conclusion of this section.

The NAEP assessments are based on frameworks developed through a national consensus process that involves educators, policymakers, assessment and curriculum experts, and the public. The frameworks are then approved by the National Assessment Governing Board (NAGB) (NCES 2003a). The mathematics assessment contains five broad content strands (number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions). It also assesses mathematical ability (conceptual understanding, procedural knowledge, and problem solving) and mathematical power (reasoning, connections, and communication). The science framework includes a content dimension divided into three major fields of science (earth, life, and physical), and a cognitive dimension covering conceptual understanding, scientific investigation, and practical reasoning (NCES 2001).

Student performance on the NAEP is measured with scale scores as well as achievement levels. The scale scores place students on a continuous ability scale based on their overall performance. For mathematics, the scale ranges from 0 to 500 across the three grades. For science, the scale ranges from 0 to 300 within each grade.

The achievement levels are set by NAGB based on recommendations from panels of educators and members of the public, and describe what students should know and be able to do at the basic, proficient, and advanced levels (NCES 2003a). The *basic* level represents partial mastery of the knowledge and skills needed to perform proficiently at each grade level. The *proficient* level represents solid academic performance and the *advanced* level represents superior performance. This review of NAEP results focuses on the proficient level (for definitions of the proficient level for grades 4, 8, and 12, see sidebars "Proficient Level in Mathematics in Grades 4, 8, and 12" and "Proficient Level in Science in Grades 4, 8, and 12").

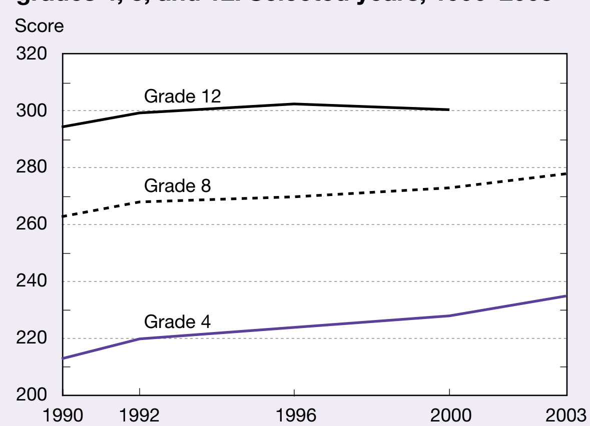
Disagreement exists about whether NAEP has appropriately defined these levels. A study commissioned by the National Academy of Sciences judged the process used to set these levels "fundamentally flawed" (Pellegrino, Jones, and Mitchell 1998), and NAGB acknowledges that considerable controversy remains over setting achievement levels (Bourque and Byrd 2000). However, both the National Center for Education Statistics (NCES) and NAGB believe the levels are useful for understanding trends in achievement. Nevertheless, they warn readers to use and interpret the levels with caution (NCES 2003a).

In this section, the NAEP results are examined in a number of ways, including changes in average scores and the proportion of students reaching the proficient level, both overall and among subgroups of students. In addition, achievement gaps between demographic subpopulations and changes in those gaps are reviewed. Examining a set of measures reveals more about student performance than examining just one measure (Barton 2004). For example, without examining changes in achievement for high-, middle-, and low-achieving students, it would be impossible to know whether a rise in average scores resulted from increased scores among only high-achieving students or whether it reflects broader improvements.

Mathematics Performance

The average mathematics scores of fourth and eighth grade students increased from 1990 (the first year in which the current assessment was given) to 2003 (NCES 2001, 2003a) (figure 1-4; table 1-1).[12] The average performance of 12th graders also improved between 1990 and 2000, when they were last assessed. The pattern of increased average scores was widespread (table 1-1; appendix table 1-5). At each grade level, average mathematics scores improved for both male and female students, and for all students regardless of eligibility for free or reduced-price lunch (a commonly used

Figure 1-4
Average mathematics score of students in grades 4, 8, and 12: Selected years, 1990–2003



NOTES: 2003 scores include English language learner and disabled students who took assessment with accommodations. Scores from 1990 to 2000 from National Assessment of Educational Progress samples where accommodations were not permitted.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); and *The Nation's Report Card: Mathematics 2000* (2001). See appendix table 1-5.

Science and Engineering Indicators 2006

Proficient Level in Mathematics in Grades 4, 8, and 12

The National Assessment of Educational Progress (NAEP) ranks student performance according to three achievement levels: basic, proficient, and advanced. The levels are set by the National Assessment Governing Board (NAGB) based on recommendations from panels of educators and members of the public of what students should know and be able to do in the subject assessed. NAGB's definition of the proficient level for mathematics for grades 4, 8, and 12 is directly quoted below. Descriptions of the other achievement levels can be found in the report cited at the end of the sidebar.

Grade 4

Fourth grade students performing at the Proficient level should consistently apply integrated procedural knowledge and conceptual understanding to problem solving in the five NAEP content strands.

Fourth graders performing at the Proficient level should be able to use whole numbers to estimate, compute, and determine whether results are reasonable. They should have a conceptual understanding of fractions and decimals; be able to solve real-world problems in all NAEP content areas; and use four-function calculators, rulers, and geometric shapes appropriately. Students performing at the Proficient level should employ problem-solving strategies such as identifying and using appropriate information. Their written solutions should be organized and presented both with supporting information and with explanations of how they were achieved.

Grade 8

Eighth grade students performing at the Proficient level should apply mathematical concepts and procedures consistently to complex problems in the five NAEP content strands.

Eighth graders performing at the Proficient level should be able to conjecture, defend their ideas, and give supporting examples. They should understand the connections among fractions, percents, decimals, and other mathematical topics such as algebra and functions. Students at this level are expected to have a thorough understanding of basic-level arithmetic operations—an understanding sufficient for problem solving in practical situations. Quantity and spatial relationships in problem solving and reasoning should be familiar to them, and they should be able to convey underlying reasoning skills beyond the level of arithmetic. They should be able to compare and contrast mathematical ideas and generate their own examples. These students should make inferences from data and graphs, apply properties of informal geometry, and accurately use the tools of technology. Students at this level should understand the process of gathering and organizing data and be able to calculate, evaluate, and communicate results within the domain of statistics and probability.

Grade 12

Twelfth grade students performing at the Proficient level should consistently integrate mathematical concepts and procedures into the solutions of more complex problems in the five NAEP content strands.

Twelfth graders performing at the Proficient level should demonstrate an understanding of algebraic, statistical, geometric, and spatial reasoning. They should be able to perform algebraic operations involving polynomials, justify geometric relationships, and judge and defend the reasonableness of answers as applied to real-world situations. These students should be able to analyze and interpret data in tabular and graphical form; understand and use elements of the function concept in symbolic, graphical, and tabular form; and make conjectures, defend ideas, and give supporting examples.

Source: NAGB 2002.

indicator for poverty).[13] Generally, gains were observed for white, black, Hispanic, and Asian/Pacific Islander 4th and 8th grade students, although at grade 12, only the scores of white students improved.[14] Higher average scores for students at the 10th, 25th, 50th, 75th, and 90th percentiles in 2003, compared with 1990, provide further evidence that gains in mathematics were widespread. (Percentiles indicate the percentage of students whose scores fell below a particular score. For example, 75% of students had scores below the 75th percentile.)

Improvements in average mathematics scores were generally mirrored by increases in the percentage of students scoring at or above the proficient level for their grade (figure 1-5; table 1-1; appendix table 1-6). This growth was substantial at grades 4 and 8, with rates about doubling between 1990 and 2003.

Although gains in mathematics achievement are encouraging, despite the improvements, most students do not demonstrate solid mathematics skills and knowledge for their grade. In the latest NAEP mathematics assessments (2003 for grades 4 and 8, and 2000 for grade 12), only about one-third of 4th and 8th graders, and even fewer 12th graders (16%), reached the proficient level (figure 1-5; appendix table 1-6).

Proficient Level in Science in Grades 4, 8, and 12

The National Assessment of Educational Progress (NAEP) ranks student performance according to three achievement levels for their grade: basic, proficient, and advanced. The levels are set by the National Assessment Governing Board (NAGB) based on recommendations from panels of educators and members of the public of what students should know and be able to do in the subject assessed. NAGB's definition of the proficient level in science for grades 4, 8, and 12 is directly quoted below. Descriptions of the other achievement levels can be found in the report cited at the end of the sidebar.

Grade 4

Students performing at the Proficient level demonstrate the knowledge and reasoning required for understanding of Earth, physical, and life sciences at a level appropriate to grade 4. For example, they understand concepts relating to the Earth's features, physical properties, structure, and function. In addition, students can formulate solutions to familiar problems as well as show a beginning awareness of issues associated with technology.

Fourth grade students performing at the Proficient level are able to provide an explanation of day and night when given a diagram. They can recognize major features of the Earth's surface and the impact of natural forces. They are also able to recognize water in its various forms in the water cycle and can suggest ways to conserve it. These students recognize that various materials possess different properties that make them useful. Students at this level are able to explain how structure and function help living things survive. They have a beginning awareness of the benefits and challenges associated with technology and recognize some human effects on the environment. They can also make straightforward predictions and justify their position.

Grade 8

Students performing at the Proficient level demonstrate much of the knowledge and many of the reasoning abilities essential for understanding of Earth, physical, and life sciences at a level appropriate to grade 8. For example, students can interpret graphic information, design simple investigations, and explain such scientific concepts as energy transfer. Students at this level also show an awareness of environmental issues, especially those addressing energy and pollution.

Eighth grade students performing at the Proficient level are able to create, interpret, and make predictions from charts, diagrams, and graphs based on information provided to them or from their own investigations. They have the ability to design an experiment and have an emerging understanding of variables and controls. These students are able to read and interpret geographic and topographic maps. In addition, they have an emerging ability to use and understand models, can partially formulate explanations of their understanding of scientific phenomena, and can design plans to solve problems. Students at this level can begin to identify forms of energy and describe the role of energy transformations in living and nonliving systems. They have knowledge of organization, gravity, and motion within the solar system and can identify some factors that shape the surface of the Earth. These students have some understanding of properties of materials and have an emerging understanding of the particulate nature of matter, especially the effect of temperature on states of matter. They also know that light and sound travel at different speeds and can apply their knowledge of force, speed, and motion. These students demonstrate a developmental understanding of the flow of energy from the sun through living systems, especially plants. They know that organisms reproduce and that characteristics are inherited from previous generations. These students also understand that organisms are made up of cells and that cells have subcomponents with different functions. In addition, they are able to develop their own classification system based on physical characteristics. These students can list some effects of air and water pollution as well as demonstrate knowledge of the advantages and disadvantages of different energy sources in terms of how they affect the environment and the economy.

Grade 12

Students performing at the Proficient level demonstrate the knowledge and reasoning abilities required for understanding of the Earth, physical, and life sciences at a level appropriate to grade 12. In addition, they demonstrate knowledge of the themes of science (models, systems, and patterns of change) required for understanding how these themes illustrate essential relationships among the Earth, physical, and life sciences. They are able to analyze data and apply scientific principles to everyday situations.

Twelfth grade students performing at the Proficient level are able to demonstrate a working ability to design and conduct scientific investigations. They are able to analyze data in various forms and utilize information to provide explanations and to draw reasonable conclusions. Students at this level have a developmental understanding of both physical and conceptual models and are able to compare various models. They recognize some inputs and outputs, causes and effects, and interactions of a system. In addition, they can correlate structure to function for the parts of a system that they can identify. These students also recognize that rate of change depends on initial conditions and other factors. They are able to apply scientific concepts and principles to practical applications and solutions for problems in the real world and show a developmental understanding of technology, its uses, and its applications.

Source: NAGB 2000.

Table 1-1
Changes in mathematics and science performance of students in grades 4, 8, and 12, by student characteristics: 1990–2003

	Mathematics			Science		
	1990–2003		1990–2000	1996–2000		
Student characteristic	Grade 4	Grade 8	Grade 12	Grade 4	Grade 8	Grade 12
Average score						
Total	▲	▲	▲	•	•	▼
Sex						
Male	▲	▲	▲	•	▲	▼
Female	▲	▲	▲	•	•	•
Race/ethnicity						
White, non-Hispanic	▲	▲	▲	•	•	▼
Black, non-Hispanic	▲	▲	•	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	▲	•	NA	•	•
American Indian/Alaska Native[b]	•	•	•	•	▼	•
Free/reduced-price lunch[c]						
Eligible	▲	▲	▲	•	▼	•
Not eligible	▲	▲	▲	•	▲	▼
Percentile score						
10th	▲	▲	▲	•	▲	•
25th	▲	▲	▲	•	•	•
50th	▲	▲	▲	•	•	▼
75th	▲	▲	▲	•	•	•
90th	▲	▲	▲	•	•	•
Percent at or above proficient level						
Total	▲	▲	▲	•	•	•
Sex						
Male	▲	▲	▲	•	▲	•
Female	▲	▲	▲	•	•	•
Race/ethnicity						
White, non-Hispanic	▲	▲	▲	•	•	•
Black, non-Hispanic	▲	▲	•	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	▲	•	NA	•	•
American Indian/Alaska Native[b]	•	•	•	•	•	•
Free/reduced-price lunch[c]						
Eligible	▲	▲	•	•	•	•
Not eligible	▲	▲	•	•	▲	•
Changes in achievement gaps in average scores						
Gender gap	•	•	•	▲	▲	•
White-black gap	▼	•	•	•	•	•
White-Hispanic gap	•	•	•	•	•	•
Eligible and not eligible for free/reduced-price lunch gap[c]	•	•	•	•	▲	•

▲ = increase; • = no change; ▼ = decrease
NA = not available

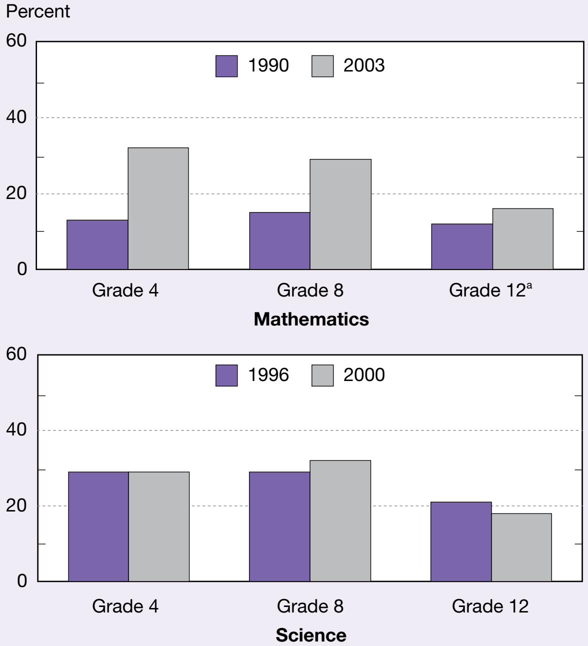
[a]National Center for Education Statistics (NCES) did not publish 2000 science scores for fourth grade Asian/Pacific Islander students because of accuracy and precision concerns.
[b]Insufficient samples sizes in earlier years of National Assessment of Educational Progress (NAEP) in mathematics and science precluded calculation of reliable estimates for American Indians/Alaska Natives. Mathematics comparisons shown here for this group are between 1996 and 2003 for grade 4, 2000 and 2003 for grade 8, and 1996 and 2000 for grade 12. Science comparison for American Indian/Alaska Natives are from 1996 to 2000.
[c]Information on student eligibility for free/reduced-price lunch first collected in 1996. Thus, comparisons shown for mathematics are from 1996 to 2003 and for science are from 1996 to 2000.

NOTE: Includes students in both public and private schools.

SOURCES: U.S. Department of Education, NCES, *The Nation's Report Card: Mathematics Highlights 2003,* NCES 2004-451 (2003); *The Nation's Report Card: Mathematics 2000,* NCES 2001-517 (2001); *The Nation's Report Card: Science Highlights 2000,* NCES 2002-452 (2001); and data from NAEP, 1990, 2000, and 2003 mathematics assessments and 1996 and 2000 science assessments. See appendix tables 1-5, 1-6, 1-7, and 1-8.

Science and Engineering Indicators 2006

Figure 1-5
Students performing at or above proficient level for their grade, by grade: 1990–2003



[a]For mathematics, latest assessment for grade 12 was 2000.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Science Performance

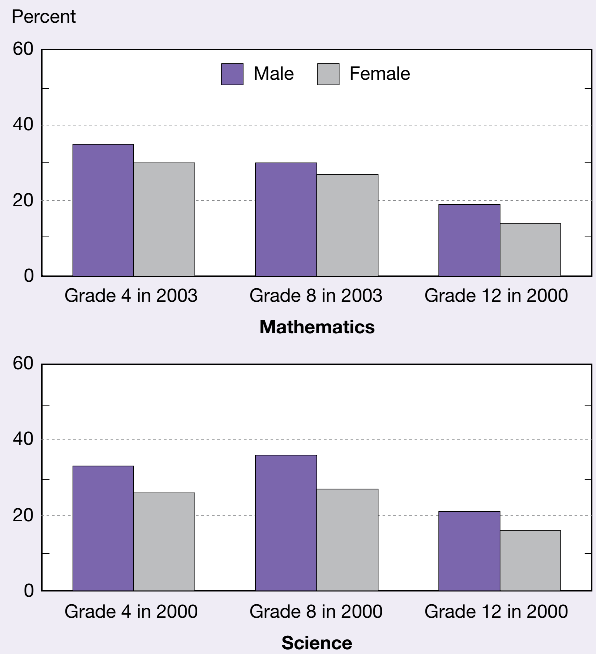
Recent trend lines for science are shorter than those for mathematics, and they suggest less improvement. Although average mathematics scores of fourth and eighth grade students increased from 1996 to 2000 (appendix table 1-5), average science scores did not change (NCES 2003b) (table 1-1; appendix table 1-7). At grade 12, average science scores declined. The proportion of students reaching the proficient level in science did not change for any of the three grades. Subgroup results in science were also generally flat between 1996 and 2000, both in terms of average scores and in the percent at or above the proficient level.[15] (The current national NAEP science assessment was administered in 1996, 2000, and 2005. The 2005 data were not available in time to be included in this report.)

In results similar to the 2003 mathematics findings, only about one-third of fourth and eighth grade students reached the proficient level in science for their grade in 2000 (figure 1-5; appendix table 1-8). Rates were lower among 12th graders, with only 18% of these students scoring at or above the proficient level.

Achievement Gaps Between Demographic Subgroups

Gender Achievement Gaps. The most recent NAEP assessments report only small sex differences in mathematics and science performance at grades 4, 8, and 12, with boys performing slightly better than girls (appendix tables 1-5, 1-6, 1-7, and 1-8).[16] For example, in 2003, 35% of fourth grade boys reached the proficient level in mathematics, compared with 30% of fourth grade girls (figure 1-6). The small gender gaps in mathematics have generally remained stable since 1990. However, the small gender gaps among fourth and eighth graders observed in science in 2000, for the most part, represent an increase from those observed in 1996 (table 1-1; appendix tables 1-5, 1-6, 1-7, and 1-8).

Figure 1-6
Students performing at or above proficient level for their grade, by sex: 2000 and 2003



SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Racial/ethnic Achievement Gaps. Substantial performance gaps exist between some racial/ethnic subgroups. At each grade level, white and Asian/Pacific Islander students performed better than black, Hispanic, and American Indian/Alaska Native students in both mathematics and science, both in terms of average scores and in percentage of students reaching the proficient level (figure 1-7; appendix tables 1-5, 1-6, 1-7, and 1-8). These achievement differences were relatively large. For example, in 2003, between four and five times as many white and Asian/Pacific Islander fourth grade students reached the proficient level in mathematics as did black students (see sidebar "Tenth Graders' Proficiency in Specific Mathematics Skill and Knowledge Areas").

Tenth Graders' Proficiency in Specific Mathematics Skill and Knowledge Areas

Achievement disparities by student and family backgrounds are observed in other national studies, such as the Education Longitudinal Study of 2002 (ELS: 2002). This base-year study assessed mathematics achievement of 10th grade students and placed their performance in one of five proficiency levels: simple arithmetical operations with whole numbers; simple operations with decimals, fractions, powers, and roots; simple problem solving requiring the understanding of low-level mathematical concepts; understanding of intermediate-level mathematical concepts and multistep solutions to word problems; and complex multistep word problems and advanced mathematics material (Ingels and Scott 2004). The skill levels represent a progression of mathematics skills and knowledge.

In 2002, a vast majority of 10th grade students (92%) were proficient in simple arithmetical operations with whole numbers, and 67% were also proficient in simple operations with decimals, fractions, roots, and powers (table 1-2). However, the proportions demonstrating proficiency in more advanced mathematics skills were lower and decreased with the progression of skill levels. The differences in proficiency in each skill area for male and female students were small, but they were larger for racial/ethnic and family socioeconomic subgroups. White and Asian/Pacific Islander students were more likely than black and Hispanic students to demonstrate proficiency in each level of mathematics skills, as were students from high-socioeconomic families compared with those from low-socioeconomic families. Followup data collection is under way. When these longitudinal data are available and can be used with other longitudinal studies such as High School and Beyond (HS&B) and the National Education Longitudinal Study (NELS), they will provide more valuable information about growth in student achievement and factors related to this growth.

Table 1-2
Tenth graders demonstrating mathemathics proficiency, by student characteristics: 2002
(Percent)

Student characteristic	Simple operations: whole numbers	Simple operations: decimals, fractions, roots, and power	Simple problem solving	Understanding intermediate-level concepts, multistep problem solving	Complex problem solving, advanced knowledge
Total	91.7	67.1	46.4	20.4	1.0
Sex					
Male	91.7	68.4	48.0	22.3	1.3
Female	91.6	65.7	44.7	18.5	0.6
Race/ethnicity					
White, non-Hispanic	95.5	77.9	57.9	27.0	1.2
Black, non-Hispanic	83.8	42.3	19.4	4.7	0.1
Hispanic	83.7	46.9	25.5	8.8	0.3
Asian/Pacific Islander	95.2	77.6	60.2	31.7	4.0
Other	90.5	63.2	39.2	14.4	0.6
Family socioeconomic status					
Low	84.8	46.6	25.0	7.6	0.2
Middle	92.4	67.8	44.9	17.9	0.6
High	97.2	86.0	70.5	38.4	2.5

NOTES: Socioeconomic status based on five equally weighted components: father's/guardian's education, mother's education, family income, father's/guardian's occupation, and mother's/guardian's occupation. Low socioeconomic status defined as bottom 20% of socioeconomic status index, middle socioeconomic status is between 20% and 80%, and high socioeconomic status is top 20%.

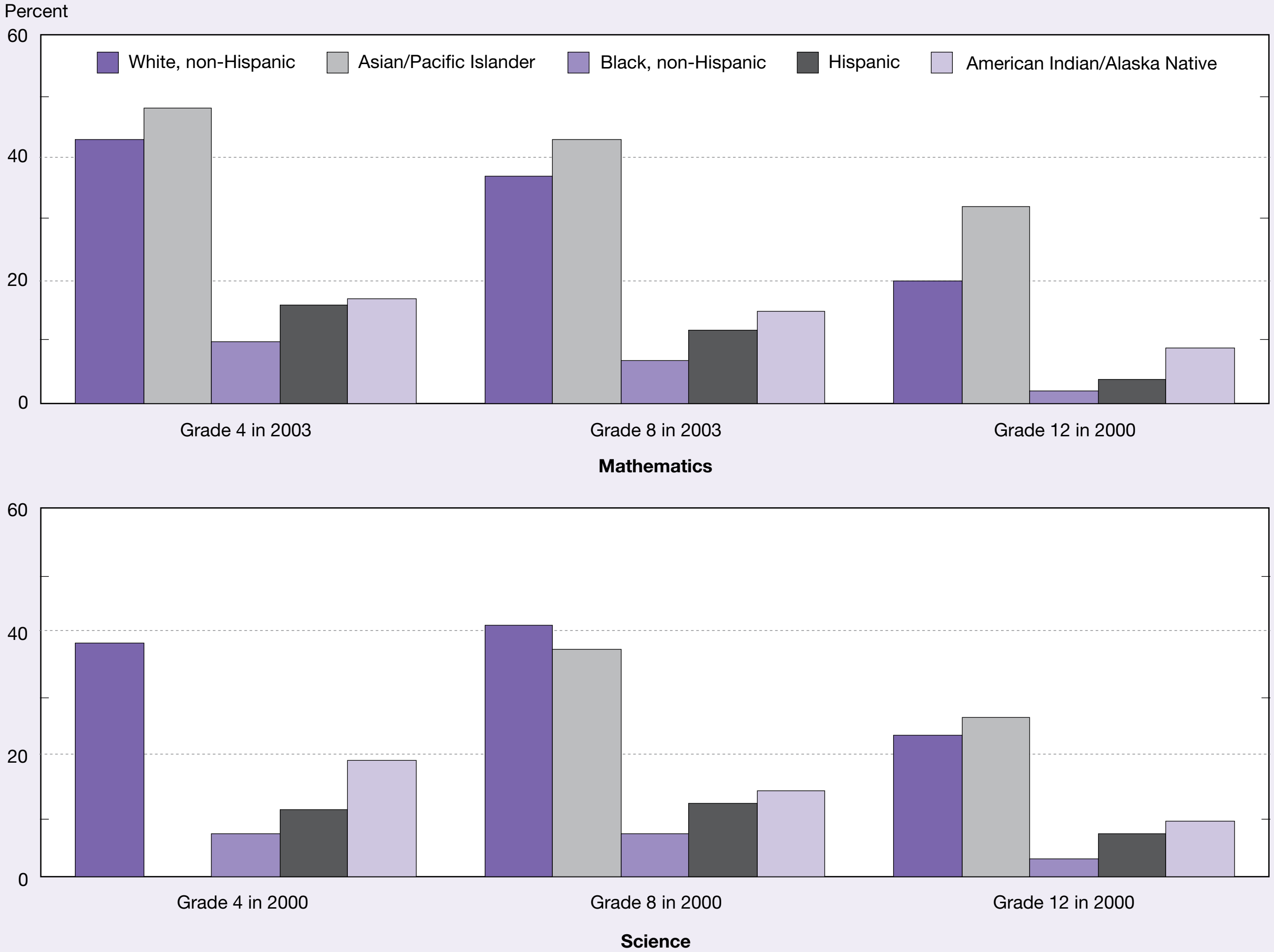
SOURCE: U.S. Department of Education, National Center for Education Statistics, Education Longitudinal Study of 2002.

Science and Engineering Indicators 2006

More subtle racial/ethnic differences in achievement were also observed.[17] For example, Asians/Pacific Islanders demonstrated slightly higher performance than whites in mathematics at each grade level, but the reverse was true for science at grades 4 and 8. In addition, in some instances, American Indian/Alaska Native and Hispanic students registered slightly higher performances than did black students (see sidebar "Projected School-Age Population of the United States").

Family Income Achievement Gaps. Mathematics and science performance also differed by family income (as measured by whether or not a student was eligible for the free or reduced-priced school lunch program) (figure 1-8; appendix tables 1-5, 1-6, 1-7, and 1-8). At each grade level, in both mathematics and science, students eligible for the subsidized lunch program (i.e., students from low-income families) had lower average scores and were less likely to reach the proficient level than

Figure 1-7
Students performing at or above proficient level for their grade, by race/ethnicity: 2000 and 2003

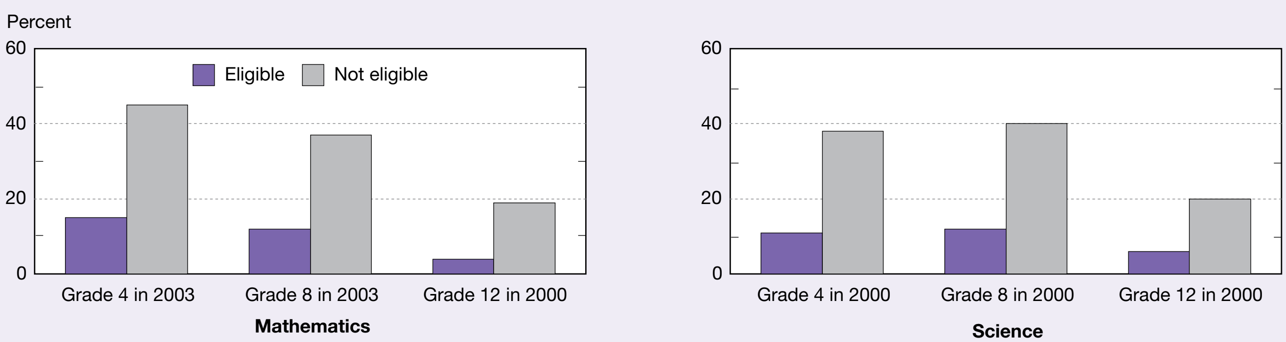


NOTE: National Center for Education Statistics (NCES) did not publish 2000 science scores for fourth grade Asian/Pacific Islander students because of accuracy and precision concerns.

SOURCES: U.S. Department of Education, NCES, *The Nation's Report Card: Mathematics Highlights 2003* (2003); *The Nation's Report Card: Mathematics 2000* (2001); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Figure 1-8
Students performing at or above proficient level for their grade, by eligibility for subsidized lunches: 2000 and 2003



NOTE: Eligibility for federal free/reduced-price lunch program is a commonly used indicator for family poverty.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); *The Nation's Report Card: Mathematics 2000* (2001); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Long-Term Trends in Student Mathematics Achievement

This chapter presents indicators of student achievement in mathematics and science based on the *national* NAEP assessments. This sidebar briefly introduces indicators of mathematics learning based on the NAEP 30-year *long-term trend* assessment of 2004 that became available in July 2005, too late for incorporation into the text of this volume.[9]

Major differences between these two NAEP programs include:

- Content in the long-term trend assessments has remained the same across administrations, whereas the national assessments have been updated periodically as the world and curricula have changed.
- The long-term trend assessment is administered to 9-, 13-, and 17-year-olds, whereas the national assessments are given to students in the 4th, 8th, and 12th grades.
- The long-term trend assessment reports achievement at the national level, whereas the national assessment reports achievement at the national and state levels and produces some district-level data.

This sidebar discusses scores on mathematics performance of representative samples of more than 11,000 students at each of the three ages assessed. More detailed data, as well as scores on reading, are available in the full report (Perie, Moran, and Lutkus 2005).

Overall Trend in Mathematics

Average scores on the long-term trend assessment in mathematics increased for 9- and 13-year olds in 2004 over the last assessment in 1999. The average score of 9-year-olds, after remaining flat throughout the 1990s, increased 9 points in 2004; the 2004 scores were 22 points higher than 30 years earlier. Thirteen-year-olds' average scale score increased 5 points in 2004 over 1999 and 15 points over 1973.

However, mathematics scores of 17-year-olds did not change from 1999 to 2004. The average score of 17-year-olds has increased 9 points since the lowest score in 1982, but has remained flat for more than a decade and is not significantly different from the average score for the first long-term trend mathematics assessment in 1973.

Trends in Mathematics Score Gaps

Samples of students for the NAEP long-term trend assessments are sufficiently large to allow reporting of scores separately for whites, blacks, and Hispanics. As table 1-3 shows, whites have, on average, scored higher than blacks and Hispanics throughout the 30-year assessment period. Although the gaps in achievement have decreased over the 30-year period, few of these declines occurred in the past 20 years.

Across the 30 years of the testing program, the gap in scores between whites and blacks decreased by 12, 19, and 12 points for 9-, 13-, and 17-year-olds, respectively. However, for each age group, the gap has remained significantly unchanged for at least the past decade.

The gap in average scores between white and Hispanic 9-year-olds was lower in 2004 than 1999 but did not differ from the 1973 gap. The gap in scores between white and Hispanic 13- and 17-year-olds decreased 12 and 9 points, respectively, between 1973 and 2004. However, this improvement was registered early in the assessment program; no statistically significant improvement has been measured since the 1970s.

Table 1-3
Trends in average mathematics scale score gaps between white students and black and Hispanic students 9, 13, and 17 years old: 1973–2004

Group	1973	1978	1982	1986	1990	1992	1994	1996	1999	2004
White versus black										
Age 9	*35*	*32*	*29*	25	27	27	25	25	28	23
Age 13	*46*	*42*	*34*	24	27	29	29	29	32	27
Age 17	*40*	*38*	32	29	*21*	26	27	27	31	28
White versus Hispanic										
Age 9	23	21	20	21	21	23	*27*	22	*26*	18
Age 13	*35*	*34*	22	19	22	20	25	25	24	23
Age 17	*33*	30	27	24	26	20	22	21	22	24

NOTES: Extrapolated data for 1973 and 1978. Data with statistically significant difference from 2004 data shown in italics. The average national score during the period ranged from 219 to 308.

SOURCE: M. Perie, R. Moran, and A.D. Lutkus, *NAEP 2004 Trends in Academic Progress: Three Decades of Student Performance in Reading and Mathematics* NCES 2005-464, figures 3-5 and 3-6. U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics (2005).

Science and Engineering Indicators 2006

Projected School-Age Population of the United States

The No Child Left Behind Act of 2001 grew out of concerns about disparities in performance among subpopulations of students. Current population projections indicate increasing student population in coming decades, particularly among several racial/ethnic subgroups currently underperforming in mathematics and science. The number of children ages 5 to 17 is expected to increase by 33% between 2000 and 2050. Population growth is estimated to occur among each group shown in table 1-4 with the exception of non-Hispanic whites, whose population is projected to decline by 6% between 2000 and 2050.

Differential growth rates across these groups are expected to change the racial/ethnic distribution of the U.S. school-age population. In 2000, Hispanic children made up 16% of the population ages 5 to 17 years, but by 2050, this percentage will almost double to 29%. The proportion of the school-age population that is white, non-Hispanic will decrease from 62% in 2000 to 44% in 2050. The percentage of the population that is Asian/Pacific Islander is expected to almost double, from 4% to 7%. The proportion of children in the "all other races" category is also expected to grow substantially from 4% to 8%. The percentage of the school-age population that is black is not forecast to change from 2000 to 2050.

Table 1-4
Projected U.S. school-age population, by race/ethnicity: 2000–50

Race/ethnicity	2000	2010	2020	2030	2040	2050
School-age population	53,155,308	53,005,348	57,367,750	61,435,403	65,382,782	70,468,455
White alone	40,914,449	40,201,343	42,604,512	44,870,848	46,576,189	49,013,479
Black alone	8,356,094	8,087,548	8,852,161	9,454,646	10,139,775	11,047,928
Asian alone	1,887,191	2,244,825	2,740,269	3,263,557	4,047,076	4,862,165
All other races	1,997,574	2,471,632	3,170,808	3,846,352	4,619,742	5,544,883
Hispanic (of any race)	8,687,080	11,050,896	13,358,135	15,435,633	17,974,565	20,579,244
White alone, non-Hispanic	32,997,850	30,165,624	30,549,998	31,046,223	30,629,572	30,937,254
Percentage of school-age population						
White alone	77.0	75.8	74.3	73.0	71.2	69.6
Black alone	15.7	15.3	15.4	15.4	15.5	15.7
Asian alone	3.6	4.2	4.8	5.3	6.2	6.9
All other races	3.8	4.7	5.5	6.3	7.1	7.9
Hispanic (of any race)	16.3	20.8	23.3	25.1	27.5	29.2
White alone, non-Hispanic	62.1	56.9	53.3	50.5	46.8	43.9

NOTES: School age is 5–17 years. "Alone" racial categories include people identified as being of one race and include both Hispanics and non-Hispanics. All other races include American Indian/Alaska Natives alone, Native Hawaiian/other Pacific Islanders alone, and those of two or more races. Both Hispanics and non-Hispanics are included in all other races.

SOURCE: U.S. Census Bureau, http://www.census.gov/ipc/www/usinterimproj/ (2004).

Science and Engineering Indicators 2006

students who were not eligible. These gaps related to family income were substantial. For example, students eligible for free or reduced lunch were at least three times less likely to score at or above the proficient level for their grade in both mathematics and science.

International Comparisons of Mathematics and Science Performance

Two mathematics and science assessments conducted in 2003 place U.S. student achievement in these subjects in an international context: the Trends in International Mathematics and Sciences Study (TIMSS) and the Programme for International Student Assessment (PISA). Results from the two assessment programs paint a complex picture. As detailed below, U.S. students scored above international averages on the TIMSS assessment and below international averages on the PISA assessment. The two programs are designed to serve different purposes, and each provides unique information about U.S. student performance relative to other countries in mathematics and science (Scott 2004). The differences in design and purpose of the assessments should be kept in mind when reviewing these divergent results.

One such difference is the grade/age of the students assessed. TIMSS provides data on mathematics and science achievement of students in primary and middle grades (grades 4 and 8 in the United States).[18] PISA reports the performance of students in secondary schools by sampling 15-year-olds, an age near the end of compulsory schooling in many countries.

Another difference between TIMSS and PISA is the relationship of the assessments to mathematics and science curriculum. TIMSS measures student mastery of curriculum-based knowledge and skills. Mathematics and science content experts and educators from many countries developed the framework

behind the TIMSS assessment, and representatives from each participating country were asked to review and comment. The goal is to assess the mathematics and science content and skills that students are taught in school.[19] It is important to note that many of the participating countries have centralized, nationally mandated curriculums, whereas in the United States, curriculum, in the form of content standards, is developed at the state and local levels (Schmidt et al. 2001).

PISA, on the other hand, places more emphasis on students' ability to apply scientific and mathematical concepts and thinking skills to problems they might encounter, particularly in situations outside of a classroom. To some degree, PISA mathematics questions tend to demand more complex reasoning and problem solving skills than those in TIMSS (Neidorf et al. forthcoming) (see sidebar "Sample Mathematics and Science Items From the Curriculum-Based TIMSS Assessment and the Literacy-Based PISA Assessment").

A third difference is the composition of the participating countries. The 46 countries participating in the 2003 TIMSS include 13 highly industrialized nations, as well as many industrializing and developing ones. TIMSS international averages are based on all of these participating countries. In contrast, the PISA results reviewed in this chapter are based on average scores from 30 OECD countries. Thus, although the TIMSS averages include scores from both developed and developing countries, the PISA averages reflect only the performance of industrialized countries.[20] In addition to comparing the performance of U.S. students to these two sets of international averages, the text and tables 1-5 and 1-6 compare the United States with other OECD and Group of 8 (G-8) nations. The G-8 are the eight most industrialized countries in the world that meet regularly to discuss economic and other policies issues: Canada, France, Germany, Italy, Japan, the Russian Federation, the United Kingdom, and the United States.

TIMSS 2003 Results for Students in Grades 4 and 8: Curriculum-Based Knowledge in Mathematics and Science

Curriculum-Based Mathematics Performance. In 2003, the average curriculum-based mathematics score of U.S. fourth and eighth grade students exceeded the TIMSS international averages for these two grades, which included scores from both developed and developing countries (Gonzales et al. 2004) (appendix tables 1-9 and 1-10). Compared with other participating G-8 nations, U.S. fourth graders were outperformed by their counterparts in England, Japan, and Russia but registered higher average scores than students in Italy (table 1-5). At grade 8, the average score of U.S. students was lower than the average score of students in Japan but higher than the average score of students in Italy. The average mathematics score of eighth grade U.S. students was approximately equivalent to the average scores of students in Russia.

TIMSS also was conducted in 1995, permitting an examination of changes in performance over time. The average mathematics score of U.S. fourth graders on this curriculum-based assessment did not change from 1995 to 2003, but eighth graders' scores improved (data not shown, see Gonzales et al. 2004). Based on these results and on changes in average performance in some of the other countries (both improvement and decline), the relative ranking of the United States in mathematics declined slightly at grade 4 but improved slightly at grade 8.[21]

Curriculum-Based Science Performance. Examination of science results shows that in 2003, the average science score of U.S. fourth and eighth grade students was higher than the

Table 1-5
Average mathematics performance of 4th graders, 8th graders, and 15-year-olds for all participating OECD and/or G-8 countries, relative to U.S. average: 2003

	TIMSS		PISA
Country	4th grade	8th grade	15-year-olds
Australia	▼	•	▲
Austria	na	na	▲
Belgium	▲	▲	▲
Canada	na	na	▲
Czech Republic	na	na	▲
Denmark	na	na	▲
England[a]	▲	na	na
Finland	na	na	▲
France	na	na	▲
Germany	na	na	▲
Greece	na	na	▼
Hungary	▲	▲	•
Iceland	na	na	▲
Italy	▼	▼	▼
Ireland	na	na	▲
Japan	▲	▲	▲
Luxembourg	na	na	▲
Mexico	na	na	▼
Netherlands	▲	▲	▲
New Zealand	▼	•	▲
Norway	▼	▼	▲
Poland	na	na	•
Portugal	na	na	▼
Russian Federation	▲	•	▼
Scotland[a]	▼	•	na
Slovak Republic	na	•	▲
South Korea	na	▲	▲
Spain	na	na	•
Sweden	na	•	▲
Switzerland	na	na	▲
Turkey	na	na	▼

▲ = score is higher than U.S. score; • = score is equivalent to U.S. score; ▼ = score is lower than the U.S. score; na = nonparticipation in assessment

OECD = Organisation for Economic Co-operation and Development; PISA = Programme for International Student Assessment; TIMSS = Trends in International Mathematics and Science Survey

[a]Participated separately in TIMSS 2003 at both grade levels but jointly as United Kingdom (including Northern Ireland) in PISA 2003. However, England did not meet response rate standards for grade 8 in TIMSS 2003 or for United Kingdom in PISA 2003.

SOURCES: E. Scott, *Comparing NAEP, TIMSS, and PISA in Mathematics and Science,* U.S. Department of Education, National Center for Education Statistics, figure 2 (2004); data from OECD, PISA 2003; and International Association for the Evaluation of Educational Achievement, TIMSS 2003. See appendix tables 1-9, 1-10, and 1-13.

Science and Engineering Indicators 2006

Sample Mathematics and Science Items From the Curriculum-Based TIMSS Assessment and the Literacy-Based PISA Assessment

Example items from the two international assessments are provided below. Trends in International Mathematics and Sciences Study (TIMSS) assesses mathematics and science skills of fourth and eighth graders in a manner closely aligned with the way these subjects are typically presented in school. The Programme for International Student Assessment (PISA) measures 15-year-olds' abilities to apply mathematics skills and knowledge.

TIMSS Eighth Grade Mathematics Item

If n is a negative integer, which of these is the largest number?

(A) $3 + n$
(B) $3 \times n$
(C) $3 - n$
(D) $3 \div n$

Correct Answer: C

Percent correct:
United States 48
International average 40

TIMSS Eighth Grade Science Item

The burning of fossil fuels has increased the carbon dioxide content of the atmosphere. What is a possible effect that the increased amount of carbon dioxide is likely to have on our planet?

(A) A warmer climate
(B) A cooler climate
(C) Lower relative humidity
(D) More ozone in the atmosphere

Correct Answer: A

Percent correct:
United States 56
International average 44

PISA 15-Year-Old's Mathematics Item

(See illustration below)

A carpenter has 32 meters of timber and wants to make a border around a garden bed. The carpenter is considering several designs for the garden bed.

Circle either "Yes" or "No" for each design to indicate whether the garden bed can be made with 32 meters of timber.

Correct Answers: Design A, Yes; Design B, No; Design C, Yes; Design D, Yes

Percent full credit:
United States 15
International average 20

PISA 15-Year-Old's Science Item

Drivers are advised to leave more space between their vehicles and the ones in front when they are traveling more quickly than when they are traveling more slowly because faster cars take longer to stop.

Explain why a faster car can take more distance to stop than a slower one.

Reasons: ____________________

Full credit: Answers that mention that:

The greater momentum of a vehicle when it is moving more quickly means that it will move further while slowing down than a slower vehicle, given the same force;

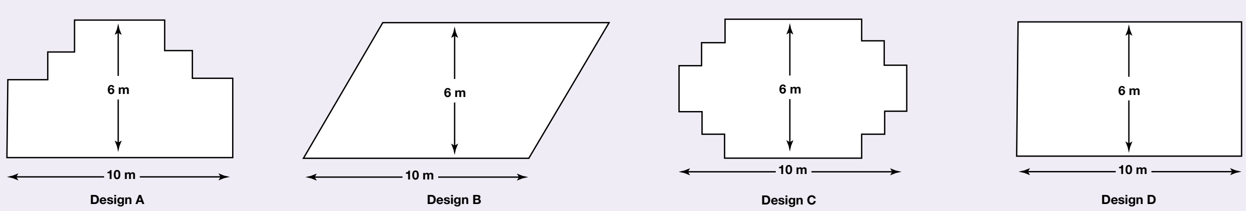
AND

It takes longer to reduce speed to zero from a greater speed, so the car will travel further in this time.

Partial credit: Answers that mention only one of the points above.

Results for this item not published.

SOURCES: Gonzales et al. 2004; OECD 2003b; and http://nces.ed.gov/surveys/pisa/Items.asp?SectionID=2&CatID=4.



Garden bed design	Using this design, can the garden bed be made with 32 meters of timber?
Design A	Yes / No
Design B	Yes / No
Design C	Yes / No
Design D	Yes / No

Table 1-6
Average science performance of 4th graders, 8th graders, and 15-year-olds for all participating OECD and/or G-8 countries, relative to U.S. average: 2003

	TIMSS		PISA
Country	4th grade	8th grade	15-year-olds
Australia	▼	•	▲
Austria	na	na	•
Belgium	▼	▼	▲
Canada	na	na	▲
Czech Republic	na	na	▲
Denmark	na	na	▼
England[a]	▲	na	na
Finland	na	na	▲
France	na	na	▲
Germany	na	na	▲
Greece	na	na	▼
Hungary	•	▲	▲
Iceland	na	na	•
Italy	▼	▼	•
Japan	▲	▲	▲
Luxembourg	na	na	▼
Mexico	na	na	▼
Netherlands	▼	•	▲
New Zealand	▼	•	▲
Norway	▼	▼	•
Poland	na	na	•
Portugal	na	na	▼
Russian Federation	•	▼	•
Scotland[a]	▼	▼	na
Slovak Republic	na	▼	•
South Korea	na	▲	▲
Spain	na	na	•
Sweden	na	•	▲
Switzerland	na	na	▲
Turkey	na	na	▼

▲ = score is higher than U.S. score; • = score is equivalent to U.S. score; ▼ = score is lower than U.S. score; na = nonparticipation in assessment

OCED = Organisation for Economic Co-operation and Development; PISA = Programme for International Student Assessment; TIMSS = Trends in International Mathematics and Science Survey

[a]Participated separately in TIMSS 2003 at both grade levels but jointly as United Kingdom (including Northern Ireland) in PISA 2003. However, England did not meet response rate standards for grade 8 in TIMSS 2003 or for United Kingdom in PISA 2003.

SOURCES: Data from OECD, PISA 2003; and International Association for the Evaluation of Educational Achievement, TIMSS 2003. See appendix tables 1-11, 1-12, and 1-14.

Science and Engineering Indicators 2006

TIMSS international averages, which were based on scores from both developed and developing countries (Gonzales et al. 2004) (appendix tables 1-11 and 1-12). Compared with the participating G-8 countries, the average score of U.S. students was higher than that of students in Italy in both grades 4 and 8 (table 1-6). In addition, U.S. eighth graders had higher average scores than their counterparts in Russia. However, Japan outperformed the United States at both grade levels and England outperformed the United States at grade 4.

Mirroring results for mathematics, average science scores of fourth graders did not change from 1995 to 2003, but science performance among eighth graders improved over this period (data not shown, see Gonzales et al. 2004). The relative ranking of U.S. students in science fell slightly between 1995 and 2003 for grade 4 but rose slightly for grade 8.[22]

PISA 2003 Assessments of Mathematics and Science Literacy of 15-Year-Olds

Although TIMSS measures how well students have mastered the mathematical and scientific content presented in school, PISA assesses students' literacy in these subjects (Lemke et al. 2004). PISA uses the term *literacy* to denote the program's goal of assessing how well students can apply their knowledge and skills to problems they might encounter, particularly in situations outside of a classroom.

In 2003, U.S. 15-year-olds performed below the OECD average in both mathematics and science literacy (appendix tables 1-13 and 1-14).[23] Among OECD nations, U.S. students were near the bottom in mathematics literacy, outperformed by students in Canada, France, Germany, the Netherlands, South Korea, Japan, and 14 other countries (table 1-5; appendix table 1-13). The United States was at rough parity with Hungary, Poland, and Spain, and scored higher than Greece, Italy, Mexico, Portugal, and Turkey. In science, average literacy scores were higher in 15 other OECD countries compared with the United States and lower in 6 (table 1-6; appendix table 1-14).

U.S. students' average science literacy scores did not change from 2000, the first year PISA was administered, to 2003 (data not shown, see Lemke et al. 2004). However, several other OECD countries registered improvements in science, and as a result, the relative position of the United States compared with the OECD average declined.[24] In 2000, the average score of U.S. 15-year-olds' science literacy did not differ from OECD averages, but in 2003, it was lower. U.S. performance in mathematics did not change from 2000 to 2003, and in both years, the U.S. average fell below the OECD average.[25]

Student Coursetaking in Mathematics and Science

Responding to calls for higher educational standards in the 1980s, many states began to increase the number of courses required for high school graduation, particularly in the core academic subjects of mathematics, science, English, and social studies, as well as in foreign language. These policies reflect widespread concern that too few U.S. students were adequately preparing for college study or self-supporting employment and that the nation's global competitive edge was threatened (National Commission on Excellence in Education 1983). Many high school graduates were also thought to lack the numeracy and literacy skills needed to make informed decisions in their adult roles as parents, citizens, and consumers (Barth 2003).

Policies requiring students to spend more time in academic courses are largely intended to push more students to complete advanced courses, which can substantially boost achievement (Adelman 1999; Campbell, Hombo, and

Mazzeo 2000; Meyer 1998; Schmidt et al. 2001). Since 1987, many states have increased the number of years that students must study mathematics and science to graduate from high school (table 1-7). In 1987, most states required 2 or fewer years of high school mathematics and science, whereas in 2002, 29 states required 3 or more years of mathematics and 23 states required 3 or more years of science. The remaining states either required fewer than 3 years or allowed school districts to set these policies. In states with requirements, school districts may also require students to take additional courses as well as to complete specific courses.

Curriculum reform efforts in the past 15–20 years have gone beyond time-based course requirements to setting standards for the skills and content that students need to learn. Organizations such as the National Council of Teachers of Mathematics, the American Association for the Advancement of Science, and the National Research Council began to develop content standards in the 1980s and 1990s. State education agencies have used these standards to develop their own standards and curriculum guides, and in some cases model lesson plans specific to subject and grade level. Along with aligned instructional, teacher training materials and assessments to test students' mastery of course material, curriculum standards are primary building blocks for accountability-based reform. Efforts to set curriculum standards have sought to make clear what students need to learn (and thus to make course content more consistent) and to raise the bar so that all high school graduates meet standards comparable to those in other industrialized nations (Achieve, Inc. 2004; Carnoy, Elmore, and Siskin 2003).

Standards documents vary greatly in their specificity and clarity as well as their level of rigor (Achieve, Inc. 2002; Cross et al. 2004). In addition, alignment between content standards and tests used for accountability is lacking in many states (AFT 2001; Barton 2004; Crossetet al. 2004). In academic year 2004, 49 states and the District of Columbia had content standards for mathematics and science, as well as for English/language arts and social studies (Editorial Projects in Education 2005, p. 86). Many states continue to revise their standards, curriculum frameworks, and instructional materials as they gain information about their classroom use. By 2004, 31 states had set a regular timeline for reviewing and modifying their standards.

Despite these initiatives, most states do not specify the courses students must complete in all academic subjects to graduate. In mathematics, for example, 22 states do not require specific courses, and only 3 states require algebra I, geometry, and algebra II,[26] which some standards advocates consider less than the minimum needed to prepare adequately for college (Achieve, Inc. 2004). Furthermore, for most students, a significant gap currently separates high school graduation requirements from the skill levels that students need to succeed in college and to prepare for jobs that can support a family (Achieve, Inc. 2004; American Diploma Project 2004; Barth 2003).

Even some students who meet college admission requirements (which are often higher than those for high school graduation) must take remedial courses before they can earn college credits (remedial coursetaking is discussed in the "Transition to Higher Education" section). To better prepare students for postsecondary study, educators are striving to increase the rigor of high school courses and encouraging more high school students to take higher-level courses. For some students, a higher level of rigor means taking college preparatory, honors, or other advanced courses, whereas others earn college credits during high school through AP or dual-enrollment courses.

This section examines the degree to which high schools offered advanced mathematics and science courses, and the proportions of graduates who completed such courses, including trends and differences by student characteristics.[27] The section concludes with a look at recent growth in the AP program of courses and exams.

Table 1-7
States requiring less than 3, 3, or 4 years of mathematics and science study for high school graduation: 1987 and 2002

Subject requirement (years)	1987	2002
Mathematics		
<3	29	16
3	9	25
4	0	4
Science		
<3	41	21
3	4	20
4	1	3

NOTE: States not included had no statewide requirement for subject and allowed districts or schools to set their own.

SOURCE: A. Potts, R.K. Blank, and A. Williams, *Key State Education Policies on PK–12 Education: 2002,* Council of Chief State School Officers (2002).

Science and Engineering Indicators 2006

Advanced Coursetaking in High School

Trends in Course Offerings

Curriculum and the degree of course difficulty influence both the content students learn and their level of skill development (Barth 2003; Cogan, Schmidt, and Wiley 2001). Not only has rigorous high school study been identified as the best predictor of making progress in college (Horn and Kojaku 2001) and completing a bachelor's degree, advanced mathematics study may be particularly useful in preparing students for college (Adelman 1999). Adelman found, for example, that although college degree completion rates differ substantially by racial/ethnic group, the gaps narrow considerably for college entrants who have completed advanced high school courses and are therefore well prepared.

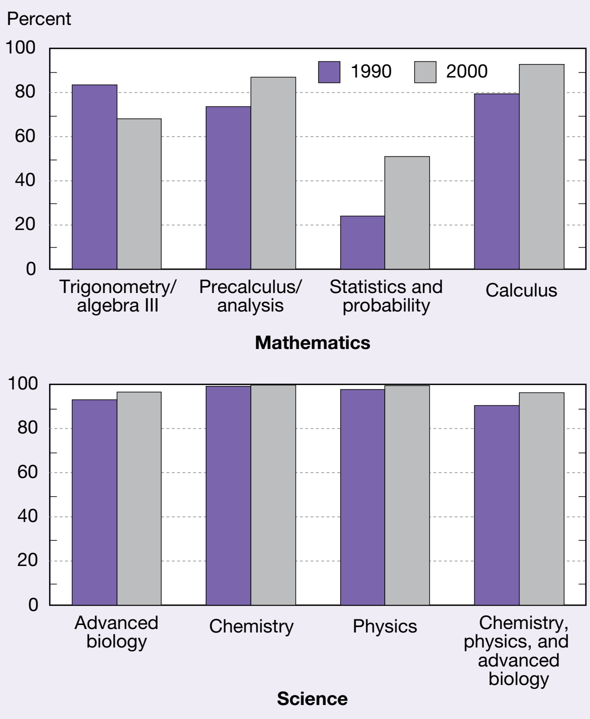
In this section, students are described as having access to courses if the school from which they graduated offers the courses, but in practice, students usually have access only

to those courses for which they can demonstrate preparation. Decisionmaking about which students may enroll in specific courses, particularly in mathematics, differs across schools, but in many high schools guidance counselors play a gatekeeping role and are influenced to varying extents by students, their parents, and teachers. By the time students reach high school, some courses are already closed to them, or are at least difficult to reach, because of earlier decisions and students' previous performance in courses and on tests. Sorting of students into curricular groups, or tracks, that differ in speed and depth of curriculum coverage is often done by teachers and counselors in consultation with parents starting as early as elementary school grades; these decisions and their repercussions are often difficult to change after the middle grades.

Students' access to advanced mathematics courses at their high school—specifically, to precalculus, statistics, and calculus—has increased since 1990 (figure 1-9; appendix table 1-15) (see sidebar "Advanced Mathematics and Science Courses"). The percentage of students attending high schools that provided a statistics/probability course has more than doubled, from 24% in 1990 to 51% in 2000. On the other hand, fewer 2000 graduates attended schools offering trigonometry or algebra III courses than graduates of a decade earlier. This decrease does not necessarily mean that fewer schools taught these topics; some schools may have reconfigured courses so that rather than providing a full semester of trigonometry, they may include that material in a precalculus or other course. Overall in 2000, 93% of graduates attended schools offering at least one calculus course and 87% were offered a precalculus or analysis course.[28]

Science course offerings showed little or no trend changes over the decade, largely because the availability of these courses was already widespread. The percentage of students who were offered advanced biology courses fluctuated between 93% and 96% over the decade, and nearly all students had access to chemistry and physics courses in every year examined. Schools have increased their offerings of AP or International Baccalaureate (IB) courses in calculus, biology, chemistry, and physics since 1998, when NAEP began coding these courses separately from other advanced courses. Almost all 2000 graduates attended schools offering courses in chemistry, physics, and advanced biology; AP and IB courses were less common but still widely available. The percentage of graduates with access to AP/IB classes was 67% for biology, 57% for chemistry, and 47% for physics. About 10% of students could take a relatively new offering, AP/IB environmental science (appendix table 1-16).

Figure 1-9
High school graduates who attended schools offering advanced mathematics and science courses: 1990 and 2000



SOURCE: U.S. Department of Education, National Center for Education Statistics. National Assessment of Educational Progress, 1990 and 2000 High School Transcript Studies. See appendix tables 1-15 and 1-16.

Science and Engineering Indicators 2006

Advanced Mathematics and Science Courses

Advanced courses as discussed in this section (and related data shown in figures and appendix tables 1-15 through 1-18) are courses that not all students complete. In other words, these courses, as a rule, are not required for graduation. However, whether all courses in certain categories should be categorized as advanced is debatable. For example, any chemistry course, even a standard college preparatory course, is included in the category "any chemistry." This point also applies to the categories "any physics" and "any calculus."

The "any advanced biology" category stands in contrast; it includes second- and third-year biology courses and those designated honors, accelerated, or Advanced Placement (AP)/International Baccalaureate (IB), plus a range of specialized courses like anatomy, physiology, and physical science of biotechnology (most of which are college-level courses). "Advanced biology" therefore does not include the standard first-year biology courses required of nearly all students. In addition, AP/IB courses are all advanced and designed to teach college-level material and develop skills needed for college study. A school's AP/IB courses are included in the broader category for the relevant subject as well as in the separate AP/IB category, which thus isolates the subset of courses that meet either of these programs' guidelines.

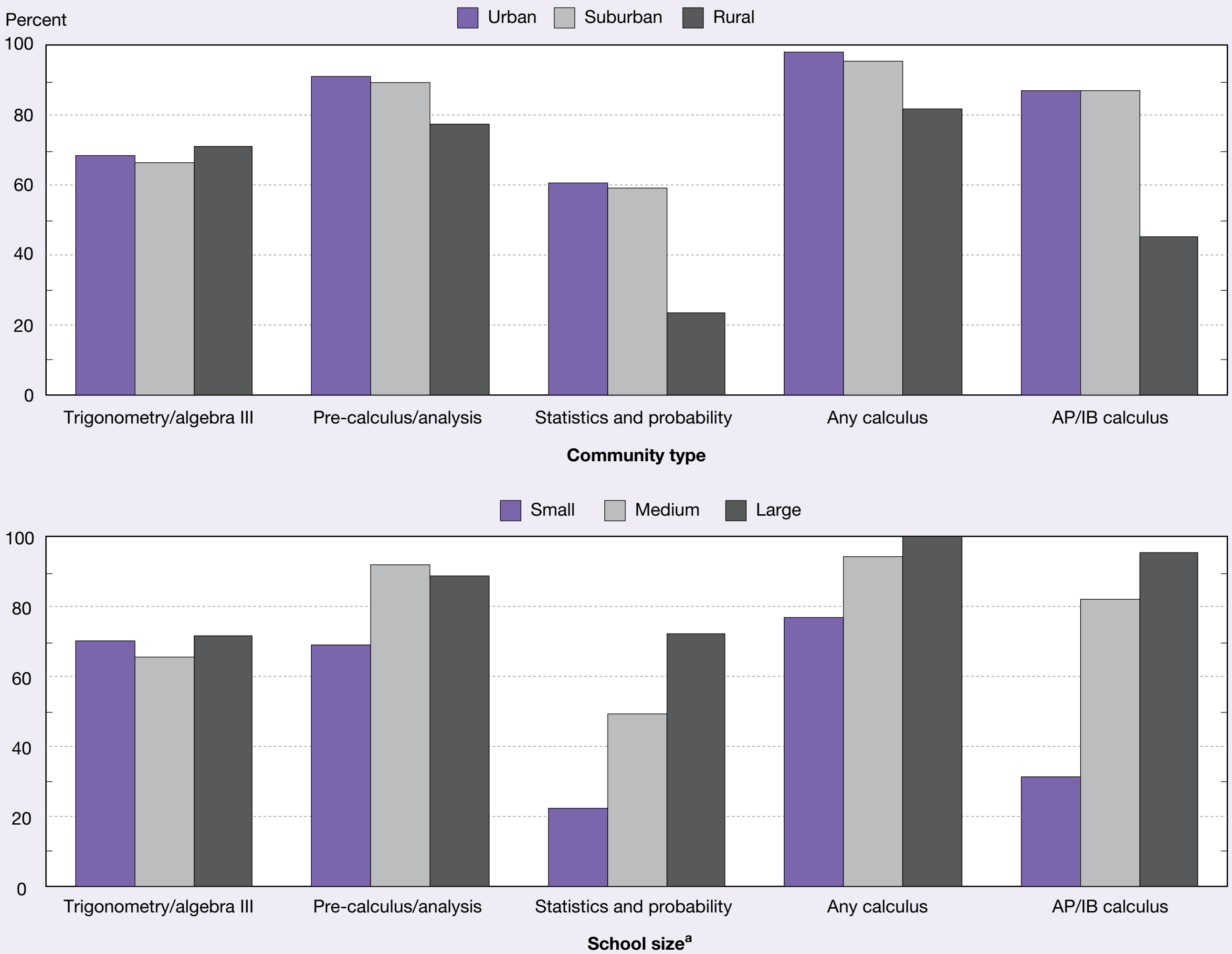
Access to Courses by School and Student Characteristics

Access to some mathematics classes differed by community type and school size. Students graduating in 2000 from urban or suburban schools, which tend to be relatively large, generally were more likely to have access to statistics/probability and calculus courses than those attending rural schools (figure 1-10). Urban and suburban schools were more than twice as likely as rural schools to offer statistics courses. Likewise, students attending small schools had less access to these mathematics courses than those attending medium or large schools, except for trigonometry and algebra III classes. Although most rural students were offered some kind of calculus (82%), an AP/IB course in calculus was far less common (45%).

No overall pattern of differential access to mathematics courses occurred by race/ethnicity (appendix table 1-15). White students, however, were less likely than their Asian/Pacific Islander counterparts to have a statistics or AP/IB calculus course offered by their school. In addition, 47% of Hispanic students had access to a statistics course in high school, compared with 68% of their Asian/Pacific Islander peers.

Chemistry, physics, and advanced biology courses were offered nearly universally by high schools; student access to these did not differ by community type (figure 1-11). However, for AP/IB courses in those three sciences, rural students were

Figure 1-10
High school graduates who attended schools offering advanced mathematics courses, by community type and school size: 2000



AP = Advanced Placement; IB = International Baccalaureate

[a]Small = <600 students, medium = 600–1,800 students, and large = >1,800 students.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2000 High School Transcript Study. See appendix table 1-15.

Science and Engineering Indicators 2006

at a disadvantage (appendix table 1-16). For chemistry and physics, rural students were less than half as likely as those in other types of communities to have access to AP/IB courses. Small schools exhibited the same patterns for AP/IB biology, chemistry, and physics, and medium-sized schools were less likely than large schools to offer these courses. White students were less likely than Asian/Pacific Islander students to attend schools that offered AP/IB chemistry or physics.

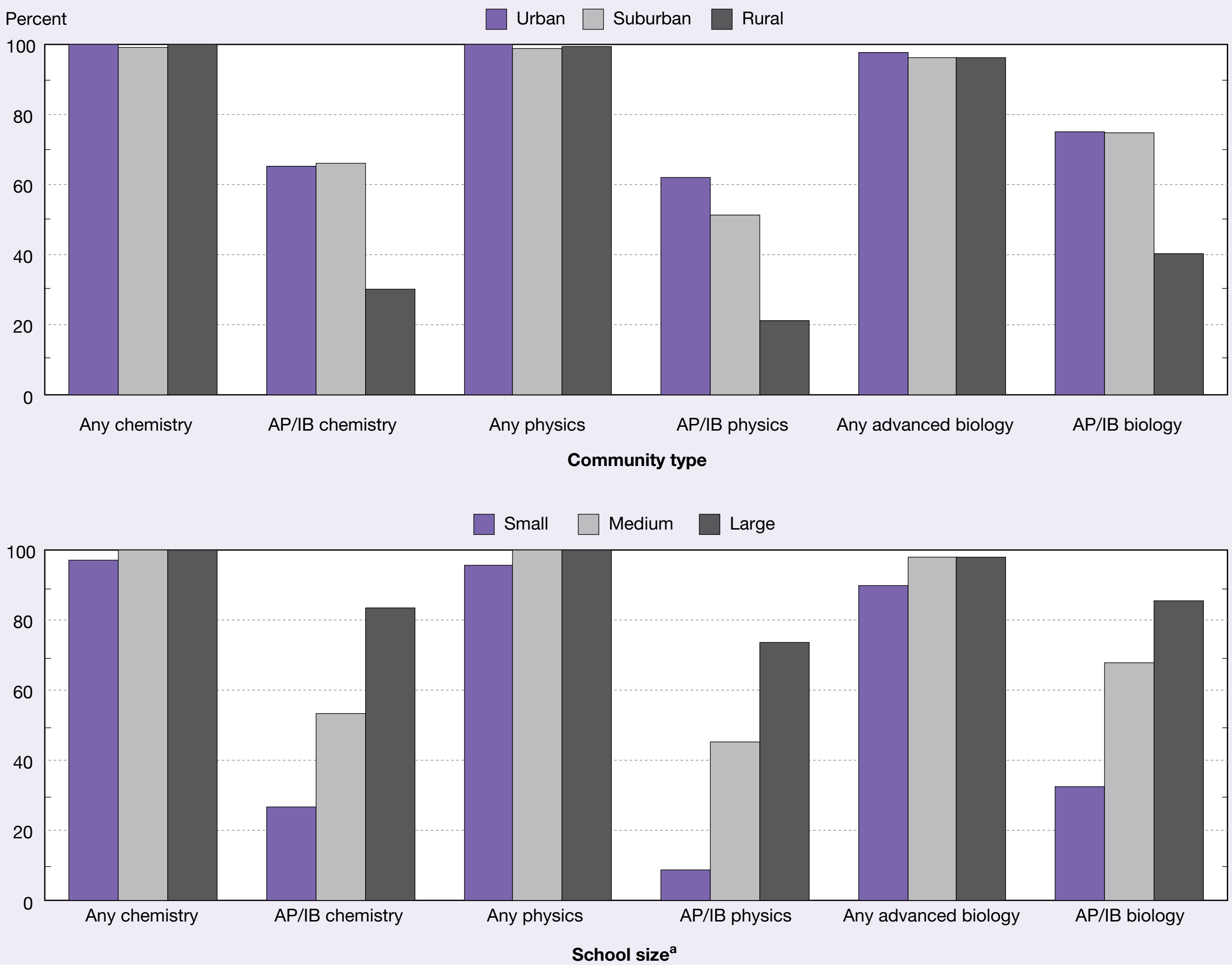
Courses Completed by High School Graduates

Trends in Coursetaking

High school students increased their course loads during the 1990s, both overall and in core academic courses (Perkins et al. 2004). In both mathematics and science, the highest level of coursework completed tended to correlate with students' NAEP scores in the respective subjects, which is consistent with earlier research demonstrating that most students gain proficiency by completing more high-level courses (Madigan 1997; Meyer 1998).

NAEP transcript data indicate increasing course completion in many advanced mathematics and science subjects during the 1990s[29] (figure 1-12). For example, students exhibited steady growth over the decade in studying precalculus, statistics or probability, and calculus (appendix table 1-17). In addition, 2000 graduates were more likely than graduates in 1998 to take an AP/IB calculus course. However, participation in trigonometry or algebra III showed no notable change. Despite gains during the 1990s, the proportions of students taking these mathematics courses remained relatively modest: thirteen percent of the 2000 graduates earned credits for

Figure 1-11
High school graduates who attended schools offering advanced science courses, by community type and school size: 2000



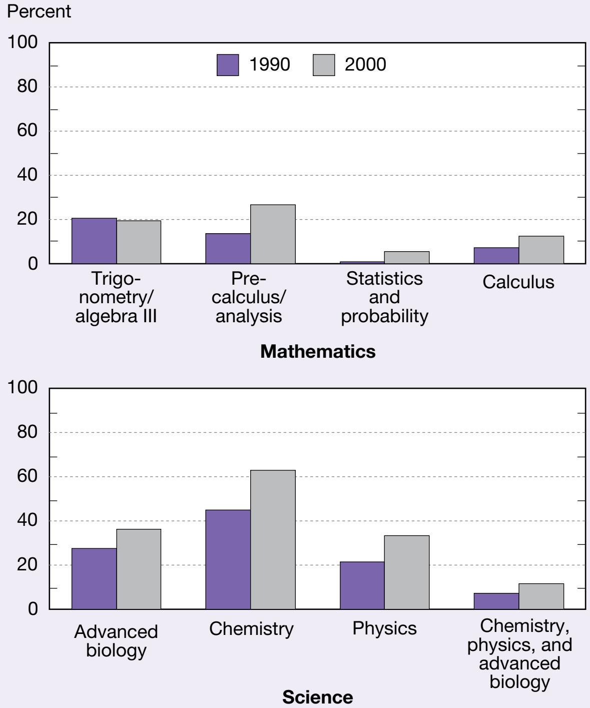
AP = Advanced Placement; IB = International Baccalaureate

[a]Small = <600 students, medium = 600–1,800 students, and large = >1,800 students.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2000 High School Transcript Study. See appendix table 1-16.

Science and Engineering Indicators 2006

Figure 1-12
High school graduates who completed advanced mathematics and science courses: 1990 and 2000



SOURCES: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 1990 and 2000 High School Transcript Studies. See appendix tables 1-17 and 1-18.

Science and Engineering Indicators 2006

calculus, 20% for trigonometry and algebra III, 27% for precalculus, and 6% for statistics and probability.

In science, the proportions of graduates completing chemistry and physics courses increased over the decade, from 45% to 63% for chemistry and from 21% to 33% for physics (figure 1-12). Study in advanced biology increased over part of the decade, then leveled off (appendix table 1-18). For the small proportion of students completing at least one course in each of three science subjects (chemistry, physics, and advanced biology), the trend climbed through 1998 to 12% and then leveled off. Few students took AP/IB courses in any of the three science subjects in either 1998 or 2000; there is insufficient evidence to conclude that their completion rates are increasing.

Coursetaking Differences by Student Characteristics

Students with different characteristics completed courses in advanced mathematics at different rates, reflecting in part their access to such courses.[30] For example, students who graduated from rural schools in 2000 were significantly less likely than others to have studied precalculus, statistics, any calculus, or AP/IB calculus. About 18% of rural graduates studied precalculus, compared with 29%–30% of urban and suburban graduates (appendix table 1-17). Similarly, students from small schools were about half as likely as those from medium or large schools to complete an AP/IB calculus course. Students at schools with very low poverty rates (those where 5% or less of students were eligible for the free or reduced-price lunch program) were generally more likely to complete courses in precalculus, calculus, and AP/IB calculus than students at other schools (figure 1-13). In part these differences are related to differing access; for example, very low school poverty rates were associated with a higher likelihood that students were offered AP/IB biology and chemistry courses.

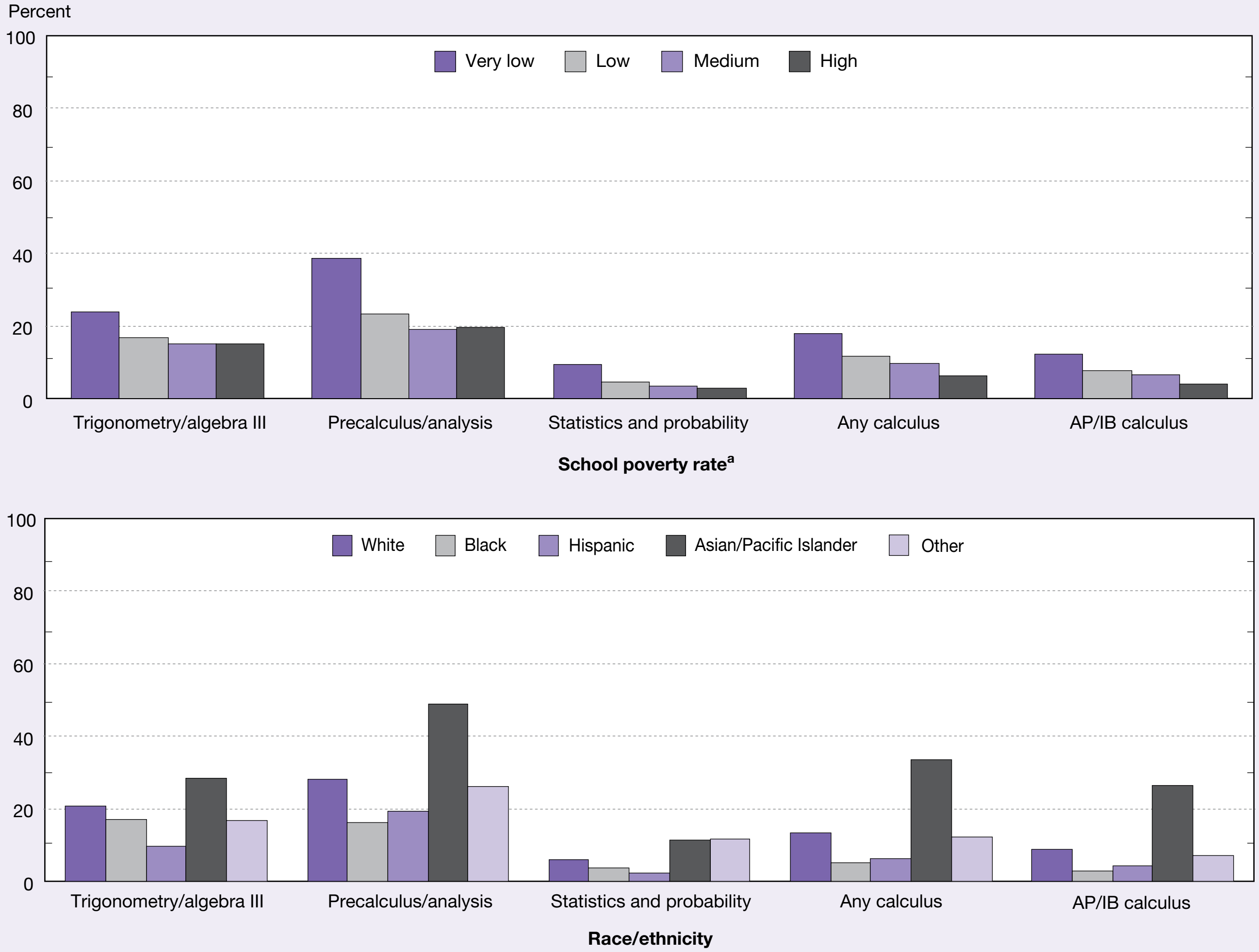
Generally, although black and Hispanic students were at least as likely as students from other groups to have advanced mathematics study offered at their school, they were less likely than others to complete these courses. Hispanic graduates were less likely than white or Asian/Pacific Islander graduates to complete any of the mathematics courses shown in figure 1-13, and Asian/Pacific Islander graduates were the most likely to complete each of these mathematics courses, except possibly for statistics and probability.[31] Black graduates were also less likely than their white or Asian/Pacific Islander peers to complete courses in precalculus and analysis, calculus, or AP/IB calculus, and less likely than Asian/Pacific Islanders to study statistics and probability. Except for trigonometry and algebra III, which black students studied at higher rates, black and Hispanic graduates did not differ from each other in their likelihood of taking these mathematics courses.

Males and females graduating in 2000 did not differ significantly in the percentage completing advanced mathematics courses (appendix table 1-17) but did differ in science coursetaking (see sidebar "Mathematics and Science Coursetaking: How Do the Sexes Differ?").

Coursetaking in science also differed by some school and student characteristics. Graduates who studied chemistry, physics, or all three science subjects (chemistry, physics, and advanced biology) were less common in rural than in urban high schools. About 52% of students at rural schools completed a chemistry course, compared with 68% at urban schools, for example. Students at schools with very low poverty rates were in general the most likely to complete courses in chemistry, physics, AP/IB chemistry, AP/IB physics, or the combination of all three science subjects; appendix table 1-18). However, advanced biology does not fit this pattern; 44% of students at schools with an intermediate poverty rate studied this subject, more than the 31−33% at schools with low or high poverty rates.

Except for advanced biology, chemistry, and AP/IB environmental science, Asian/Pacific Islander students were consistently more likely than their peers in each other group to complete science courses included in appendix table 1-18. Hispanic students were less likely than white students to study advanced biology, physics, AP/IB physics, or the array of three subjects. In none of these science categories did Hispanic and black students differ significantly in course completion rates.

Figure 1-13
High school graduates who completed advanced mathematics courses, by school poverty rate and race/ethnicity: 2000



AP = Advanced Placement; IB = International Baccalaureate

[a]Students eligible for national free/reduced-priced lunch program: very low = ≤5%, low = 6–25%, medium = 26–50%, and high = 51–100%.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2000 High School Transcript Study. See appendix table 1-17.

Science and Engineering Indicators 2006

Participation in AP Testing

The AP program provides students with an opportunity to demonstrate a high level of proficiency in a subject by passing a rigorous AP Exam. About two-thirds of public high schools offer one or more AP courses, reflecting steady growth over the years. The number of students taking AP tests also has grown rapidly, both overall and in mathematics and science subjects. (The AP test-taking data discussed in this section are actual counts collected by the College Board; they should not be confused with AP/IB course data discussed in the previous section. The latter are data estimated in the NAEP study of high school students' transcripts.) Between 1990 and 2004, for example, the number of students taking the Calculus AB exam (see sidebar "Multiple AP Courses/Tests in One Subject") nearly tripled, and the number taking Calculus BC increased almost fourfold (table 1-9). The number of students taking AP science exams increased sharply as well, more than tripling for Physics C and Biology and increasing nearly fivefold for Physics B. To put this growth in perspective, the high school student population increased from 1990 to 2004 by about 24% (NCES 2004b).

Students earning a passing score on an AP Exam generally receive college credit for an introductory course in that subject, allowing them to begin at a higher level of college study, and in some cases, reducing the time needed to earn a bachelor's degree. Overall, a majority of students who take AP Exams receive a passing score, but passing rates vary by subject. The 2004 passing rates for AP mathematics and science tests ranged from 56% for chemistry to 80% for Calculus BC (table 1-9). Nationally, about 13% of students

Mathematics and Science Coursetaking: How Do the Sexes Differ?

Over the past three decades, females have made significant progress in many aspects of education (Freeman 2004). Large gaps favoring males that existed in the past have significantly decreased, disappeared, or even been reversed. For example, female students now have higher educational aspirations and earn more than half of bachelor's degrees (Peter and Horn 2005; NCES 2004a).

High school coursetaking trends in mathematics and science further illustrate recent educational advances by girls and women. Females have reached parity with males in advanced mathematics course completion and have surpassed males in some science subjects. Among 1990 high school graduates, males were more likely than females to take calculus in high school, but this gap had disappeared by 1994, and in subsequent years through 2000 the sexes completed calculus courses at about the same rates (table 1-8). The absence of a sex difference for other advanced mathematics coursetaking was consistent from 1990 through 2000.

In science, male and female graduates were about equally likely to take chemistry or advanced biology in 1990, but by 1994, females had surpassed males in these two subjects. Physics is the only advanced science subject in which males completed courses at consistently higher rates than females during the decade.* (Other advances by women in mathematics and science education are discussed in Chapter 2, Higher Education in Science and Engineering.)

* In 1994, the apparent sex difference in physics study favoring males was not statistically significant, but it was in each of the other years shown.

Table 1-8
High school graduates who completed advanced mathematics and science courses in high school, by sex and year of graduation: Selected years, 1990–2000
(Percent)

	1990		1994		1998		2000	
Subject	Male	Female	Male	Female	Male	Female	Male	Female
Mathematics								
Trigonometry/algebra III	20.6	20.9	23.0	24.9	19.4	22.5	17.9	21.1
Precalculus/analysis	14.4	13.0	16.3	18.4	23.1	22.9	25.4	27.9
Statistics and probability	1.2	0.8	2.0	2.1	3.4	4.0	5.8	5.6
Calculus	8.3	6.2	10.3	10.1	12.0	11.6	13.3	12.0
Science								
Advanced biology	25.7	29.2	31.5	37.8	33.8	40.8	31.5	40.5
Chemistry	43.8	46.1	47.5	53.3	53.3	59.2	58.1	66.8
Physics	24.9	18.3	26.7	22.5	31.0	26.6	35.6	31.5

SOURCES: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 1998, and 2000 High School Transcript Studies.

Science and Engineering Indicators 2006

graduating from high school in 2004 had passed one or more AP tests, up from 10% in 2000 (The College Board 2005). Passing rates for 2004 increased for every state and the District of Columbia over 2003.

Although the number of students taking these AP tests has increased greatly since 1990, the percentages earning passing scores have declined slightly (table 1-9). For most subjects, the drop in the overall passing rate was relatively small, with the exceptions of Calculus AB and Chemistry.

Increases in the numbers of students taking AP tests from 1997 to 2004 occurred for both males and females and for all racial/ethnic groups. Gaps in the percentage of those passing the tests by sex and race/ethnicity were consistent across mathematics and sciences in 1997 and 2004: male test takers were more likely than females to pass the tests (with the single exception of Computer Science AB in 1997), as were whites and Asians/Pacific Islanders compared with blacks and Hispanics (appendix table 1-19). Although passing rates of white and Asian/Pacific Islander students were mostly far above 50%, those for blacks and Hispanics generally ranged from 23% to 48% in 2004. The single exception was Calculus BC; 58% of blacks and 62% of Hispanics passed in 2004.

Summary

The preceding discussion shows that high schools have increased their offerings of advanced mathematics and science courses since 1990. Students in smaller and rural schools were less likely than others to have certain courses taught at their school. High school students have responded to tighter high school graduation requirements by taking more academic courses overall; more students also completed courses in advanced mathematics and science subjects as the 1990s progressed. Nevertheless, relatively modest proportions complete any of these courses except for chemistry.

Table 1-9
Students who took mathematics and science Advanced Placement tests, and percent who had passing scores, by subject: 1990, 1997, and 2004

	Students taking test (number)			Students who passed (%)		
Subject	1990	1997	2004	1990	1997	2004
Mathematics						
Calculus AB	62,676	108,437	170,330	71.7	59.3	59.0
Calculus BC	13,096	22,349	49,332	81.9	78.9	79.5
Statistics	NA	7,551	65,063	NA	62.1	59.8
Science						
Biology	32,643	69,468	108,888	61.5	67.3	60.8
Chemistry	19,289	40,803	69,032	64.1	58.1	56.4
Computer science A	NA	6,992	13,872	NA	47.0	57.2
Computer science AB	NA	4,367	5,919	NA	71.7	63.3
Physics B	8,826	20,610	41,844	60.9	59.8	57.0
Physics C: electricity and magnetism	3,351	5,717	10,503	67.6	65.9	64.9
Physics C: mechanics	5,499	11,740	21,541	74.3	70.8	69.6

NA = not available

NOTE: Most U.S. colleges and universities grant college credit or advanced placement for scores of 3, 4, or 5 on Advanced Placement tests (on a scale of 1–5).

SOURCES: *Advanced Placement Program National Summary Reports, 1997 and 2004*. Copyright 1997, 2004 by the College Board. Reproduced with permission. All rights reserved. www.collegeboard.com.

Science and Engineering Indicators 2006

Multiple AP Courses/ Tests in One Subject

For some academic subjects, more than one Advanced Placement (AP) course and test are offered; they differ in the following ways.

Calculus AB and Calculus BC are both year-long courses and cover some of the same material in similar depth. However, Calculus BC extends to additional topics and aims to substitute for an additional college course beyond the course(s) Calculus AB replaces.

Computer Science A includes a subset of the topics addressed in Computer Science AB and covers some in less depth (for example, algorithms, data structures, design, and abstraction).

The two AP physics courses, Physics B and Physics C, differ primarily in depth and level of mathematics they require. Physics B rarely uses calculus but requires knowledge of algebra and trigonometry. It is equivalent to a 1-year terminal college course often taken by students majoring in fields such as life sciences, certain applied sciences, or premedicine. Physics C requires extensive use of calculus methods and is equivalent to college courses of up to 2 years' duration that are designed for students majoring in the physical sciences or engineering. Students take one Physics C exam, but components are scored separately for electricity and magnetism and for mechanics. For more detailed information, see http://www.apcentral.collegeboard.com/colleges/research/0,3060,154-181-0-2014,00.html.

Very small proportions of students complete advanced mathematics or science courses that provide college credit (such as AP/IB courses). The most popular category among these is AP/IB calculus; even there, only 8% of 2000 graduates completed such a course. More females than males completed courses in advanced biology, AP/IB biology, and any chemistry, although males had the edge in AP/IB physics. Participation in AP test taking has grown rapidly since 1990 in all mathematics and science subjects, whereas the percentage of test takers who earn passing scores has dropped slightly in most subjects. Males were more likely than females to earn passing scores, as were Asians/Pacific Islanders and whites compared with their black and Hispanic peers.

Mathematics and Science Teachers

Strengthening the quality of teachers and teaching has been central to efforts to improve American education in recent decades (NCTAF 1996 and 1997). Research findings consistently point to the critical role of teachers in helping students to learn and achieve (Darling-Hammond 2000; Goldhaber 2002; Wright, Horn, and Sanders 1997). Today's teachers are being called on to provide the nation's children with a high-quality education and to teach in new ways (Little 1993). Many believe that professional development is essential to improving teacher quality and that changes in teaching practices will occur if teachers have consistent and high-quality professional training (Desimone et al. 2002). Although professional development can help improve the quality of teachers and instruction, its effectiveness is diminished if schools cannot keep the most successful teachers in the profession. The issues of teacher salaries and working conditions have come under increasing scrutiny in recent years because

cumulative evidence suggests that these are two key influences on teachers' persistence in the profession and professional satisfaction (Hanushek, Kain, and Rivkin 2004; NCTAF 2003; Odden and Kelley 2002). This section uses data from various sources to examine important issues related to teaching in mathematics and science, including teacher quality, participation in professional development, pay, and working conditions. Indicators in this section traditionally have relied heavily on the Schools and Staffing Survey (SASS) of the U.S. Department of Education. The SASS: 2003–04 data collections have been completed, but these new data were not available when this chapter was prepared.

Teacher Quality

The NCLB emphasizes the importance of teacher quality and requires all public school teachers of core academic subjects to meet specific criteria in preparation for teaching by academic year 2006.[32] In recent years, many states have developed new standards for teaching and implemented policies to improve the quality of teaching (Hirsch, Koppich, and Knapp 2001; Potts, Blank, and Williams 2002) (see sidebar "State Education Policies Related to Teachers and Teaching"). Although there is substantial agreement that teacher quality is one of the most important influences on student learning, disagreement remains about what specific knowledge and skills constitute "quality" (Goldhaber and Anthony 2004; Greenberg et al. 2004; McCaffrey et al. 2003; Wilson, Floden, and Ferrini-Mundy 2001). The following indicators of teacher quality focus on traditional measures identified in the literature on teaching effectiveness (Darling-Hammond 2000; Hanushek 1996): the academic background of college graduates entering the teaching force and congruence between teacher preparation and their assigned teaching fields.[33]

State Education Policies Related to Teachers and Teaching

Prompted by the publication of *A Nation At Risk* in the 1980s, many states have initiated a broad set of education policy reforms, including increased course credit requirements for graduation, higher standards for teacher preparation, teacher tests for certification, state curriculum guidelines and frameworks, and new statewide student assessments (CCSSO 2003). The No Child Left Behind Act of 2001 (NCLB) reaffirmed the key role of states by requiring all states to report on school and district performance using state assessments aligned to state standards in mathematics, science, and language arts. NCLB also requires states to ensure that all classrooms have highly qualified teachers in core academic subjects. Table 1-10 lists policies that states have developed and implemented to improve the quality of K–12 teachers and teaching. The trend data indicate increasing numbers of states involved in each activity.

Table 1-10
States with policies to improve teaching quality: Selected years, 1995–2002
(Count)

State policy	1995	1998	2000	2002
State content standards specifying goals for student learning				
Four core academic subjects (English/language arts, mathematics, science, social studies/history)	18	NA	NA	47
Mathematics	25	42	49	49
Science	23	41	46	47
State standards for teacher licensure	NA	34	42	47
State-mandated teacher assessments for new licensure, total	NA	37	NA	47
Assessment of basic skills	NA	NA	38	41
Assessment in field of teaching license	NA	NA	30	30
Assessment of professional knowledge of teaching	NA	NA	28	35
Performance assessment	NA	NA	23	22
Subject area preparation required for teacher license				
Major in content field	19	21	19	22
Major/minor in content field	9	10	13	12
Induction programs for new teachers	NA	NA	NA	23
Professional development requirements for teacher license renewal	42	44	47	48
State assessments of teacher education programs	NA	NA	NA	39
Policy linking professional development with content standards for student learning	NA	NA	NA	24

NA = not available

SOURCE: Council of Chief State School Officers, *Key State Education Policies on PK–12 Education: 2002* (2002).

Science and Engineering Indicators 2006

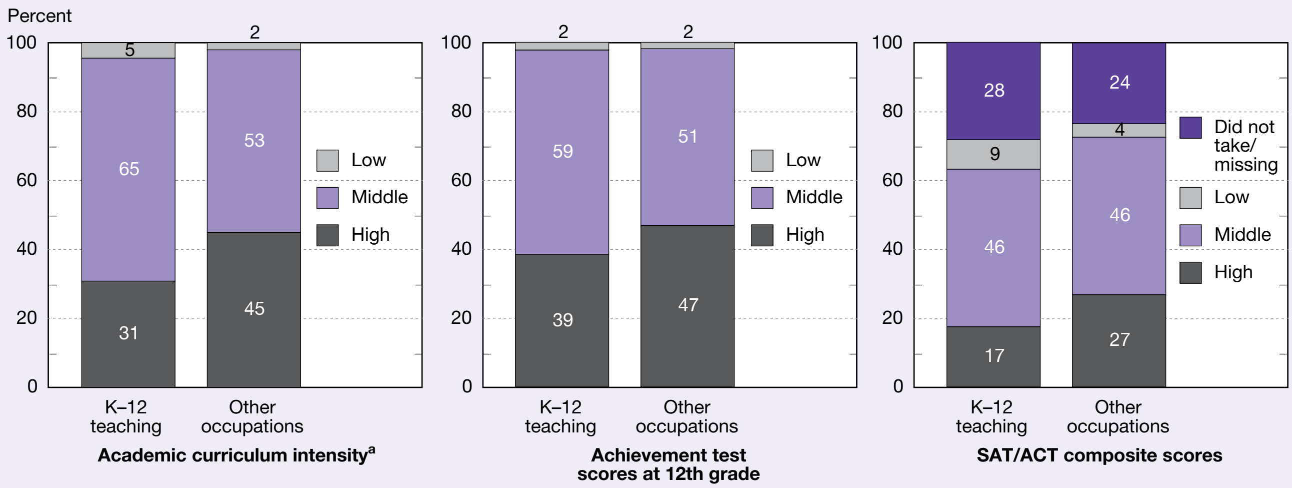
Academic Background of Entering Teachers

Early research on the sources of teacher effectiveness often examined their academic background and skills because these attributes predict teacher subject mastery and verbal ability, two elements believed to be critical to effective teaching (Darling-Hammond 2000; Vance and Schlechty 1982; Weaver 1983). Measures of academic competence commonly used over the past two decades are standardized test scores (Henke et al. 1996; Murnane et al. 1991; Vance and Schlechty 1982; Weaver 1983). Based on test scores, research shows that college graduates who became teachers had less rigorous academic preparation than those who did not go into teaching (Murnane et al. 1991; Vance and Schlechty 1982; Weaver 1983). These findings are further supported by transcript data from the National Education Longitudinal Study of 1988 (NELS:88), which tracks student progress from middle school through postsecondary education. Among 12th graders in the high school class of 1992 who had earned bachelor's degrees by 2000, those who entered K–12 teaching trailed graduates in nonteaching occupations on a number of academic measures in high school and college: they took fewer rigorous academic courses in high school, had lower achievement test scores at the 12th grade, and scored lower on college entrance examinations (figure 1-14). The differences were particularly salient when comparing teachers with those who entered the fields of engineering or architecture; research, science, or technology; computer science; and health care (appendix table 1-20). Teachers also were more likely to attend less-selective colleges and less likely to graduate from selective institutions, particularly when compared with those entering engineering, architecture, research, science, or technical fields and those working as editors, writers, reporters, or performers (appendix table 1-20).[34]

Congruence Between Teacher Preparation and Teaching Assignments

Although almost all U.S. teachers hold at least basic qualifications (e.g., a bachelor's degree and teaching certification) (Henke et al. 1997), many are teaching subjects for which they lack adequate academic training, certification, or both (Seastrom et al. 2002). This mismatch, commonly termed *out-of-field teaching,* has been a major policy concern, and its elimination has become a target of federal and state reform initiatives (Ingersoll 2002, 2003). The discussion below focuses on two important credentials required by NCLB for a teacher to meet the law's definition of *highly qualified:* certification and a college major or minor in the subjects taught.

Figure 1-14
Selected high school academic characteristics of 1992 12th graders who earned bachelor's degree by 2000, by current or most recent occupation: 2000



SAT = Scholastic Aptitude Test; ACT = American College Test

[a]Composite index constructed based on following high school curriculum components: highest level of mathematics, total mathematics credits, total Advanced Placement courses, total English credits, total foreign language credits, total science credits, total core laboratory science credits, total social science credits, total computer science credits. See more information in C. Adelman, *Answers in the Toolbox: Academic Intensity, Attendance Patterns, and Bachelor's Degree Attainment,* PLLI 1999–8021, U.S. Department of Education, Office of Educational Research and Improvement (1999); and C. Adelman, *Principal Indicators of Student Academic Histories in Postsecondary Education,* 1972–2000, U.S. Department of Education, Institute of Education Sciences (2004).

NOTE: Low level includes bottom 20% of all students with valid data, middle level includes middle 60%, and high level includes top 20%.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988, NELS:88/2000, fourth follow-up, Postsecondary Education Transcript Study (PETS), 2000. See appendix table 1-20.

Science and Engineering Indicators 2006

Certification in the Assigned Teaching Field. Teaching certification is generally awarded by state agencies to teachers who have completed specific requirements. These requirements vary across states but typically include completing a bachelor's degree, completing a period of practice teaching, and passing one or more exams (Kaye 2002). A teaching certificate in their assigned teaching field provides basic but essential documentation of teachers' academic preparation and teaching skills (Goldhaber and Brewer 2000) (see sidebar "National Board-Certified Teachers").

In 2002, 80% of public high school mathematics teachers had full certification in mathematics (table 1-11); one-fifth were either not fully certified or certified in a field other than mathematics.[35] The percentage of public high school science teachers with full certification in their teaching field ranged from a high of 83% for biology teachers to a low of 72% for earth science teachers. Certification rates for public middle-grade (seventh and eighth grade) mathematics and science teachers were lower: 60% and 58%, respectively.

Certification rates of mathematics and science teachers declined from 1990 to 2002. The percentage of public high school mathematics teachers with full certification in mathematics decreased from 90% in 1990 to 80% in 2002. Declines also occurred among biology, chemistry, physics, and earth science teachers. At the middle-grade level, the picture is somewhat different. The percentage of mathematics and science teachers with full certification increased in the late 1990s but declined subsequently.[36]

Certification rates varied greatly across states, reflecting, in part, different state policies and licensing requirements. In 1999–2000, the percentage of public school teachers who taught mathematics to 7th to 12th graders and who had full certification in mathematics ranged from 100% in Rhode Island and West Virginia to 65% in Hawaii (appendix table 1-21). Likewise, certification rates for public school 7th to 12th grade science teachers ranged from 100% in Idaho, Vermont, and Wyoming to 77% in Kentucky.

College Major or Minor in the Assigned Teaching Field. A growing body of research shows that teacher subject-matter knowledge is significantly associated with student learning (Greenberg et al. 2004; Hill, Rowan, and Ball 2004; Monk and King 1994), but what counts as "useful subject-matter knowledge" for teaching remains largely unspecified. One indicator used to gauge the breadth and depth of teacher subject-matter knowledge is whether they have a college major or minor in their teaching field (Ingersoll 2003). The assumption is that teachers acquire their subject-area expertise mostly in college, so a college minor in a subject is the minimum prerequisite for teaching that subject.

In 1999–2000, 71% of public school teachers who taught mathematics to 7th to 12th graders had a college major or minor in mathematics, and 77% of public school teachers who taught science in these same grades had a college major or minor in science (appendix table 1-22). In other words, 29% and 23%, respectively, of 7th to 12th grade mathematics and science teachers in public schools had neither a major nor a minor in the subject they taught.

As with certification, the distribution of mathematics and science teachers with a college major or minor in their field was uneven across states. In 1999–2000, only in Arkansas did 90% of 7th to 12th grade mathematics teachers have a college major or minor in mathematics, and only in Minnesota and New Jersey did more than 90% of 7th to 12th grade science teachers have a college major or minor in science (appendix table 1-22). More than 30% of teachers lacked even a college minor in their assigned teaching fields in 21 states for mathematics and 10 states for science.

National Board-Certified Teachers

The National Board for Professional Teaching Standards (NBPTS) has developed a voluntary assessment and certification process to identify highly effective teachers. To receive board certification, applicants undergo a rigorous and extensive performance-based assessment that focuses on classroom practices, content and pedagogical knowledge, and community and professional involvement. Although only fully licensed and experienced teachers may apply, participation in the NBPTS program has grown rapidly: the number of board-certified teachers increased from fewer than 100 in 1995 to 40,033 in 2004 (Editorial Projects in Education 2005; Goldhaber and Anthony 2004).

Does the presence of a high-quality board-certified teacher result in improved student academic outcomes? Goldhaber and Anthony analyzed achievement data for North Carolina students in grades 3, 4, and 5 and found that students of board-certified teachers had higher achievement gains in reading and mathematics than those of non-board-certified teachers; the differences were more pronounced for younger and low-income students. Positive effects of National Board certification were also reported in other studies that examined the effects of board certification on mathematics test scores of 9th and 10th graders in Miami-Dade County, Florida (Cavalluzzo 2004) and on the Stanford achievement tests in reading, mathematics, and language arts of students in grades 3 through 6 in Arizona (Vandevoort, Amrein-Beardsley, and Berliner 2004). Conflicting results exist, however. A study conducted by Stone (2003), for example, examined board-certified teachers of third to eighth graders in Tennessee and did not find these teachers to be more effective in improving student achievement than other teachers. Given the constraints on educational resources and the cost of the NBPTS program, research and debate continue on whether the NBPTS credential is a better indicator of teacher quality than other readily available measures, such as licensure status or academic degree.

Table 1-11
Public middle and high school mathematics and science teachers with full certification in assigned teaching field: Selected years, 1990–2002
(Percent)

	High school (grades 9–12)					Middle school (grades 7 and 8)	
Year	Mathematics	Biology	Chemistry	Physics	Earth science	Mathematics	Science
1990	90	92	92	88	NA	NA	NA
1994	88	90	92	86	81	54	63
1998	88	86	89	86	68	72	73
2000	86	88	88	85	82	66	68
2002	80	83	82	75	72	60	58

NA = not available

SOURCE: Council of Chief State School Officers, *State Indicators of Science and Mathematics Education: 2003* (2003).

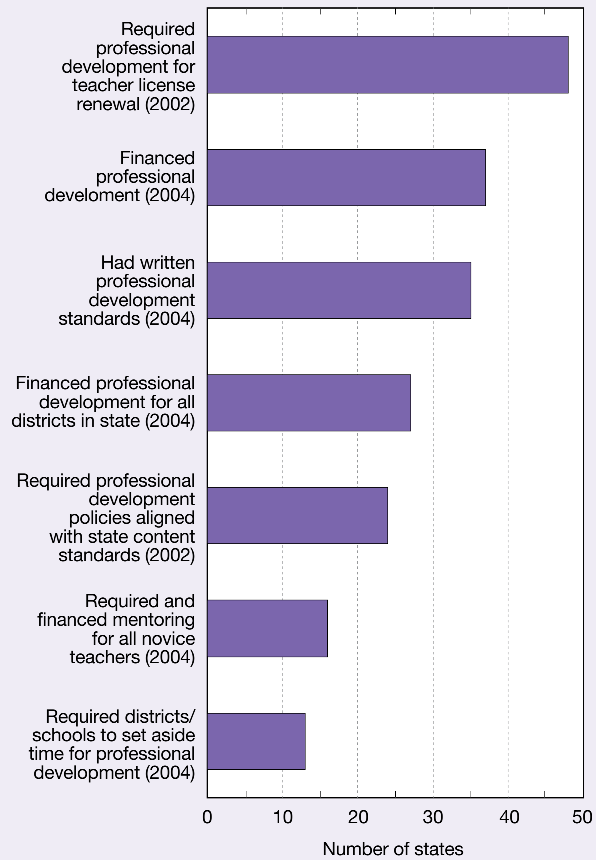
Science and Engineering Indicators 2006

Some recent studies suggest several reasons for the prevalence of out-of-field teaching. Demand for qualified teachers may exceed the supply, forcing school districts to hire less-qualified candidates to fill vacancies (Broughman and Rollefson 2000; Howard 2003). Also, schools may assign current staff members to out-of-field classes rather than expending administrator time and effort and school resources on finding and hiring new teachers in the field (Ingersoll 2003). Furthermore, the perception of precollegiate teaching as a female-dominated and easy-to-enter occupation not requiring a great deal of expertise, skill, and training may foster the belief that teaching credentials do not matter very much, thus out-of-field teaching is considered a tolerable practice (Wang et al. 2003).

Teacher Professional Development

Ongoing efforts to raise academic standards in mathematics and science require teachers to have knowledge and skills that many did not acquire during their initial preparation for teaching (NCTM 2000; NRC 1996). The changing and expanding demands of teaching jobs have prompted increased attention to the importance of professional development in providing teachers with opportunities to acquire new knowledge and keep abreast of advances in their field (Elmore 2002; Little 1993). For two decades, the U.S. government has made teacher professional development a component of its reform efforts (Porter et al. 2000). Many states also have developed and implemented policies designed to promote participation in professional development and to improve its quality (CPRE 1997; Hirsch, Koppich, and Knapp 1999, 2001). By 2002, 48 states had required professional development for teacher license renewal, and 24 had adopted professional development policies aligned with state content standards (figure 1-15). As of 2004, 37 states financed some professional development programs, 35 had standards in place for professional development, 27

Figure 1-15
States with various professional development policies for teachers: 2002 or 2004



SOURCES: Editorial Projects in Education, State of the States, *Education Week, Quality Counts 2005* 24(17):94 (2005); and A. Potts, R.K. Blank, and A. Williams, *Key State Education Policies on PK–12 Education: 2002,* Council of Chief State School Officers (2002).

Science and Engineering Indicators 2006

provided professional development funds for all districts in the state, 16 required and financed mentoring programs for all novice teachers, and 13 required districts or schools to set aside teacher time for professional development (Editorial Projects in Education 2005; Potts, Blank, and Williams 2002) (see sidebar "New Models and Current Practices in Professional Development").

Effects of Professional Development

Research literature contains a mix of large- and small-scale studies, including intensive case studies of classroom teaching (e.g., WestEd 2000), evaluations of programs designed to improve teaching and learning (e.g., Banilower 2002; Weiss, Banilower, and Shimkus 2004), and surveys of teachers about professional development experiences (e.g., Choy and Chen 1998; Parsad, Lewis, and Farris 2001). Thus far, strong evidence of the positive effects of professional development is limited to teaching practices. Relatively few rigorous studies have directly linked teacher professional development to improved student outcomes (Elmore 2002; Guskey 2003). More research is needed following the advent of mathematics and science testing under NCLB. Several recent studies on the effects of professional development are summarized below.

- In their longitudinal study tracking the experiences of mathematics and science teachers participating in various professional development activities, Desimone et al. (2002) found that professional development focusing on specific teaching strategies (e.g., use of technology, higher-order instruction, use of alternative assessments) increased teachers' use of these strategies in the classroom. Also, the effects on teachers' instruction were stronger when professional development included collective participation of teachers from the same school, department, or grade; active learning opportunities such as reviewing student work or obtaining feedback on teaching; and coherence such as linking to other activities or building on teachers' previous knowledge. The Consortium of Chicago School Research also found that "high-quality" professional development programs (those characterized by sustained and coherent training, collaborative learning, and followup support) had a significant effect on teachers' instructional practices (Smylie et al. 2001).
- Studies conducted by NCES based on national data found that a majority of teachers who had participated in professional development programs on various topics relating to teaching and instruction reported that these programs were useful and improved their classroom teaching practices (Choy and Chen 1998; Parsad, Lewis, and Farris 2001; Smith and Desimone 2003).

New Models and Current Practices in Professional Development

For many years, teacher professional development has consisted of district- or school-sponsored workshops or conferences in which an outside consultant or curriculum expert offers teachers a one-time seminar on a pedagogic or subject-matter topic on a staff development day (Choy and Chen 1998; Parsad, Lewis, and Farris 2001). This approach has been widely criticized in the professional literature for lack of focus, continuity, and coherence (Corcoran 1995; Little 1993; Miller 1995; Sprinthall, Reiman, and Thies-Sprinthall 1996). Recognizing the limitations of this traditional model, the education research community began to look for new models for professional development (Corcoran 1995; Guskey 2003; Loucks-Horsley et al. 2003; Miller 1995). A consensus has emerged that professional development yields the best results when it covers both content and pedagogy, addresses teachers' needs and involves them in planning, fosters collaboration among teachers and between teachers and principals, incorporates evaluation of its effects on teaching practice and student outcomes, is part of an overall reform plan, and is continuous and ongoing with followup support for further learning (Garet et al. 2001; Hawley and Valli 1999; Loucks-Horsley et al. 2003). Both qualitative and quantitative research studies now point to a consensus on several important qualities of effective professional development such as extended duration, collective participation of teachers in a school, active learning opportunities, focus on content, and coherence with other activities at the school (Cohen and Hill 2000; Desimone et al. 2002; Garet et al. 2001; Loucks-Horsley et al. 2003; Porter et al. 2003).

However, these new models of professional development require substantially more resources, time, and effort than traditional workshops. States and districts have been struggling to find ways to provide effective and ongoing professional development, to encourage teachers to participate, and to reward them for completing such programs (Hirsch, Koppich, and Knapp 2001). Studies have found that the typical professional development experience is not of high quality (Desimone et al 2002; Porter et al. 2000). Although more teachers have been participating in professional development overall, especially in content-focused programs (Smith and Desimone 2003), professional development in many school districts in the late 1990s still consisted primarily of one-time workshops with little followup (Choy and Chen 1998; Parsad, Lewis, and Farris 2001). As of 1999–2000, almost all public school teachers (99%) participated in professional development, but the dominant forms were still traditional workshops and conferences (95%) (Choy, Chen, and Bugarin forthcoming). Furthermore, many teachers attend professional development programs for 8 or fewer hours over the course of a school year.

- Studies show that teacher participation in professional development affects teaching practice, which in turn affects student performance. For example, the National Staff Development Council examined the features of award-winning professional development programs at eight public schools that had made measurable gains in student achievement (WestEd 2000). The researchers observed that, in each school, the nature of professional development had shifted from isolated learning and occasional workshops to focused, ongoing organizational learning built on collaborative reflection and joint action. Wenglinsky (2002) found that higher student test scores in mathematics and science were linked with teachers' professional development training in higher-order thinking skills.
- Based on an extensive review of studies on the effects of professional development on student achievement, Clewell et al. (2004) concluded that the content of professional development linked to subject-matter knowledge was more important than its format in terms of improving student achievement. Clewell and her colleagues cited the work of Kennedy (1998) and Cohen and Hill (2000) to support their conclusion. Based on 12 studies of professional development programs that reported effects on student achievement, Kennedy (1998) found that the programs showing the greatest effects were those that focused on subject-matter knowledge and on student learning in a particular subject. Cohen and Hill (2000) also reported that students of California elementary school teachers who attended curriculum-focused workshops and learned about the state assessment system had higher achievement scores on the assessment.
- Numerous studies indicate that sustained and intensive professional development is an important factor in influencing change in teachers' attitudes and teaching behaviors (Clewell et al. 2004). For example, the amount of time teachers spent on professional development activities was positively related to their perceptions of these activities' usefulness (Parsad, Lewis, and Farris 2001). The more time teachers spent on professional development in using computers for instruction, the more likely they were to have their students use computers during class (Choy, Chen, and Bugarin forthcoming).
- Based on data from the NSF-funded Local Systemic Change (LSC) project,[37] researchers found that participation in LSC professional development positively changed teachers' attitudes and teaching behaviors (Banilower 2002; Boyd et al. 2003; Weiss, Banilower, and Shimkus 2004). Changes were most evident among those who participated intensively (e.g., more than 60 hours or even more than 80 hours) in LSC professional development (Boyd et al. 2003; Weiss, Banilower, and Shimkus 2004). Other research also suggests that teachers typically need at least 80 hours of intensive professional development before they change their classroom behaviors and practices significantly (Supovitz and Turner 2000).

Teacher Salaries

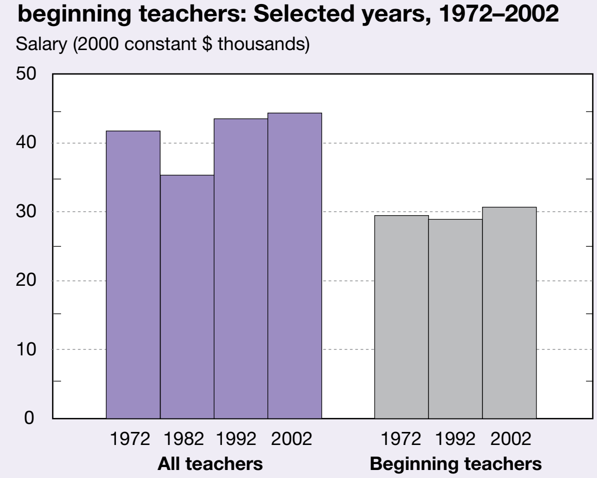
Teacher salaries are the largest single cost in education, making compensation a critical consideration for policymakers seeking to increase the quality of the teaching force. For many years, schools have tried to attract highly qualified and skilled people to teaching and to keep the most able ones from leaving the profession (Hanushek, Kain, and Rivkin 2004; Macdonald 1999). Evidence suggests that teacher salaries play an important role in determining both the supply of new teachers and retention of current teachers (Odden and Kelley 2002; Shen 1997). The indicators below review changes in U.S. teacher salaries and compare their salaries with those of teachers in other nations.

Trends in U.S. Teacher Salaries

The average salaries (in constant 2002 dollars) of all U.S. public school K–12 teachers decreased from 1972 to 1982, increased from 1982 to 1992, and remained about the same between 1992 and 2002 (figure 1-16; appendix table 1-23). The net effect was that the average inflation-adjusted salary of all public school K–12 teachers was $44,367 in 2002, just about $2,598 above what it was in 1972. The average salary for beginning teachers followed a similar trend.

Teacher salaries are often lower compared with the salaries of other white-collar occupations (Allegretto, Corcoran, and Mishel 2004; Horn and Zahn 2001), but comparing teachers' annual salaries to those of other workers is complicated by some unique features of the teaching profession, such as a shorter work year. To control for differences in time worked, a recent study focused on the weekly wages of teachers from 1996 to 2003.[38] The results showed that teachers' weekly wages consistently and considerably lagged

Figure 1-16
Average salaries of U.S. public school K–12 and beginning teachers: Selected years, 1972–2002



NOTE: Beginning teachers' salary in 1982 not available.

SOURCE: F.H. Nelson and R. Drown, *Survey and Analysis of Teacher Salary Trends 2002,* American Federation of Teachers (2003). See appendix table 1-23.

Science and Engineering Indicators 2006

behind those of other workers with similar education and experience and that this gap had enlarged over time (Allegretto, Corcoran, and Mishel 2004).

International Comparisons of Teacher Salaries

After adjusting for the cost of living, U.S. teachers earn more than teachers in many other countries (OECD 2004). In 2002, the beginning, midcareer (after 15 years of teaching), and top-of-the-scale statutory salaries for U.S. public primary and secondary school teachers were all higher than the corresponding OECD averages (figure 1-17).[39] However, regardless of experience, teachers in Germany and Switzerland earned significantly more than U.S. teachers and the gaps seemed to increase with the level of schooling. Teachers with 15 years of experience in Japan and South Korea also earned more than their U.S. counterparts (appendix table 1-24).

Statutory salaries may not capture all differences in salaries because teaching time varies considerably across countries. To control for this variation, an alternative measure of teacher pay is the ratio of annual salary to the number of hours per year the teacher is required to spend teaching students in class (referred to as *salary per instructional hour).* When instructional time was taken into account, U.S. teachers did not fare well compared with teachers in other nations (appendix table 1-24). The salary per instructional hour of U.S. teachers with 15 years of experience was lower than the OECD average at both the lower and upper secondary levels and was the same at the primary level.

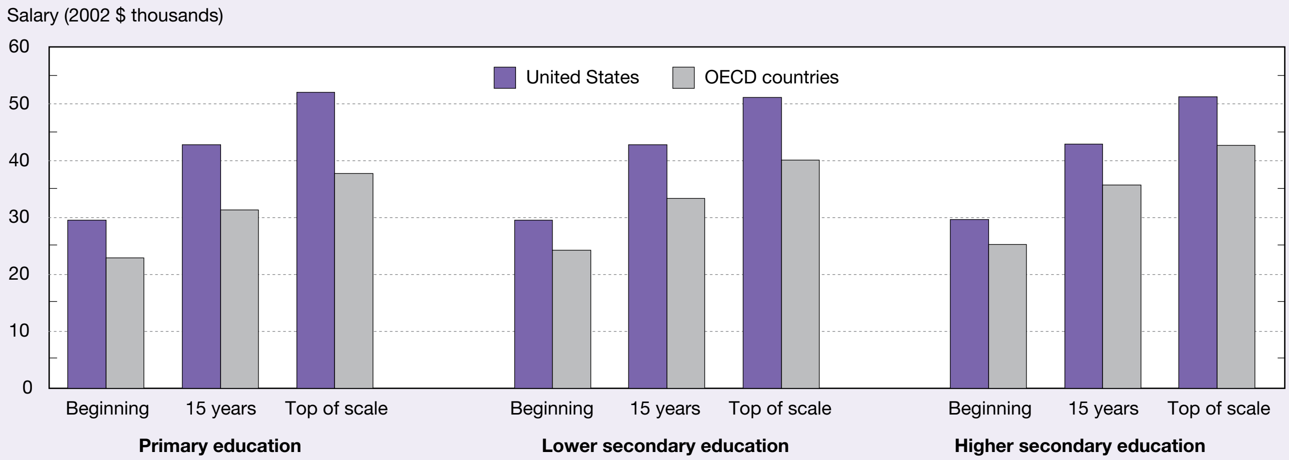
Another way to compare teacher salaries across countries is to compute the ratio of salaries to the per capita gross domestic product (GDP). The resulting ratio compares teacher salaries with a country's overall wealth and may indicate a nation's financial investment in teaching as a profession. Appendix table 1-24 shows the ratio of teacher salaries after 15 years experience to per capita GDP. U.S. ratios were below the average for OECD countries for all three levels of education.

Attrition and Mobility of Mathematics and Science Teachers

In addition to salary, working conditions affect the career decisions of potential and current teachers and their professional satisfaction with teaching (Bogler 2002; Hanushek, Kain, and Rivkin 2004; Hardy 1999; Luekens, Lyter, and Fox 2004; Ma and Macmillan 1999; Shen 1997). Research shows that teacher effectiveness can be enhanced in environments that support and value their work and can be diminished by poor working conditions, lack of professional support, widespread student problems, and inadequate facilities and resources (Macdonald 1999; NCTAF 2003; Scott, Stone, and Dinham 2001). The following indicators examine the attrition and mobility of mathematics and science teachers, discuss their reasons for moving or leaving the profession, and examine their views on school working conditions.

Various studies, commissions, and national reports on teacher supply and demand have concluded that teacher shortages in mathematics and science are considerable (AAEE 2003; NCTAF 2003). Teacher attrition (teachers leaving the teaching profession) is a general contributing factor, whereas teacher mobility (teachers moving from one school to another) also creates staffing problems in individual schools. Between

Figure 1-17
Annual statutory salaries of public school teachers at beginning, after 15 years of experience, and at top of scale for United States and OECD country average, by school level: 2002



OECD = Organisation for Economic Co-operation and Development

NOTES: Statutory salaries refer to salaries set by official pay scales. Converted to equivalent 2002 U.S. dollars using OECD purchasing power parities. OECD countries are Australia, Austria, Belgium, Belgium (Flemish community), Czech Republic, Denmark, England, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Scotland, Slovak Republic, South Korea, Spain, Sweden, Switzerland, Turkey, and United States.

SOURCE: OECD, *Education at a Glance: OECD Indicators 2004* (2004). See appendix table 1-24.

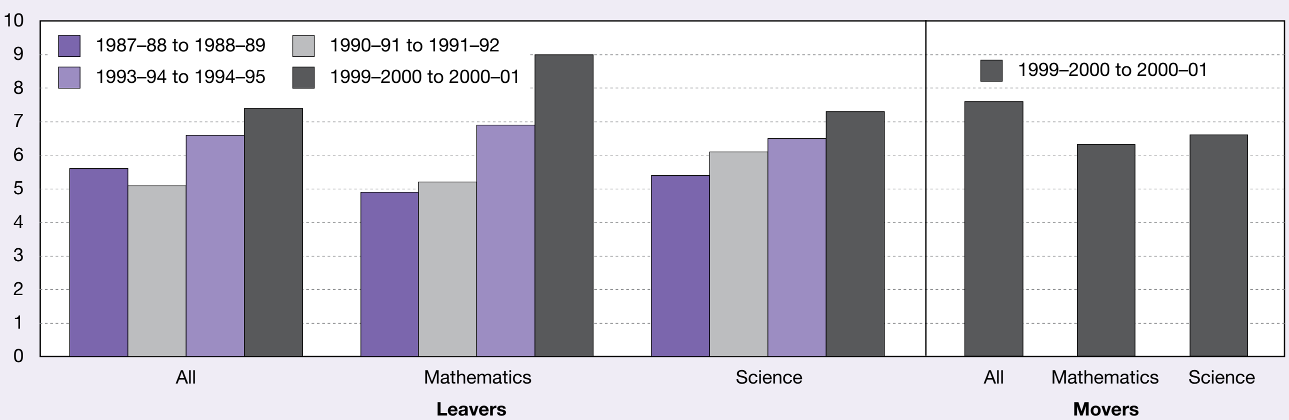
Science and Engineering Indicators 2006

the 1999–2000 and 2000–01 school years, 7% to 9% of public school mathematics and science teachers left the teaching profession and 6% to 7% moved to a different school (figure 1-18). The attrition of mathematics and science teachers appears to be increasing over time: only about 5% of public school mathematics and science teachers left the profession between the 1987–88 and 1988–89 school years.

Reasons for Leaving or Moving

In 2000–01, both mathematics and science teachers and other teachers rated the following reasons as very or extremely important in their decision to leave teaching: pursuing another career, obtaining a better salary or benefits, and retiring (table 1-12). However, mathematics and science teachers were more likely than other teachers to cite pursuing another career as a very or extremely important reason for leaving, whereas others were more likely to give retirement as a very or extremely

Figure 1-18
Public school teachers who left teaching or moved to a different school: Selected school years



SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), 1999–2000 School and Staffing Survey; 2000–01 Teacher Follow-up Survey; and S.D. Whitener, K.J. Gruber, H. Lynch, K. Tingos, M. Perona, and S. Fondelier, *Characteristics of Stayers, Movers, and Leavers: Results From the Teacher Follow-up Survey: 1994–95,* NCES 97-450 (1997).

Science and Engineering Indicators 2006

Table 1-12
Public school teacher leavers who rated various reasons as very or extremely important in their decision to leave profession: 2000–01
(Percent)

Reason for leaving	Mathematics/ science teachers	Other teachers
Pursue another career	25.8*	19.7
Better salary or benefits	22.5	18.4
Retirement	21.8*	30.4
Changed my residence	20.4*	9.3
Health	17.8	9.3
Take courses to improve career opportunities outside education	12.1	9.1
Take sabbatical or other break from teaching	11.3	11.3
Feel unprepared to implement or disagree with new reform measures	9.2	8.4
Pregnancy or child rearing	9.1*	17.7
Dissatisfied with job description or responsibilities	7.1*	14.1
School received little support from community	5.9	6.5
Dissatisfied with changes in job description or responsibilities	4.8*	12.0
Take courses to improve career opportunities within education	4.5	7.6
Laid off or involuntarily transferred	3.7	3.1
Lack of certification	1.7	2.1

*p = .05, statistically significant difference between mathematics/science teachers and other teachers.

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01Teacher Follow-up Survey.

Science and Engineering Indicators 2006

important reason for leaving. These results suggest that retaining mathematics and science teachers can be particularly difficult because they may find more lucrative career opportunities elsewhere (see sidebar "Occupations of Former Teachers").

Teachers who moved to another school seem to have different motives from those who left the profession. Among the top reasons given by mathematics and science teachers who moved to a new school were dissatisfaction with support from school administrators (40% for mathematics and science teachers and 38% for other teachers) and dissatisfaction with workplace conditions (37% for mathematics and science teachers and 32% for other teachers) (table 1-13). Mathematics and science teachers who moved were more likely to report changing schools to obtain a better salary or benefits (29% and 18%) but less likely to move for a better teaching assignment (26% and 42%).

Perceptions of Working Conditions by Teachers Who Moved, Left, or Stayed

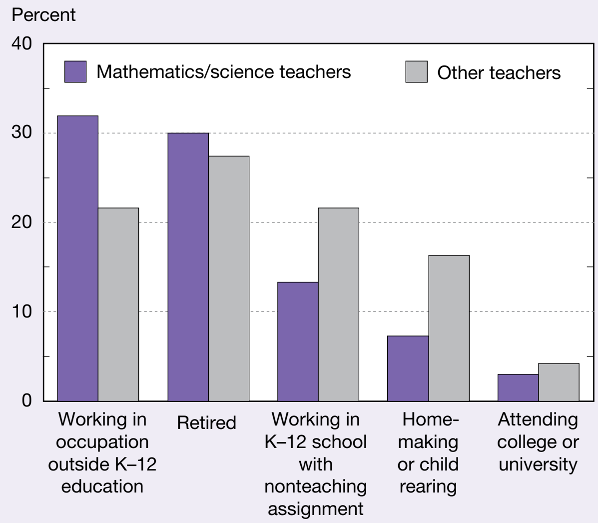
In general, teachers who left or moved expressed less satisfaction with their schools' conditions than did those who stayed (appendix table 1-25). Among public school mathematics and science teachers, those who left the profession were less likely than those who stayed to report satisfaction with the amount of autonomy and control they had over their classrooms, with teaching in their current or last year's schools and teaching overall, with the availability of computers and other technology for their classrooms, and with opportunities for professional development.[40] Mathematics and science teachers who left for nonteaching jobs appeared to be more satisfied with their new jobs (see sidebar "Former Teachers' Satisfaction With New Jobs Compared With Teaching").

Those who moved to a different school also appeared to be more critical of experiences and conditions in their former

Occupations of Former Teachers

Where do teachers go when they leave teaching? Among public school mathematics and science teachers who left teaching between 1999–2000 and 2000–01, 32% worked outside education, 30% retired, 13% stayed in education but not in teaching, 7% became homemakers or at-home parents, and 3% attended a college or university. Mathematics and science teachers were more likely to choose an occupation outside education (figure 1-19).

Figure 1-19
Main occupational status of public school teachers who left teaching profession: 2000–01



SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01 Teacher Follow-up Survey.

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Table 1-13
Public school teacher movers who rated various reasons as very or extremely important in their decision to move to different school: 2000–01
(Percent)

Reason for moving	Mathematics/ science teachers	Other teachers
Dissatisfied with support from administrators at previous school	40.0	38.0
Dissatisfied with workplace conditions at previous school	37.1	31.5
Better salary or benefits	28.9*	17.8
Opportunity for better teaching assignment	26.2*	41.5
Changed my residence	21.3	23.0
Higher job security	14.1	16.4
Dissatisfied with opportunities for professional development at previous school	10.3	15.2
Dissatisfied with changes in job description or responsibilities	10.1*	19.8
Feel unprepared to implement or disagree with new reform measures	9.3	8.8
Laid off or involuntarily transferred	5.0*	11.1
Did not have enough autonomy over classroom at previous school	4.8	8.6

*p = .05, statistically significant difference between mathematics/science teachers and other teachers.

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01Teacher Follow-up Survey.

Science and Engineering Indicators 2006

Former Teachers' Satisfaction With New Jobs Compared With Teaching

Mathematics and science teachers who left for a job outside education were more satisfied with their new jobs than with teaching. In an evaluation of 17 occupational characteristics, such as salary, general working conditions, and intellectual challenge, they rated 15 characteristics better in their current job than in teaching, with the exceptions being benefits and a safe working environment. Differences in the ratings for some characteristics were large, including manageability of workload, general work conditions, opportunities for professional advancement, professional prestige, intellectual challenge, opportunities for professional development, opportunities for learning from colleagues, recognition and support from administrators, and autonomy or control over one's own work (table 1-14).

Table 1-14
Former public school mathematics and science teachers who rated various aspects of their current occupation as worse than teaching, better than teaching, or about the same: 2000–01
(Percent distribution)

Aspect of occupation	Worse than teaching	Better than teaching	About same
Salary	22.2	55.9*	21.9
Benefits	50.2	40.1*	9.7
Job security	20.1	46.1*	33.8
Intellectual challenge	15.0	59.0*	26.0
Opportunities for professional development	13.9	58.1*	28.0
Professional prestige	9.0	63.4*	27.6
General work conditions	3.4	64.3*	32.3
Safety of environment	20.4	25.3	54.3
Manageability of workload	15.1	76.9*	8.1
Procedures for professional evaluation	15.1	50.6*	34.3
Autonomy or control over own work	18.7	57.6*	23.7
Influence over workplace policies and practices	12.8	41.9*	45.3
Availability of resources and materials/equipment for doing job	33.5	55.9*	10.7
Recognition and support from administrators/managers	12.1	51.7*	36.2
Professional caliber of colleagues	17.2	43.6*	39.2
Opportunities for learning from colleagues	12.9	57.1*	30.0
Opportunities for professional advancement	7.2	63.6*	29.2

*p = .05, statistically significant difference between worse than teaching and better than teaching.

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01 Teacher Follow-up Survey.

Science and Engineering Indicators 2006

schools than those who stayed: they were less likely to report satisfaction with the subject they were assigned to teach, with the amount of autonomy and control, with feeling safe inside or outside the school, with job security, with the high caliber of professionalism, with school emphasis on academic success, with supportive administrators, and with uninterrupted class time (appendix table 1-25).

Summary

Indicators in this section reveal both progress and ongoing challenges in strengthening the U.S. teaching force. Based on a number of measures, ranging from the rigor of high school coursetaking and achievement test scores at the 12th grade to college entrance examination scores and the selectivity of the institutions from which teachers enrolled and graduated, teaching appears to attract a higher share of college graduates with weak academic backgrounds. Although almost all public middle-grade or high school mathematics and science teachers held a bachelor's degree and teaching certification, many were teaching subjects for which they did not have certification or a college major or minor in the field. The distribution of out-of-field teaching in mathematics and science was uneven across states.

During the past decade, many states have developed and implemented professional development policies and increasing proportions of teachers participated in professional development programs. Although the characteristics of high-quality professional development have been identified, most teachers' professional development experiences were not of high quality. The dominant form of professional development in the late 1990s were still one-time workshops with little followup and most teachers attended programs for only a few hours over the course of the school year, far below the minimum of 60 to 80 hours some studies show as needed to bring about meaningful change in teaching behaviors.

Between the 1999 and 2000 academic years, 7%–9% of public school mathematics and science teachers left the teaching profession, and another 6%–7% changed schools.

Those who left often reported they planned to pursue another career. Those who moved cited various aspects of poor working conditions as reasons for changing schools. One-third of leavers found a job outside the field of education and many reported more satisfaction with their new job than with teaching.

Information Technology in Education

The United States has made great progress in introducing and upgrading information technology (IT) in classrooms, school libraries, and computer labs over the past decade. Federal, state, and district agencies have provided funds and incentives to increase students' access to hardware and software resources. Initiatives (including the E-rate program) have targeted funding toward high-poverty and rural or urban public schools, and recent legislation has supported effective teacher training for integrating IT with curriculum and instruction. In addition, as families have obtained home computers and Internet connections, children and adolescents have increased their IT use at home, often for school work.

National survey data have focused on measures such as student access to IT and frequency of use, and other research has examined important questions about how teachers and students use IT resources and how integration of IT with instruction may influence student learning. One goal of providing computers in schools is to develop students' computer literacy, which is needed for college and for many jobs. A second goal, using IT as an instructional tool to enhance learning in other subjects, is more difficult to reach, partly because of the many ways the tools can be deployed. A substantial body of research indicates that tutorials and other computer-based instruction in basic skills can improve students' achievement on standardized tests in math and science (e.g., Becker 1994; Kulik 2003; Van Dusen and Worthen 1994). The preponderance of these studies shows that well-designed tutorials can supplement teacher guidance, providing more immediate responses to students' efforts and allowing them to work at their own pace. However, two recent studies found that student use of computers at school is not necessarily beneficial and may be associated with lower mathematics achievement (Angrist and Lavy 2002; Fuchs and Woessman 2004).

Less evidence exists for IT effectiveness in applications other than tutorials, such as simulations and computer-based labs in science (Kulik 2003). Experts have noted IT's promise for supporting inquiry-based instruction: for example, helping students learn how to locate, evaluate, organize, and synthesize information to solve complex problems (Ringstaff and Kelley 2002; Sandholtz, Ringstaff, and Dwyer 1997). High-capacity multimedia computers and high-speed Internet connections can enhance students' research and collaboration activities, increasing their access to up-to-date materials and allowing rapid communication with experts outside the school, for example. However, the research base is sparse on any effects of technology used for such learning methods, and results tend to rely on subjective measures.

The indicators in this section present more detail on students' increasing access to IT, including trends in the "digital divides" related to family income, race/ethnicity, and geographic location. In addition, data describe how students use computers and the Internet for a variety of activities at home and in school. The section concludes with a discussion of third grade teachers' ratings of their preparation for integrating technology into their teaching and their technical support at school.

Trends in IT Access at School

School systems have invested heavily in IT during and since the 1990s to expand opportunities for learning and to overcome gaps in home access for students (Donnelly, Dove, and Tiffany-Morales 2002). Supported by government funds and sometimes corporate and community contributions, these efforts have been largely successful. First, IT resources have become much more widely available in schools, and second, schools have helped equalize access for disadvantaged students (DeBell and Chapman 2003; NTIA 2002).

The number of students per public school computer has decreased sharply, and schools have made dramatic progress in providing Internet access: the 3% of instructional rooms with an online connection in 1994 rose to 93% in 2003 (Parsad and Jones 2005). Urban public school classrooms were slightly less likely than those in towns or rural areas to have online connections in 2002, however. In public schools with Internet access, 95% had broadband connections, which indicates rapid change since 1996 when 74% used dial-up. In addition, the ratio of public school students to online computers improved from about 12:1 in 1998 to 4:1 in 2003 (Parsad and Jones 2005).

Gaps by school poverty concentration narrowed over these 5 years, as high-poverty schools greatly increased their supply of Internet-connected machines. However, students in high-poverty public schools remained at a disadvantage in 2003, with 5.1 students per online computer compared with 4.2 students in low-poverty schools.

Trends in IT Access at Home

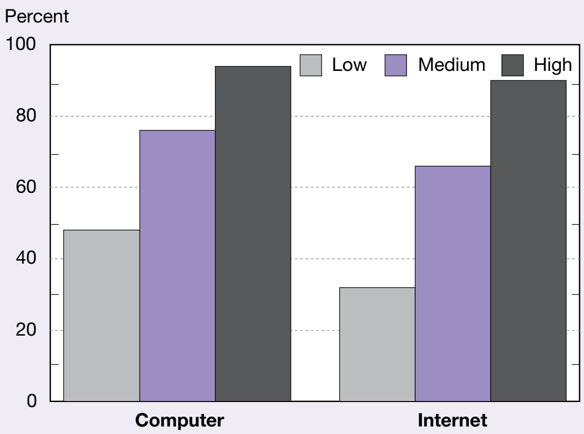
Home computer ownership and Internet access grew rapidly during the 1990s among all population groups. From 1984 to 2001, the inequality of home computer ownership by family income decreased, particularly over the last few years of the period (NTIA 2002). Computer ownership rates increased for all groups over these 17 years but grew more rapidly for lower-income families. Regarding home Internet access, the digital divides related to income and householders' education also narrowed from 1998 to 2001 (NTIA 2002). Rural residents were less likely to use the Internet than metropolitan-area residents through 1998, but this gap had closed by 2001 (NTIA 2002). Gaps among demographic groups have diminished as computer ownership and online connectivity costs have declined.

Access to home computers and Internet connections continued to grow from 2001 to 2003, and the most rapid change occurred in the proportion of households with broadband Internet connections, which more than doubled from 9% to 20% over these 2 years (NTIA 2004). People with broadband access tend to use the Internet more frequently and for a wider range of activities, including educational purposes. The greater speed and continuous connection that broadband provides increase the feasibility and efficiency of doing Internet research and taking online courses.

In 2003, 77% of students in grades K–12 lived in a household with a computer and 67% had Internet access at home (appendix table 1-26). The access gaps noted above remained. Students from high-income families, for example, were nearly three times more likely than those from low-income families to have home Internet access, 90% versus 32% (figure 1-20). Similarly, although 94% of high-income students had a computer at home, only 48% of low-income students had such access. The likelihood of having these resources at home also increased sharply with level of parental education (appendix table 1-26).

White and Asian/Pacific Islander students were far more likely in 2003 to have a computer in their homes (86% and 87%, respectively) than were black and Hispanic students (55% and 57%); similar gaps were evident in rates of home Internet access (figure 1-21). In addition, students attending public schools were less likely than their peers in private schools to have either computer or Internet access at home. However, students' use of IT resources at school differed little by sector (appendix table 1-26).

Figure 1-20
K–12 students who had computer and Internet access at home, by family income: 2003



NOTE: Low income includes families in lowest 20% of income distribution, middle income includes middle 60%, and high income includes highest 20%.

SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-26.

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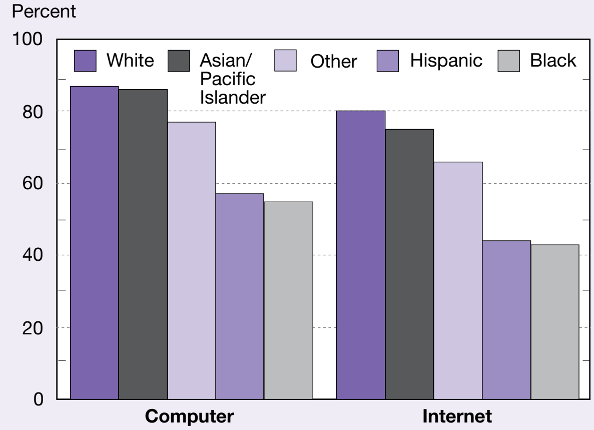
Figure 1-21
K–12 students who had computer and Internet access at home, by race/ethnicity: 2003



SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-26.

Science and Engineering Indicators 2006

IT Use at School and at Home

Student Use of IT at School

Computers can be used for instructional activities ranging from tutorials (used in mathematics and other classes) to simulations and specialized laboratories (used in some science classes). Internet access facilitates certain student-directed learning activities, such as conducting research on the Web, contributing to data collection and analysis projects based outside the school, and communicating with experts and other students for projects. IT's potential for expanding students' understanding and interest in learning has generated public support for bringing these resources into schools and encouraging their effective integration into lessons.

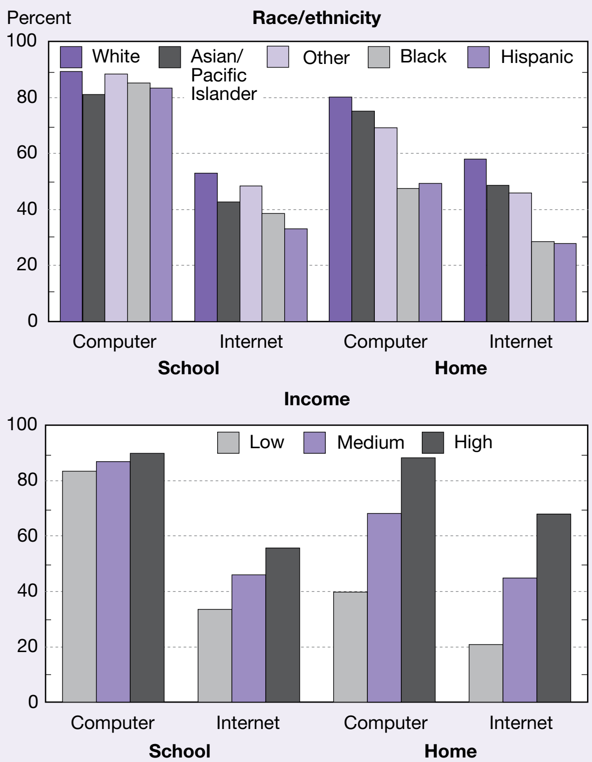
However, IT is not necessarily more effective than other educational tools. Results largely depend on how computers are used and whether they effectively support teachers' instructional goals. A recent study of 15-year-olds in the United States and 29 other nations that participated in PISA found that using computers and the Internet at school may support learning up to a point, but more frequent use was associated with lower achievement (Fuchs and Woessman 2004). This analysis controlled for school resources, which were related to socioeconomic and other characteristics of students' families. However, these data present a one-time snapshot and cannot show causality. Another recent study found that the introduction of computer-aided instruction in elementary and middle grades in Israel was consistently linked to lower mathematics test scores for fourth and eighth graders, although there was less clear evidence of a link with the latter (Angrist and Lavy 2002).

In addition to extending access, schools also serve to equalize students' use of IT resources. Not only are overall use rates higher at school than at home, but this difference is

more pronounced for less-advantaged students. Low-income students, for example, were more than twice as likely to use a computer at school than at home in 2003, 84% compared with 40% (figure 1-22). Even middle-income students were more likely to use computers at school than at home. Furthermore, the demographic differences in school computer use were small compared with those for home use; the percentage of students who used computers at school ranged from 84%–90% by family income and from 81%–89% across racial/ethnic groups.

Although nearly all schools had an Internet connection, just under half (47%) of students accessed the Internet at school in 2003 (appendix table 1-26). As with school computer use, school Internet use was related to race/ethnicity, family income, and parental education. Students in secondary grades were far more likely to use the Internet at school, perhaps because the Internet is often used for research tasks more suited to older students. Male and female students did not differ substantially in their likelihood of using either computers or the Internet at school.

Figure 1-22
K–12 students who used computers and Internet at school and home, by race/ethnicity and family income: 2003



NOTE: Low income includes families in lowest 20% of income distribution, middle income includes middle 60%, and high income includes highest 20%.

SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-26.

Science and Engineering Indicators 2006

Computer Use in Third Grade Classrooms

In 2002, teachers of third grade students reported how often they required their students to access the Internet and to use a computer for some other purpose such as games or tutorials.[41] Computer use for purposes other than Internet access was much more common for third graders: 56% of students were given computer work at least three times weekly, whereas only 22% were assigned Internet use that often (appendix table 1-27). These computer uses were more frequent in public school classrooms; for example, 24% of public school students used the Internet that often in class compared with 9% of private school students.

In the past, teaching experience and teacher age were inversely related to frequency of IT use in the classroom, partly because veteran teachers were less likely to have gained computer skills through informal exposure in their preservice years (Smerdon et al. 2000). However, in 2002, more experienced third grade teachers were more likely than those with less experience to give students computer tasks at least three times a week (appendix table 1-27). These results suggest that at least in the early elementary grades, professional development and generally increased levels of computer literacy may be compensating for the variance in IT skills that teachers bring to their jobs.

Uses for Home Computers and the Internet

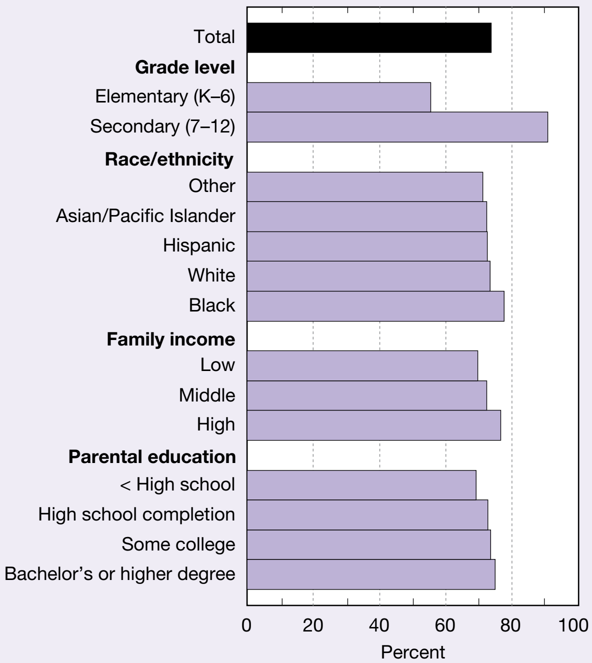
Students use IT resources at home for a variety of purposes, some of which may be educational.[42] Using educational software, e-mail, and accessing Web pages at home have been linked to higher achievement in mathematics after controlling for family background characteristics (including parental education) (Fuchs and Woessman 2004). Overall, about three in four students with access to a computer at home used it for school work in 2003 (appendix table 1-28), which was less common than for playing games (83%) but more common than for e-mail (49%).

Groups more likely to use a home computer for school work were students in secondary grades and those who were female or black, who came from higher-income families, or who had more highly educated parents. For example, secondary students with access were far more likely than elementary students to use home computers for school work, 91% versus 55% (figure 1-23).

E-mail was also a more common pursuit for older students, at 70% compared with 27% for those in elementary grades (appendix table 1-28). In 2003, younger students were somewhat more likely than older ones to play computer games: 87% compared with 78% (figure 1-24). (Some games may be educational, either by teaching specific skills and knowledge by design or by incidentally developing skills like planning or problem solving.)

Students in the elementary and secondary grades also tend to use the Internet differently. Overall, secondary students who had access used the Internet quite frequently: 53% used it at least once a day, 36% less often but at least weekly, and only 11% less than weekly (appendix table 1-28).

Figure 1-23
Among K–12 students with access, percentage who used home computers for schoolwork, by student characteristics: 2003



NOTE: Low income includes families in lowest 20% of income distribution, middle income includes middle 60%, and high income includes highest 20%.

SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-28.

Science and Engineering Indicators 2006

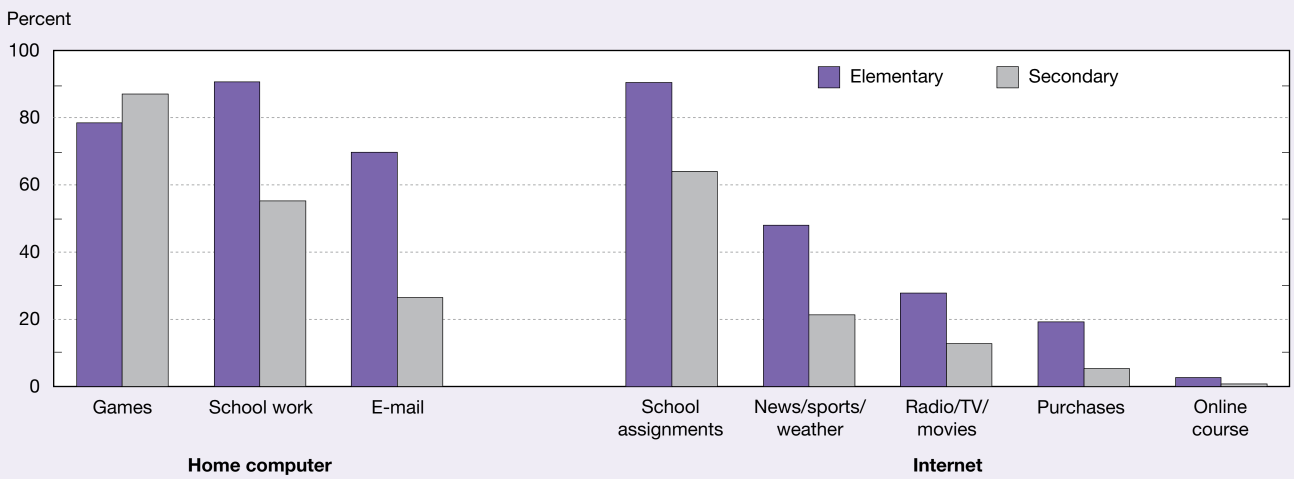
Elementary school students were less frequent Internet users, with only 27% using it at least once a day. In the secondary grades, almost all students (91%) with access used the Internet for school assignments (figure 1-23). Less common uses for the Internet were seeking news or sports information (48%), enjoying movies or television or radio programs (28%), purchasing goods or services (19%), and taking an online course (3%). In the elementary grades, a majority of students (64%) used the Internet for school assignments.

Teacher Preparation for Using IT and Technical Support

In 2003, 38 states had teacher qualification standards that included a technology component (Editorial Projects in Education 2004). In addition, certification requirements in 15 states included preservice training in using IT for teaching, and 9 states required prospective teachers to pass a test demonstrating technology skills and knowledge. For recertification, 10 states required teachers to demonstrate their knowledge about IT use, either through professional development or by passing a test. Twelve states had incentive policies to encourage teachers to use IT in their classrooms.

Research supporting such policies indicates that thorough IT training not only encourages teachers to use computers more extensively in classrooms but also can improve their teaching (Coley, Cradler, and Engel 1997; Sivin-Kachala and Bialo 2000). Most teachers lack extensive training in integrating computers with instruction and in making the most of IT potential, however (Ringstaff and Kelley 2002; Silverstein, Frechtling, and Miyoaka 2000). Preservice training has focused more on developing computer literacy than on

Figure 1-24
K–12 students with access who used home computers or Internet (from any location) for specific tasks, by grade level: 2003



SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-28.

Science and Engineering Indicators 2006

effectively integrating computers into instruction (Moursund and Bielefeldt 1999; Sandholtz 2001; Willis and Mehlinger 1996), at least until recent years.

Teacher Professional Development in IT Use

Types of Training. Professional development in IT may be shifting away from basic skills and toward developing advanced skills and using computers to support instructional goals. In 1999, public school teachers were very likely to be offered professional development in basic computer and Internet skills and software applications (87%–96%); integrating IT into instruction and advanced training were offered somewhat less frequently (79% and 67%, respectively) (Smerdon et al. 2000). In fall 2002, teachers in 87% of public schools had been offered training in integrating the Internet into curriculum in the preceding year (Kleiner and Lewis 2003).

In 2000–01, 63% of public school teachers reported participating in some professional development on using computers for instruction during the previous year. Roughly half said they had trained on one or more of three topics: the mechanics of using IT, integrating computers into instructional activities, and using the Internet (appendix table 1-29). However, only about half of the teachers who trained said each topic was central to the training; for the other half, the topic was merely mentioned. For example, about 29% of public school teachers had received recent professional development for which the central topic was integrating computers into instructional activities; for 25%, integration was mentioned in the training. Math and science teachers differed little or not at all from elementary or other teachers on these measures[43] (figure 1-25).

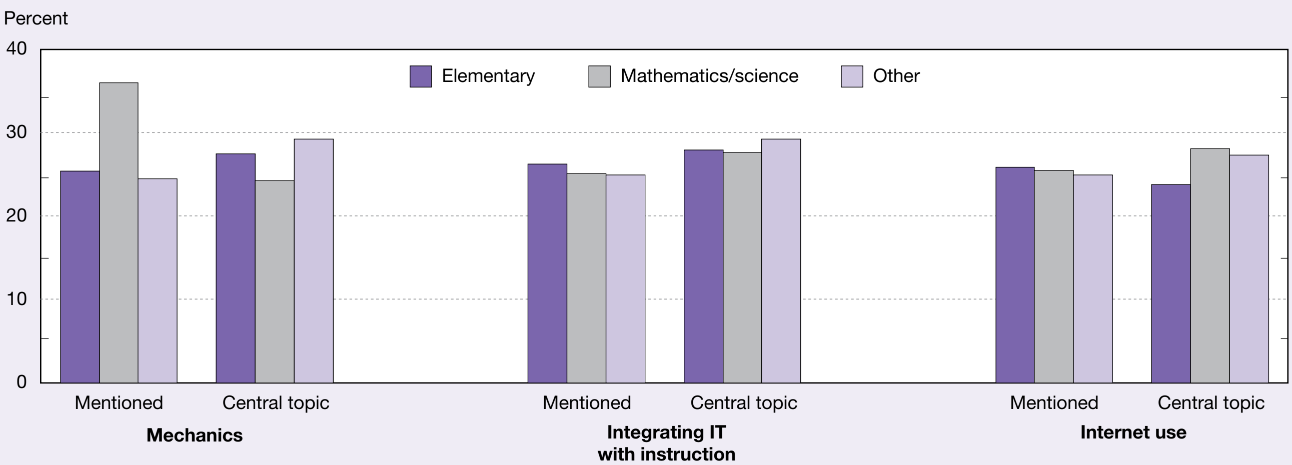
Few 2000–01 public school teachers had extensive recent training in IT use. About 37% had no such training, 33% had 8 hours or less, and only 8% had more than 32 hours of computer-related training in the last year. These data are consistent with findings described in the previous section, "Teachers of Mathematics and Science," on the relatively short amounts of time most teachers spend on professional development.

Adequacy of Training. Many public school teachers surveyed in 1999 indicated that their preparation for using IT in instruction was inadequate; 53% said they felt only somewhat prepared, and 13% said they felt not at all prepared (Smerdon et al. 2000). For the most part, these teachers had participated in little recent IT training: about half had 1 day or less in the past 3 years and only 12% had more than 4 days. The study noted that teachers who felt better prepared were far more likely to use IT resources for a range of activities, including creating instructional materials, obtaining model lesson plans and researching effective practices, and communicating with colleagues and parents. Middle and secondary school mathematics and science teachers in 1999–2000 often rated further training in IT use as a high priority (NSB 2004).

Third Grade Teacher Confidence in IT Skills and Technical Support

In contrast to these earlier findings, 62% of 2002 third grade students had teachers who indicated they felt prepared to use computers for instruction (figure 1-26); that is, their teachers either agreed (45%) or strongly agreed (17%) with the statement, "I am adequately prepared to use computers for instruction in my class." Only 20% indicated that they lacked adequate preparation for using computers to teach. The apparent improvement in preparation may be explained

Figure 1-25
Public school teachers with IT training that mentioned or focused on computer mechanics, integrating information technology with instruction, and Internet use, by main teaching field: 2000–01

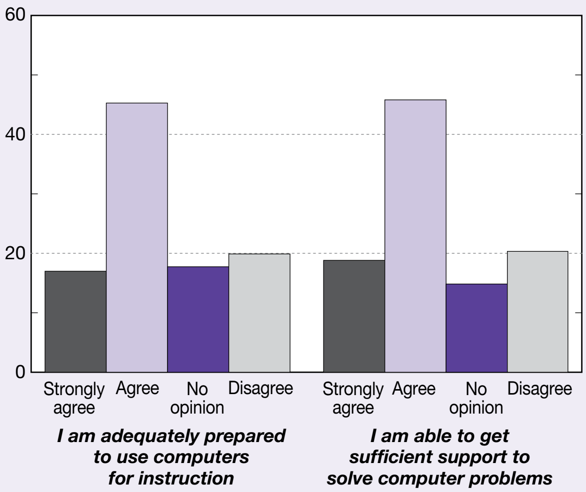


IT = information technology

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01 Teacher Follow-up Survey. See appendix table 1-29.

Science and Engineering Indicators 2006

Figure 1-26
Third grade teachers' agreement with statements about their own preparation to use computers and about their school's technical support: 2002



SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Fall 1998 Kindergartners in Spring 2002. See appendix table 1-30.

Science and Engineering Indicators 2006

partly by differences in grade levels; the earlier data apply to all teachers, whereas in 2002 they apply only to third grade teachers. Integrating IT with instruction is more likely in elementary grades, where teachers focus on basic skills development (Hedges, Konstantopoulos, and Thoreson 2003; Sutton 1991).

Another survey provides some complementary data. Most 2000–01 elementary and secondary teachers reported being fairly comfortable using computers: 75% in all agreed, and 35% said they strongly agreed, with the statement, "I am reasonably familiar and comfortable with using computers" (appendix table 1-29). (The statement is broad rather than focused on the educational uses of computers, however.) Mathematics or science teachers were far more likely than others to express strong agreement, and teachers with at least 10 years of experience were somewhat less likely than those with less seniority to feel very comfortable using computers.

The proportions of third grade teachers who had a positive assessment of their school's technical support were similar to the proportions who had confidence in their own IT skills. About 65% of students had teachers who agreed or strongly agreed with the statement, "In this school, I am able to get sufficient support to solve any computer problems I have," with 19% expressing strong agreement (figure 1-26). No substantial differences separated teachers at urban, suburban, or rural schools or at schools with different concentrations of minority students for either IT preparation or technical support (appendix table 1-30). Earlier gaps between advantaged and disadvantaged schools, and among schools in different community types, in teacher preparation for using IT may be narrowing as training becomes more widespread (Smerdon et al. 2000; Wenglinsky 1998). Teachers with different amounts of teaching experience differed little in their confidence about using computers, as 16%–19% strongly agreed that they were prepared. These findings suggest that at least basic training for using IT has reached many early elementary school teachers at different kinds of schools.

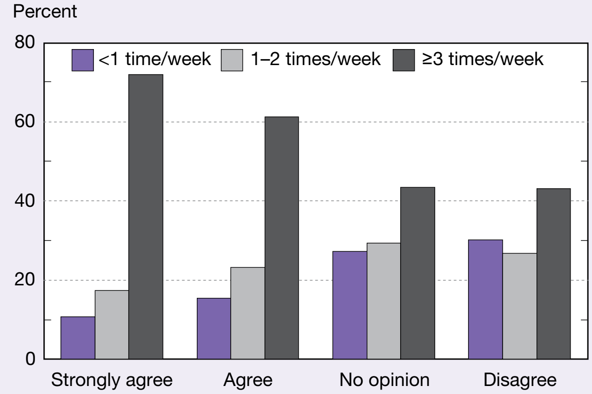
Third grade teachers' evaluation of their IT preparation was closely related to having their students use computers and access the Internet frequently (figure 1-27). About 72% of students whose teachers had strong IT confidence used computers for non-Internet tasks at least three times weekly, compared with only 43% of those whose teachers felt lacking in preparation.[44]

Similarly, when teachers thought they had better technical support, their students were more likely to use IT resources in class at least three times a week (appendix table 1-27). Along with extensive teacher training in computer use, strong technical support has also been associated with teachers' effective use of IT (Becker 1994; Cuban 1999; Hruskocy et al. 2000).

Summary

Access to IT resources, particularly in schools, has increased in the past two decades, generally leveling the playing field for disadvantaged students. Virtually all public schools were connected to the Internet in 2003, and nearly all had broadband connections. Gaps by family income and race/ethnicity in student use of computers and the Internet at school have decreased greatly. However, despite diminishing for years, substantial gaps in home access persisted in

Figure 1-27
Frequency of assigning non-Internet computer work to third grade students, by teachers' confidence in their preparation to use computers for instruction: 2002



NOTE: Third grade teachers' agreement with the statement: *I am adequately prepared to use computers for instruction.*

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Fall 1998 Kindergartners in Spring 2002. See appendix table 1-27.

Science and Engineering Indicators 2006

2003. At a particular disadvantage are students from low-income families, who were about one-third as likely as those from affluent families to have home Internet access in 2003. Nearly all students used a computer at school, whereas just under half of them accessed the Internet there. Computer use for non-Internet purposes was quite common for third graders; 56% of them reportedly did computer work at least three times a week in 2002.

Among students with access at home, the most common computer use was playing games, followed by schoolwork, with e-mail a distant third. Most likely to work on home computers for school work were students in secondary grades, female or black students, those from affluent families, and those with highly educated parents. About 80% of students used the Internet (from any location) for school assignments.

Teachers' professional development in IT may be shifting toward using computers to more effectively support instructional goals and away from computer literacy skills. Roughly half of 2000−01 public school teachers had trained in the last year on one or more of three topics: the mechanics of using IT, integrating computers into instructional activities in their subject, and/or using the Internet. However, such training tended to be brief rather than sustained. Third grade teachers with different characteristics and at different kinds of schools differed little or not at all in their confidence about using computers for instruction, whereas in the past, veteran teachers more often assessed their computer knowledge as lacking compared with that of their junior colleagues. The more confident third grade teachers assigned their students computer and Internet more often than did other teachers.

Transition to Higher Education

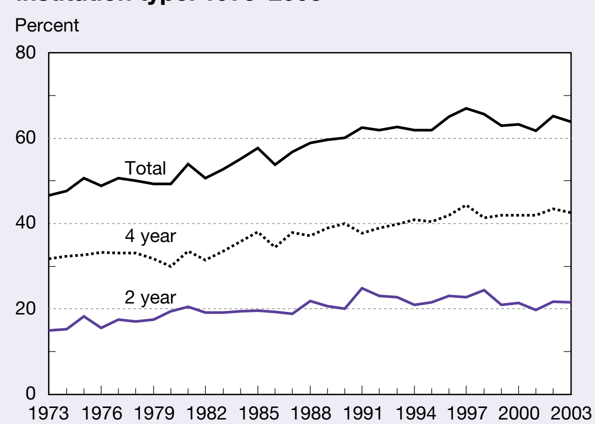
Student progress in completing high school and entering postsecondary education provides measures of the effectiveness of education at the secondary level. Today, a vast majority of students expect to continue their education after high school and many anticipate earning a bachelor's or higher degree. (In 2002, 80% of 10th graders expected to attain a bachelor's or higher degree and another 11% expected some postsecondary education [NCES 2004a].) In fact, increasing numbers of students are entering college directly from high school (NCES 2005). This bright picture, however, is clouded by the ongoing challenge of the dropout problem. In 2002, 10% of 16–24-year-olds (about 3.7 million) had left school without earning a high school credential (NCES 2005).[45] Although dropouts may return to earn a diploma, many do not go on to postsecondary education (Hurst, Kelly, and Princiotta 2004). Further, the increasing rates of immediate college enrollment belie the large numbers of entering freshmen who are poorly prepared for college work and need remedial help. This section presents indicators related to students' transition to college: long-term trends in the immediate college enrollment rates of U.S. high school graduates, first-time entry rates into postsecondary education in the United States and other countries, and remedial coursetaking among U.S. college freshmen. Together, these indicators provide an overview of the accessibility of higher education to high school students and their academic preparation for college-level work.

Immediate Enrollment in Postsecondary Education

The proportion of students choosing to continue their education directly after high school is on the increase (NCES 2005). One indicator of this trend is the percentage of students who enter college immediately following their high school graduation (referred to as the *immediate college enrollment rate*).[46] The immediate college enrollment rate was about 50% between 1973 and 1980, increased to 67% in 1997, and has since leveled off (figure 1-28). In 2003, 64% of high school graduates entered college directly after high school. Enrollment rates increased at both 4- and 2-year institutions: in 1973, 32% of students entered 4-year institutions immediately after completing high school, and 15% entered 2-year institutions. By 2003, the percentages had increased to 43% and 22%, respectively.

Immediate college enrollment rates increased for both males and females during this period, but the rates for females increased faster (figure 1-29). In fact, between 1973 and 2003, the rate of female enrollment in 4-year institutions increased faster than that of males at 4-year institutions and of both males and females at 2-year institutions. White high school graduates had persistently higher immediate enrollment rates than their black and Hispanic counterparts

Figure 1-28
High school graduates enrolled in college in October after completing high school, by institution type: 1973–2003



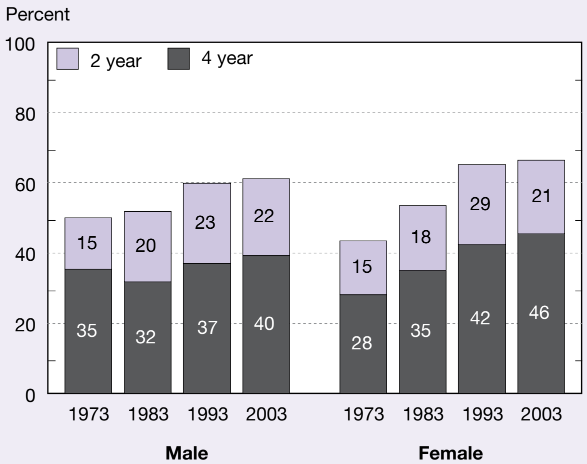
NOTE: Includes students 16–24 years old completing high school in survey year.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005,* NCES 2005-094 (2005). See appendix table 1-31.

Science and Engineering Indicators 2006

(appendix table 1-31). Likewise, differences in immediate enrollment rates by family income have persisted. In each year between 1975 and 2003, students from high-income families were more likely to enter college than their counterparts from low-income families (figure 1-30).

Figure 1-29
High school graduates enrolled in college in October after completing high school, by sex and institution type: Selected years, 1973–2003

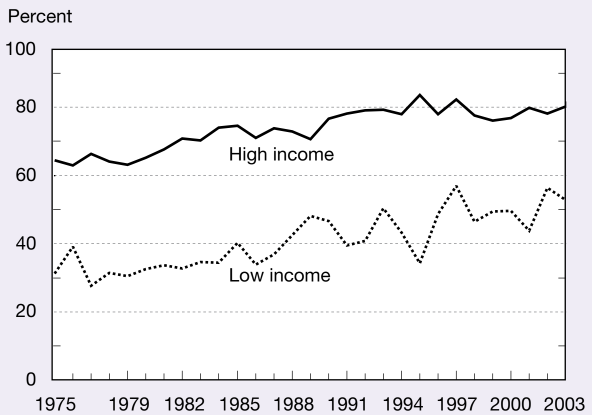


NOTE: Includes students 16–24 years old completing high school in survey year.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005*, NCES 2005-094 (2005).

Science and Engineering Indicators 2006

Figure 1-30
High school graduates enrolled in college in October after completing high school, by family income: 1975–2003



NOTES: Includes students 16–24 years old completing high school in survey year. Low income includes bottom 20% of all family incomes, high income includes top 20% of all family incomes.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005,* NCES 2005-094 (2005). See appendix table 1-31.

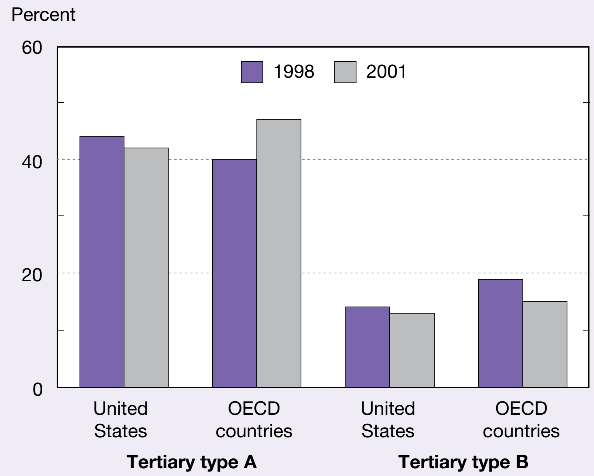
Science and Engineering Indicators 2006

International Comparisons

Participation in education beyond secondary schooling has been rising in many countries in recent years (OECD 2000 and 2003a). One measure of such participation is the OECD-developed first-time entry rate into postsecondary programs. OECD distinguishes between postsecondary programs that are largely theory oriented and designed to prepare students for advanced research programs and high-skills professions (tertiary type A) and those that focus on occupationally specific skills for direct entry into the labor market (tertiary type B).[47] In the United States, tertiary type A programs are mostly offered at 4-year institutions and lead to bachelor's degrees, and tertiary type B programs are often offered at community colleges and lead to associate's degrees.[48]

In 2001, the average first-time entry rate into tertiary type A programs was 47% for the 26 OECD countries with available data (figure 1-31). The United States had an entry rate

Figure 1-31
First-time entry rates into postsecondary (tertiary) education, United States and OECD country average, by program type: 1998 and 2001



OECD = Organisation for Economic Co-operation and Development

NOTES: Tertiary type A programs provide education that is largely theoretical and is intended to provide sufficient qualifications for gaining entry into advanced research programs and professions with high-skill requirements. Entry into these programs normally requires successful completion of upper secondary education (i.e., high school); admission is competitive in most cases. Minimum cumulative theoretical duration at this level is 3 years of full-time enrollment. Tertiary type B programs are typically shorter than tertiary type A programs and focus on practical, technical, or occupational skills for direct entry into labor market, although they may cover some theoretical foundations in respective programs. They have minimum duration of 2 years of full-time enrollment at tertiary level. OECD calculates entry rates by dividing number of first-time entrants of specific age in each type of tertiary program by total population in corresponding age group and then adding results for each single year of age. Entry rates for tertiary type A and B programs cannot be combined to obtain total tertiary-level entry rate because entrants into both types of programs would be counted twice.

SOURCES: OECD, *Education at a Glance: OECD Indicators 2000* (2000); and *Education at a Glance: OECD Indicators 2003* (2003). See appendix table 1-32.

Science and Engineering Indicators 2006

of 42%, slightly lower than the overall average.[49] Australia, Finland, Iceland, New Zealand, Norway, Poland, and Sweden all had entry rates of more than 60% (appendix table 1-32). Between 1998 and 2001, first-time entry rates into tertiary type A programs increased in 19 of the 22 OECD countries with data, except for the United States and United Kingdom, where rates declined, and Turkey, where rates remained the same.

Entry rates into tertiary type B programs were generally lower and more variable in many countries. In 2001, the average first-time entry rate into tertiary type B programs was 15% for the 23 OECD countries with available data. The rate for the United States was 13%. From 1998 to 2001, the OECD average entry rate into type B programs declined from 19% to 15%, whereas U.S. rates remained virtually unchanged (14% to 13%).

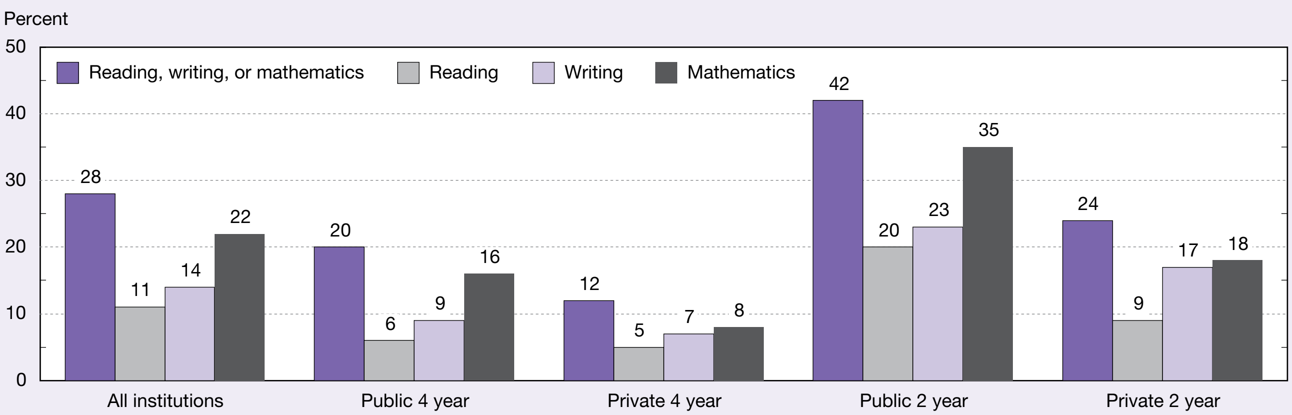
Remedial Education for Entering College Freshmen

Academic preparation in high school plays a critical role in students' ability to enroll and succeed in postsecondary education. For example, high school students who completed rigorous curricula were more likely to enroll in a 4-year college, persist through postsecondary education, and earn a bachelor's degree (Adelman 1999 and 2004; Horn and Kojaku 2001). Despite the increasing numbers of U.S. students completing advanced high school courses and even earning college credits by passing AP Exams, many others are poorly prepared for college academic work and need remediation before they are ready to enroll in standard college-level courses. Postsecondary remedial education has been the subject of an ongoing debate among educators, policymakers, and the public (Parsad and Lewis 2003). Although providing remedial courses at 2-year institutions may be necessary and appropriate given the type of students who attend, there is considerable debate about offering remedial courses at 4-year institutions. Proponents argue that remedial education is necessary because it expands educational opportunities for underprepared students; critics counter that college-level remediation should be discouraged because offering courses covering content and skills that should have been learned in high school is both inefficient and costly to the higher education system (Hoyt and Sorenson 2001). A study by Adelman (2004) shows that students who took remedial courses graduated from college at significantly lower rates; no "cause-and-effect" conclusions, however, can be drawn from the study.

In fall 2000, 76% of all degree-granting 2- and 4-year institutions offered at least one remedial reading, writing, or mathematics course (Parsad and Lewis 2003).[50] At these institutions, 28% of freshmen enrolled in at least one remedial reading, writing, or mathematics course (figure 1-32). Freshmen appeared to need more remediation in mathematics than in the other two subjects: 22% undertook remediation in mathematics, compared with 14% in writing and 11% in reading. Freshmen at public 2-year institutions that offered remedial courses were especially likely to receive remedial help: 42% of freshmen at these institutions, compared with 12%–24% of their peers at other types of institutions, enrolled in a remedial course in fall 2000.

Most freshmen took remedial courses for less than a year. However, time spent in remediation was much longer at public 2-year institutions than at other types of institutions. In fall 2000, 63% of public 2-year institutions offering remedial courses reported that the average time a student spent in remediation was 1 year or more, compared with 38% and 17%, respectively, of public and private 4-year institutions offering remedial courses (figure 1-33). The average length of time spent in remediation also increased over time. Between 1995

Figure 1-32
Freshmen enrolled in remedial courses, by subject area and institution type: Fall 2000

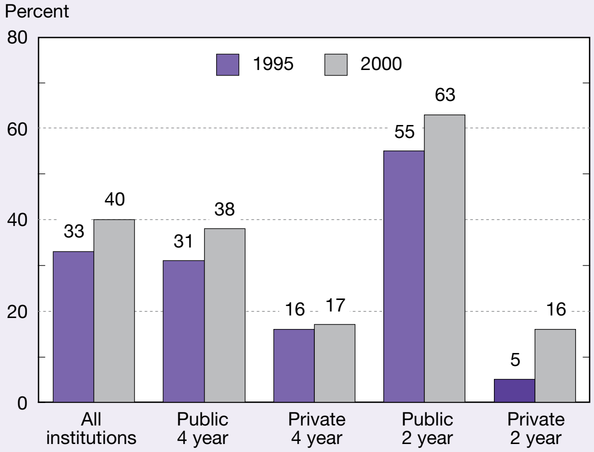


NOTE: Includes only postsecondary institutions that offered remedial courses.

SOURCE: B. Parsad and L. Lewis, *Remedial Education at Degree-Granting Postsecondary Institutions in Fall 2000,* NCES 2004-010, U.S. Department of Education, National Center for Education Statistics (2004).

Science and Engineering Indicators 2006

Figure 1-33
Institutions reporting average time freshmen took remedial courses was 1 year or more, by institution type: Fall 1995 and 2000



NOTE: Includes only postsecondary institutions that offered remedial courses.

SOURCE: B. Parsad and L. Lewis, *Remedial Education at Degree-Granting Postsecondary Institutions in Fall 2000,* NCES 2004-010, U.S. Department of Education, National Center for Education Statistics (2004).

Science and Engineering Indicators 2006

and 2000, the proportion of institutions reporting that the average time spent in remediation was a year or more increased from 33% to 40%. This increase occurred in all types of institutions, except for private 4-year institutions.

Conclusions

Raising academic achievement levels for all students is a top priority for education reform at all levels across the United States. In mathematics and science, improvements in the performance of U.S. elementary and secondary students have been uneven. In mathematics, achievement on NAEP rose from 1990 to 2003 among 4th and 8th graders and from 1990 to 2000 for 12th graders. The mathematics gains occurred in many demographic subgroups. In science, between 1996 and 2000, the average scores changed little at the 4th and 8th grade levels and declined at the 12th grade level.

The proportion of students reaching the proficient achievement level (which is based on judgments of what students should know and be able to do at each grade level) raises additional concerns. In both mathematics and science, most 4th, 8th, and 12th graders did not demonstrate proficiency in the knowledge and skills taught at their grade level. Students from disadvantaged backgrounds lagged behind their more advantaged peers with these disparities starting as early as kindergarten, persisting across grades, and, for some kinds of skills, widening over time.

International assessments also yielded both encouraging and discouraging results. Although U.S. students performed above the international average on the TIMSS tests (which evaluate mastery of curriculum-based knowledge and skills), they performed below the international average on the PISA tests (which assess their ability to apply mathematics and science). However, the number and type of participating countries differed between the two assessments. Furthermore, despite showing some improvement in mathematics and science performance in recent years, U.S. students continued to lag behind their peers in many other developed countries.

Many factors influence student performance, either directly or indirectly. Access to challenging courses, qualified and experienced teachers, school environments that support learning and teaching, and opportunities for using computers and the Internet are all important factors. Educational policies on curriculum standards, testing and accountability, and instructional materials also help define the broad learning context, and their practical effects on curriculum, teaching methods, and learning materials all shape the experiences of teachers and students. Looking at these and other factors affecting education provides a context for the student achievement results reported here.

- **Course offerings.** Access to advanced mathematics courses has increased since 1990, and access to advanced science courses remained nearly universal. In 2000, most high school students had access to advanced mathematics courses, such as trigonometry or algebra III, precalculus, and calculus, and virtually all students had access to advanced science courses such as chemistry, physics, and advanced biology. For most students, however, a significant gap separates current high school graduation requirements from the skill levels needed to succeed in college and to prepare for family-sustaining jobs. Also, despite overall availability of advanced course offerings, access varied by school characteristics. Students attending urban or suburban schools, large schools, or low-poverty schools were generally more likely to be offered advanced mathematics and science courses than those attending rural schools, smaller schools, or high-poverty schools.

- **Coursetaking.** High school students increased their advanced coursetaking in mathematics and science throughout the 1990s, but despite this increase, overall participation in advanced courses remained relatively modest. In 2000, the proportion of high school graduates completing various advanced mathematics courses was 27% or lower, and the proportion completing advanced science courses ranged from 33% for physics and 36% for advanced biology to 63% for chemistry. Even such moderate levels may overstate participation in advanced coursetaking because the definition of advanced used in this report sets a minimal bar: courses that not all students complete and are not widely required for graduation. Some courses included in certain categories may not meet other definitions of advanced that are based on the content and skills they require.

- **Advanced coursetaking differed by school and student characteristics.** Students from rural, smaller, or high-poverty schools were less likely to take advanced mathematics and science courses. Although males and females were equally likely to take advanced mathematics courses, females were more likely to take chemistry and advanced biology courses and males more likely to take physics courses. Asians/Pacific Islanders were generally more likely than other racial/ethnic groups to take advanced mathematics and science courses.
- **Participation in AP programs.** The number of students taking AP tests has grown rapidly since 1990, both overall and specifically in mathematics and science subjects. Female AP test takers were less likely than their male counterparts to earn passing scores, which allow students to earn college credits. Blacks and Hispanics were also less likely than their Asian/Pacific Islander and white peers to earn passing scores.
- **Teacher quality.** College graduates entering the teaching profession tended to have somewhat lower academic skills, as evidenced by their lower rates of participation in rigorous academic courses in high school, lower scores on high school senior achievement tests and college entrance examinations, and lower rates of attending and graduating from selective colleges. Although virtually all mathematics and science teachers held a bachelor's degree and teaching certification, many, particularly those in the high-school grades, were teaching subjects for which they had little academic preparation. This so-called *out-of-field teaching,* measured as teachers lacking either a certificate or a college major or minor in their assigned teaching field, was prevalent in many states and appeared to be increasing over time.
- **Teacher attrition and working conditions.** About 7%–9% of public school mathematics and science teachers left the teaching profession between the 1999 and 2000 academic years. Among those who left, one-third did so for a job outside the field of education, and many of those found more satisfaction with their new job than with teaching. Although some mathematics and science teachers left to pursue more lucrative career opportunities outside education, others left because of poor working conditions in their schools. Data indicate that compared with those who stayed, mathematics and science leavers were less satisfied with teaching in their former schools and expressed less positive views about various aspects of working conditions. These findings suggest that the school environment may play a role in teachers' decisions to leave the profession.
- **Access to and use of IT.** Access to computers and the Internet has become more widespread both at school and at home. Home computer ownership and Internet access continue to differ by family income, parental education, and race/ethnicity, although these gaps are narrowing over the long term. The rapid growth in access to computers and the Internet at school have helped equalize access for disadvantaged students. Most students, especially at the secondary level, used home computers and the Internet for schoolwork, although playing games was also a common activity. About 62% of third grade teachers indicated in 2002 that they felt adequately prepared to use computers for instruction. Third grade teachers' confidence in their IT skills was related to how frequently they assigned their students to use computers and access the Internet.
- **Participation in postsecondary education.** Increasing proportions of students continue their education immediately after high school, but gaps persist among student subpopulations. The gender gap was relatively small and favored females starting in the late 1980s, but gaps by race/ethnicity and family income continued to be large, with lower rates for black and Hispanic students and those from low-income families.
- **Remediation in college.** Despite the rising participation in AP programs and advanced coursetaking, many college freshmen were not ready for college-level work and needed remedial assistance (particularly in mathematics) after their transition to college. Among freshmen taking remedial courses, most spent less than a year in remediation, but trends indicate increases in the average length of time spent. It is possible that the rising immediate college enrollment rate is partially responsible for the increased need for remediation among college freshmen.

The indicators presented in this chapter provide an overview of the conditions of U.S. mathematics and science education. The results show both improvement and weaknesses in its various aspects. The tasks of encouraging students to take more rigorous academic courses, improving the overall quality of the teaching force, and creating better working environments for both students and teachers will remain a critical challenge as the nation seeks to improve the achievement of all students.

Notes

1. A series of reports based on data from the ECLS-K study and released by the National Center for Education Statistics (NCES) can be found at: http://nces.ed.gov/ecls.

2. The ECLS-K assessment measures students' overall mathematics achievement through both scale scores and their specific mathematics skills and knowledge as measured through a set of proficiency scores. The scale scores place students on a continuous ability scale based on their overall performance on the assessment, whereas the proficiency scores are based on clusters of items assessing particular skills and report whether students mastered those skills. When describing gains over the kindergarten year, this review focuses on proficiency in specific areas. When reporting on growth in achievement from kindergarten to third grade, scale scores are discussed. For more information on the ECLS assessment battery and scoring, including the Item

Response Theory (IRT) methodology used, see Rathbun and West (2004) and West, Denton, and Reaney (2000).

3. The studies reviewed in this chapter report combined results for Asians and Pacific Islanders. It is important to note that this category combines groups that have very different cultural and historical backgrounds, and whose achievement varies widely.

4. In later years of the ECLS-K study, family income below the federal poverty level was substituted for the welfare assistance risk factor. Students were classified as having no family risk factors, one risk factor, or two or more risk factors.

5. About 10% of the cohort was in second grade, and another 1% was in another grade. For the sake of simplicity, the students in the 2002 followup are referred to as third graders.

6. Trends in mathematics and science performance by gender are not easily summarized, with girls outperforming boys in some age groups and boys outperforming girls in other cases. See *Science and Engineering Indicators – 2004*, page 1-7, for more details on long-term trends in mathematics and science performance of males and females. See sidebar in this issue "Long-Term Trends in Student Mathematics Achievement."

7. Students were identified as attending private schools continuously, attending public schools continuously, or attending a combination of private and public schools between the beginning of kindergarten and the end of third grade. There were no statistically significant differences in gains in average mathematics scores across these three groups.

8. Because students have been assessed in science only once in the ECLS, the study has thus far produced less information on science learning. As of yet, only science scale scores have been reported. As the study continues to follow these students, future reports will likely provide more detail on science achievement.

9. NAEP consists of three assessment programs. The *long-term trend assessment* is based on nationally representative samples of 9-, 13-, and 17-year-olds. It has remained the same since it was first given in 1969 in science and 1973 in mathematics, permitting analyses of trends over three decades. A second testing program, the *national* or main NAEP, assesses national samples of 4th, 8th, and 12th grade students. The national assessments are updated periodically to reflect contemporary standards of what students should know and be able to do in a subject. The third program, the *state* NAEP, is similar to the national NAEP but involves representative samples of students from participating states.

10. These recent trends are based on data from the national NAEP program. The current national mathematics assessment was first administered in 1990 and was given again in 1992, 1996, 2000, and 2003. In 2003, only fourth and eighth grade students were assessed. The current national science assessment was first administered in 1996 and was given again in 2000 and 2005. The 2005 results were not available in time for inclusion.

11. The 2002 and 2004 volumes reviewed trends in science from 1969 to 1999 and in mathematics from 1973 to 1999. The long-term trend assessment in mathematics was administered again in 2004, but those data were not released in time to be included in the text of this chapter (see sidebar "Long-Term Trends in Student Mathematics Achievement"). The long-term trend assessment in science has not been given since 1999.

12. NAEP is in the process of changing the way it includes students with disabilities and limited English proficiency in assessments. Before 1996, these students were not allowed to use testing accommodations (e.g., extended time, one-on-one testing, bilingual dictionary); as a result, many did not participate. In 1996 and 2000, the assessment was administered to split samples of "accommodations not permitted" and "accommodations permitted." In 2003, the NAEP mathematics assessment completed the transition to an "accommodations permitted" test.

13. Using eligibility for the free or reduced-price lunch program as a proxy for family poverty is not as reliable in the higher grades because older students may attach stigma to receiving a school lunch subsidy.

14. Sample size was insufficient to permit reliable mathematics estimates for American Indian/Alaska Natives prior to 1996 for grades 4 and 12 and prior to 2000 for grade 8.

15. NCES did not publish 2000 science scores for fourth grade Asian/Pacific Islander students because of accuracy and precision concerns; therefore, those scores are not included.

16. In science, the apparent difference at grade 12 in average scale scores by gender was not statistically significant. However, a greater proportion of 12th grade boys reached the proficient level in science than did girls.

17. For detailed racial/ethnic group comparisons see NCES (2003, 2001a, 2001b).

18. The primary grade assessed in each country was "the upper of the two adjacent grades with the most 9-year-olds" (Mullis et al. 2005). In the United States, and most other countries, this was the fourth grade. The middle grade assessed was defined as the "upper of the two adjacent grades with the most 13-year-olds." In the United States and most countries, this was the eighth grade. Students in their final year of secondary school (12th grade in the United States) were assessed with TIMSS in 1995. For a review of those results, see page 1-14 in *Science and Engineering Indicators – 2004* or Takahira et al. (1998). Subsequent TIMSS administrations have focused on the middle grades.

19. To be assessed in TIMSS, the specific content domains and topics had to be included in the curricula of "a significant number of participating countries" (Mullis et al. 2005). It is important to note that whereas the TIMSS program identified common mathematics and science curriculum across participating countries, there are many differences in the way countries delivered that curriculum and in their breadth of coverage (Sherman, Honegeger, and McGivern 2003).

20. More information about TIMSS and PISA assessments can be found at http://nces.ed.gov/TIMSS/ and http://nces.ed.gov/Surveys/PISA/.

21. Of the 14 other countries that participated in both the 1995 and 2003 grade 4 TIMSS mathematics assessments, the United States was outperformed by four countries in 1995 and by seven countries in 2003. Of the 21 other countries that participated in both the 1995 and 2003 grade 8 mathematics assessments, 12 had average scores higher than the U.S. average score in 1995 and 7 had higher scores in 2003.

22. Of the 14 other countries that participated in both the 1995 and 2003 grade 4 TIMSS mathematics assessments, only 1 had a higher average score than the United States in 1995, but 2 did in 2003. At grade 8, of the 21 countries that participated in both years, 9 had higher average scores than the United States in 1995, whereas 5 did in 2003.

23. Forty-one countries participated in the 2003 PISA assessment—30 OECD member countries and 11 non-OECD countries. This section summarizes a report released by NCES (2004c) that presents PISA results from a U.S. perspective. That report omitted data from the United Kingdom because of low response rates and from Brazil because these data were not yet available. That report and this section compare U.S. averages first to OECD averages (i.e., average of national averages from the 29 OECD countries for which data were available, including the United States) and, second, to individual country averages (both OECD and non-OECD countries).

24. Data for both 2000 and 2003 are available for 26 OECD countries, including the United States. Of these countries, nine improved their science scores and five registered declines.

25. Comparing change in mathematics performance is complicated by the fact that the 2003 PISA assessment was more extensive than the 2000 assessment. In 2000, two content areas were assessed: *space and shape* and *change and relationship.* In 2003, those two areas, along with two additional content areas (*quantity* and *uncertainty*) were tested. Thus, change in mathematics performance can be examined only for the two content areas assessed in both years. The average scores for U.S. students did not change from 2000 to 2003 on either the *space and shape* or the *change and relationship* content areas. Of the 25 other countries that participated in both assessment years, 18 outperformed the United States in the *space and shape* area in 2003 compared with 19 in 2000. In the *change and relationship* area, 17 countries outperformed the United States in 2003, and 14 did in 2000.

26. Even in these three states, students and parents may choose a less rigorous program, but these requirements are the default. These requirements were in effect in Texas for the class of 2008 and were scheduled to begin in the near future in Arkansas and Indiana.

27. The data on courses offered and completed are from the NAEP High School Transcript Study from 1990 to 2000. A caveat: courses are classified based on titles and content descriptions. However, material studied, methods used, and overall difficulty can differ widely across schools for courses with similar titles or in the same category.

28. It may seem odd that the calculus courses percentage is larger than the precalculus percentage. However, although most students would be required to study precalculus or similar content to prepare for calculus, in some schools such material may be taught in a course such as trigonometry or algebra III, or even, in rare cases, in a course not included in the categories shown in the table.

29. Coursetaking and course completion are used interchangeably in this section. The NAEP data show credits for specific courses; students earn credits by completing a course and earning a passing grade.

30. Percentages taking courses are percentages of all graduates who had complete transcripts rather than of the subset who had access to each type of course.

31. A single exception qualifies this statement: Asian/Pacific Islander graduates did not differ from graduates in the group classified as “other” in the likelihood of completing a statistics course.

32. NCLB defines a *highly qualified* elementary or secondary school teacher as someone who holds a bachelor’s degree and full state-approved teaching certificate or license (excluding emergency, temporary, and provisional certificates) and who demonstrates subject-matter competency in each academic subject taught by having an undergraduate or graduate major or its equivalent in the subject; passing a test on the subject; holding an advanced teaching certificate in the subject; or meeting some other state-approved criteria. NCLB requires that new elementary school teachers must pass tests in subject-matter knowledge and teaching skills in mathematics, reading, writing, and other areas of the basic elementary school curriculum. New middle and high school teachers either must pass a rigorous state test in each academic subject they teach or have the equivalent of an undergraduate or graduate major or advanced certification in their fields.

33. Teaching experience is another indicator of teacher quality and was examined in the 2004 edition of *Science and Engineering Indicators*. Because of a lack of national data, that indicator cannot be examined in this edition. Other factors may also play important roles in teacher quality, including ability to motivate students, manage classroom behavior, maximize instructional time, and diagnose and remedy students’ learning difficulties (Goldhaber and Anthony 2004; McCaffrey et al. 2003; Rice 2003). These characteristics are rarely examined in nationally representative surveys because they are difficult and costly to measure.

34. Other research has found that teachers tend to have higher undergraduate GPAs than other graduates (Frankel and Stowe 1990; Gray et al. 1993; Henke et al. 1996). However, grades are not standardized among or within institutions, which makes it difficult to compare teachers’ academic performance with that of other graduates.

35. Full certification refers to a state’s regular, standard, advanced, or probationary certificate. It does not include

temporary, alternative, provisional, or emergency certificates granted to those who have not fulfilled requirements for licensing. These teachers are referred to as "not fully certified."

36. Researchers often cited teacher shortages as a major reason for this decline, claiming that increasing student enrollment, reduction of class sizes, high rates of teacher turnover, and lack of qualified candidates have created teacher shortages, which in turn have forced schools and districts to hire less-qualified candidates to fill vacancies (Boe and Gilford 1992; Howard 2003). This explanation, however, has not been empirically demonstrated.

37. The purpose of the LSC project is to improve the teaching of science, mathematics, and technology by focusing on the professional development of teachers within whole schools or districts. Each participating teacher is required to have a minimum of 130 hours of professional development over the course of the project. The training focuses on preparing teachers to implement designated exemplary mathematics and science instructional materials in their classrooms (Weiss, Banilower, and Shimkus 2004).

38. Data on weekly pay of teachers come from the Bureau of Labor Statistics' Current Population Survey (CPS). Weekly earnings were either reported directly by respondents or estimated using the number of weeks worked and annual, monthly, or biweekly earnings.

39. *Statutory salaries* refers to salaries set by official pay scales. These figures should be distinguished from the actual salaries teachers receive. The 2002 U.S. salaries were estimated from average scheduled salaries from the 1999–2000 SASS. The 1999–2000 figures were adjusted for inflation by 3.8% for 2000–01 and an additional 2.9% for 2001–02 (OECD 2004).

40. Differences in other items also appear large, but are not statistically significant, because of large standard errors associated with mathematics and science teacher leavers.

41. About 90% of students in the sample were in third grade at the time of the followup survey; most of the remaining 10% were in second grade.

42. Data on computer tasks apply to students' use of home computers only, whereas the Internet tasks and frequency of use apply to Internet use at any location. The percentages in appendix table 1-28 discussed in this section are based only on students who had access to computers at home and access to the Internet anywhere, whereas in appendix table 1-26 and the text on access, the base for percentages is all students in K–12.

43. Teachers in the Teacher Followup Survey for 2000–01 were divided into three groups based on their main assignment field: elementary if it was kindergarten, general elementary, or early childhood special education; mathematics or science if the subject was in those fields; and other for all other fields. The latter two categories consist primarily of secondary grade teachers.

44. Causality may not flow in only one direction, however. For example, teachers who are required to use IT resources may seek out more training, and school leaders who emphasize teaching with technology may strongly encourage teachers both to participate in IT training and to use computers frequently.

45. There are different ways to estimate dropout rates. This rate, typically called the "status dropout rate," represents the percentage of an age group not enrolled in school and not holding a high school credential (i.e., diploma or equivalent, such as a General Educational Development [GED] certificate).

46. The base for immediate enrollment rates is the population of high school graduates. The rates would be lower if all high school students, including dropouts, were considered.

47. OECD calculates the first-time entry rates for its member countries by dividing the number of first-time entrants of a specific age in each type of tertiary education by the total population in the corresponding age group and then adding the results for each single year of age (OECD 2003a). The purpose is to make the rates comparable across countries with different college entry ages. First-time entry rates for tertiary-type A and B programs cannot be added together to obtain the total tertiary-level entry rate because entrants into both types of programs would be counted twice.

48. This distinction is fairly general. Some U.S. community colleges offer strong transition programs and make their courses equivalent to the lower-division courses of 4-year institutions, and therefore resemble 4-year institutions. On the other hand, vocationally oriented courses are not offered exclusively in community colleges; many 4-year institutions also offer such courses. In addition, the U.S higher education system and those of other countries are different, so simple comparisons may lead to inaccurate conclusions.

49. First-time entry rates cannot be directly compared with immediate college enrollment rates because of the different population bases and calculation methods for the two measures. In computing immediate college enrollment rates, the base is all high school graduates. In calculating first-time entry rates, the base is a country's population.

50. Depending on institutional requirements, courses considered "remedial" may vary across postsecondary institutions.

Glossary

Advanced Placement: An opportunity to study college-level material while in high school and to demonstrate advanced proficiency in a subject by passing a rigorous exam.

Digital divide: The gap between those with access to new technologies and those without; this division tends to fall along socioeconomic and racial/ethnic lines.

International Baccalaureate: An internationally recognized preuniversity course of study designed for secondary school students.

Out-of-field teaching: A mismatch between the subjects a teacher teaches and that teacher's academic training and/or certification.

Time-based course requirements: Requirements based on the number of years a student should take a particular subject; this type of requirement is losing popularity to those that set standards for the skills and content students need to learn.

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Chapter 2
Higher Education in Science and Engineering

List of Sidebars

List of Tables

List of Figures

Highlights

Overall Trends in Enrollments and Degrees in U.S. Universities

Enrollment in U.S. higher education is projected to continue rising over the next decade because of increases in the U.S. college-age population.

- Enrollment rose from 12.6 million in 1983 to 15.7 million in 2001.
- The number of individuals between the ages of 20 and 24 in the U.S. population is projected to rise through about 2015, although the demographic composition will shift. The number of people ages 20 to 24 is projected to decline from 2015 to 2020.
- Whites are projected to decline from 66% of the population mentioned above in 2000 to 58% by 2020, as the shares of Asians/Pacific Islanders and Hispanics increase from 4% to 6% and 15% to 22%, respectively. The percentages of blacks and American Indians/Alaska Natives are projected to remain at 14% and 1%, respectively.

The number of science and engineering degrees awarded at all levels is rising.

- The numbers of S&E bachelor's and master's degrees reached new peaks of 415,600 and 99,200, respectively, in 2002.
- The number of S&E doctoral degrees, after declining for 4 years, rose in 2003 for both U.S. citizens and temporary visa holders.

S&E bachelor's degrees have constituted about one-third of all baccalaureate degrees awarded for more than 20 years.

- S&E bachelor's degrees made up 32% of all bachelor's degrees awarded in 1983 and in 2002, fluctuating between 30% and 34% in the intervening years.
- Bachelor's degrees in the natural sciences (physical, life, environmental, and computer sciences, and mathematics) are about 12%, engineering baccalaureates are about 5%, and social/behavioral science baccalaureates are about 15% of all baccalaureates awarded.
- Percentages of all bachelor's degrees earned in the natural sciences, engineering, and social/behavioral sciences have fluctuated very narrowly over the past 20 years, but with an increase in the percentage of bachelor's degrees in psychology (from 4% to 6%) and a decrease in the percentage in engineering (from 7% to 5%).

S&E graduate enrollment in the United States reached a new peak of 566,800 in 2003.

- Following a long period of growth beginning in the 1970s, graduate enrollment in S&E declined in the latter half of the 1990s, but then rebounded in the past several years.
- Graduate enrollment in engineering and in life sciences drove most of the recent growth, but enrollment did increase in all major science fields.

After dropping from 1998 through 2002, the number of S&E doctorates awarded overall increased in 2003. Most major S&E fields also saw increases.

- U.S. citizens accounted for most of the decline between 1998 and 2002, but the number of permanent residents earning S&E doctorates also declined in this period.
- Temporary residents accounted for most of the 2003 increase. The number of U.S. S&E doctorates earned by temporary residents increased by 9% from 2002 to 2003, and the number earned by U.S. citizens increased by 2%.

The number of doctorate recipients with S&E postdoctoral appointments at U.S. universities more than doubled in the past two decades.

- Noncitizens account for most of the increase in S&E postdocs during the period.
- Noncitizens accounted for 58% of S&E postdocs in 2003.
- About two-thirds of S&E postdocs are in the biological/medical/other life sciences.

Financial Support of S&E Graduate Students

The federal government was the primary source of support for about one-fifth of full-time S&E graduate students in 2003.

- Federal support came mostly in the form of research assistantships (RAs), which accounted for 70% of federal support in 2003, up from 61% two decades earlier. The share of federally supported S&E graduate students receiving traineeships declined from 19% in 1983 to 12% in 2003.
- Federal support reaches relatively more students in the physical sciences; earth, ocean, and atmospheric sciences; agricultural sciences; biological sciences; and engineering. Relatively few students receive federal support in mathematics, computer sciences, social sciences, and psychology.

- The proportion of full-time S&E graduate students funded by the National Institutes of Health (NIH) rose to 30% in 2003, and the National Science Foundation (NSF) funded 24%. Support from the U.S. Department of Defense declined to 11% of full-time S&E graduate students.

Primary mechanisms of support differ widely by S&E field of study.

- Full-time students in physical, agricultural, and biological sciences and engineering are supported mainly by RAs.
- In mathematics, primary student support comes from teaching assistantships (TAs) and self-support.
- Full-time graduate students in the social and behavioral sciences are mainly self-supporting or receive TAs.

About one-fourth of 2003 S&E doctorate recipients still owed money from their undergraduate education, and one-third owed money related to their graduate education.

- The majority had no undergraduate debt (73%) or no graduate debt (66%).
- High levels of educational debt were most associated with graduate education: 13% had more than $35,000 of graduate debt, but only 2% had similar amounts of undergraduate debt.
- Levels of debt vary by field, with doctorate recipients in psychology, social sciences, agriculture, and medical/health sciences having higher levels of debt.

Enrollment of and Degrees to Women and Underrepresented Minorities

Women earned more than half of all bachelor's degrees and S&E bachelor's degrees in 2002, but major variations persist among fields.

- Women earned more than half of the degrees awarded in psychology (78%), biological/agricultural sciences (59%), and social sciences (55%), and almost half (47%) in mathematics.
- However, women received 21% of bachelors degrees awarded in engineering, 27% in computer sciences, and 43% in physical sciences.

Underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives) do not enroll in or complete college at the same rate as whites. However, among those who do earn bachelor's degrees, similar percentages of underrepresented minorities and whites earn their degrees in S&E.

- The percentages of blacks and Hispanics ages 25 to 29 in 2003 who completed bachelor's or higher degrees were 18% and 10%, respectively, compared with 34% for whites.
- Among high school graduates, the percentages of blacks and Hispanics ages 25 to 29 in 2000 who had completed bachelor's or higher degrees stood at 21% and 15%, respectively, compared with 36% for whites.
- About one-third of all bachelor's degrees earned by every racial/ethnic group, except Asians/Pacific Islanders, are in S&E. Asians/Pacific Islanders, as a group, earn almost half of their bachelor's degrees in S&E.

The recent increase in S&E graduate enrollment occurred across all major demographic groups: women, minorities, white men, and foreign students.

- The number of women enrolling in S&E graduate programs has continued to increase for the past two decades (except for a decline in computer sciences in 2003).
- The number of white S&E graduate students decreased from 1994 to 2000, then increased through 2003.
- The number of underrepresented minority students enrolling in S&E graduate programs has increased each year since 1985.

Enrollment of and Degrees to Foreign Students

Students in the United States on temporary visas earned a small share (4%) of S&E bachelor's degrees in 2002.

- The number of S&E bachelor's degrees awarded to students on temporary visas increased over the past two decades from 14,100 in 1983 to 16,300 in 2002.
- In 2002, these students earned 8% of bachelor's degrees awarded in computer sciences and 7% of those awarded in engineering.

Although total enrollment of foreign S&E graduate students continued to increase, first-time full-time enrollment declined in fall 2002 and fall 2003.

- The number of S&E graduate students on temporary visas more than doubled between 1983 and 2003, rising from 19% to 27% of all graduate S&E students over that period.
- The number of first-time full-time S&E graduate students with temporary visas declined 5% in fall 2002, the first full academic year since September 11, 2001, and declined another 8% in fall 2003.
- These declines were concentrated mainly in engineering and in computer sciences; however, first-time full-time foreign enrollment increased in physical sciences and in psychology and remained stable in the other major science fields in 2003.

Students on temporary visas earned about one-third (32%) of all S&E doctorates awarded in the United States in 2003 (and more in some fields).

- ♦ More than half (55%) of engineering doctorates were awarded to students on temporary visas.
- ♦ Students on temporary visas earned 43%–44% of U.S. doctorates in mathematics, computer sciences, and agricultural sciences.

Historically, half or more of students on temporary visas have stayed in the United States immediately after degree conferral; however, this percentage has risen in recent years.

- ♦ Although the number of S&E doctoral degrees earned by foreign students declined after 1996, the number of students who had firm plans to remain in the United States continued to increase through 2001, then declined slightly in 2002 and 2003.
- ♦ In the period from 1992 to 1995, 68% of foreign S&E doctoral degree recipients stated they planned to remain in the United States after receiving their degrees. By 2000–03, 74% intended to stay in the United States.
- ♦ Stay rates vary by place of origin, with relatively high percentages of S&E doctorate recipients from China and India and relatively low percentages of those from Taiwan, Japan, South Korea, France, Italy, and Spain accepting firm offers for employment or postdoctoral research in the United States.

Global S&E Education

Global competition for foreign students has increased in the past two decades.

- ♦ The U.S. share of foreign students has declined in recent years, although the United States remains the predominant destination for foreign students, accounting for 40% of internationally mobile students in 2004.
- ♦ The shares of Australia and the United Kingdom have increased, accounting for 6% and 18%, respectively, of foreign students enrolled worldwide. Germany and France also attract large numbers of foreign students, accounting for 15% and 12%, respectively, of internationally mobile students in 2004.

Worldwide, a number of countries are expanding doctoral S&E education.

- ♦ About 78% of S&E doctorates worldwide were earned outside the United States.
- ♦ The numbers of natural sciences and engineering (NS&E) doctoral degrees awarded in China, South Korea, and Japan have continued to rise.
- ♦ In the late 1990s and early 2000s, the numbers of NS&E doctoral degrees leveled off or declined in the United States, the United Kingdom, and Germany.

Introduction

Chapter Overview

The importance of higher education in science and engineering is increasingly recognized around the world for its impact on innovation and economic development. S&E higher education provides the advanced skills needed for a competitive workforce and, particularly in the case of graduate S&E education, the research necessary for innovation. A number of key influences shape the nature of U.S. S&E higher education and its standing in the world.

In recent years, demographic trends and world events have contributed to changes in both the numbers and types of students participating in U.S. higher education. After declining in the 1990s, the U.S. college-age population is currently increasing and is projected to increase for the next decade. The composition of the college-age population is also changing, with Asians/Pacific Islanders and Hispanics becoming an increasing share of the population. Recent enrollment and degree trends reflect, to some degree, these changes. For example, graduate S&E enrollment and the number of S&E degrees at all levels are up, and the proportion of S&E degrees earned by minorities is increasing.

In the 1990s, the number of foreign students coming to the United States for higher education study, particularly from countries in Asia, increased substantially. The increases in foreign students contributed to most of the growth in overall S&E graduate enrollments in recent years. Although the number of foreign students remains high and is on the increase, the number of foreign students entering graduate school dropped since September 11, 2001. From fall 2002 to fall 2003, the number of foreign first-time full-time S&E graduate students dropped 8% (about 2,700 fewer students).

Finally, global competition in higher education is increasing. Although the United States has historically been a world leader in providing broad access to higher education and in attracting foreign students, many other countries are expanding their own higher education systems, providing comparable educational access to their own population and attracting large numbers of foreign students. In recent years, a number of countries, including the United Kingdom, Japan, Canada, Australia, and Germany, have expanded their recruitment and enrollment of foreign S&E graduate students.

Chapter Organization

This chapter describes the structure, student inputs, and degree outputs of the U.S. higher education system, followed by (and set in the context of) a description of increasing world capacity for advanced S&E education. It begins with characteristics of higher education institutions providing S&E education, and freshmen interest and enrollment in S&E fields. Trends in degree completions and postdoctoral study are discussed, including trends by sex, race/ethnicity, and citizenship; patterns of financial support while in graduate school; and doctoral degree student debt. The chapter highlights the flows of foreign students into the United States by country and their intentions to remain in this country. The chapter then presents various international higher education indicators, including comparative S&E degree production in several world regions and the growing dependence of all industrialized countries on foreign graduate S&E students.

Structure of U.S. Higher Education

Higher education institutions in the United States are diverse in terms of highest degree granted (associate's, bachelor's, master's, doctorate), institutional control (public or private), size, mission, and learning environment (NCES 2004a). New institutional forms featuring (alone or in combination) control by profit-making firms, certificate programs designed to enhance specific skills, or primary reliance on distance education have also emerged in recent years. Thus far, however, these new forms play a limited role in S&E education.

Institutions Providing S&E Education

In 2002, approximately 2,500 accredited institutions of higher education in the 50 states, the District of Columbia, and the U.S. territories and outlying areas awarded more than 1.8 million bachelor's or higher degrees, about 540,000 of them in S&E. In addition, approximately 1,700 2-year institutions primarily offer associate's degrees as the highest award (NCES 2004b). Two-year institutions are the largest segment of the higher education enterprise in the United States, accounting for 41% of all academic institutions. They provide S&E coursework that is affordable, remedial, and transferable (see sidebar "New Directions in Community Colleges"). They also serve as a bridge for students who go on to major in S&E at 4-year institutions. Almost 29% of students who began at a community college in the 1995–96 academic year had transferred to a 4-year institution as of 2001 (NCES 2003). Community colleges are not, however, major sources of degrees in S&E fields.

Research institutions, although few in number, are the leading producers of S&E bachelor's, master's, and doctoral degree holders (figure 2-1; appendix table 2-1). (See sidebar "Carnegie Classification of Academic Institutions," for definitions of academic institution types.) In 2002, they awarded 81% of S&E doctoral degrees, half of the master's degrees, and 42% of the bachelor's degrees in S&E fields. Master's (or comprehensive) institutions awarded another 28% of S&E bachelor's degrees and 24% of S&E master's degrees in 2002 (appendix table 2-2).

New Institutional Forms

Certificate programs, private for-profit colleges and universities, and various forms of industrial learning centers play a small but growing role in S&E higher education. Information technology (IT) is amplifying the delivery and learning of S&E within both traditional and nontraditional institutions.

New Directions in Community Colleges

Community colleges (2-year institutions) provide access to higher education for students who may lack the academic background, language skills, or financial means to go to 4-year academic institutions, or who may simply want additional job skills (NCES 2003). They are often the first college experience for many students who are the first in their family to seek education beyond high school (Adelman 2005; NSF 2004a). Most students in community colleges do not earn formal degrees, and most are enrolled part time.

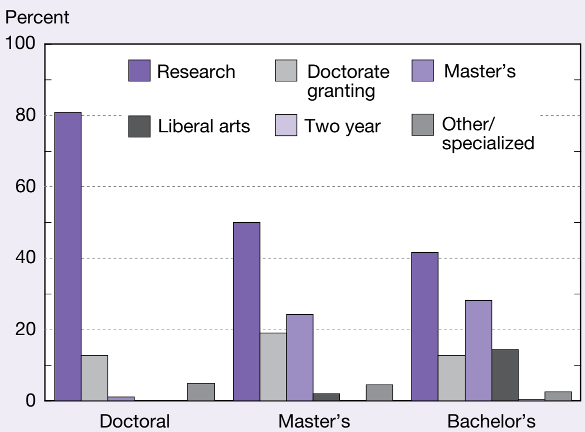
Community colleges provide the science and mathematics coursework for many K–8 teachers and high school science and mathematics teachers. New directions for community colleges include establishing baccalaureate programs in teacher education; establishing certification and associate degree programs for paraprofessionals, many with a mathematics and/or science focus (Shkodriani 2004); and establishing nondegree (alternative certification) programs for individuals already holding a baccalaureate degree who wish to earn a teaching credential in their specialty (Durdella 2003).

Community colleges are expanding their interaction with high schools and the type of degrees they offer. As part of the effort to decrease high school dropout rates and increase college attendance rates, particularly among disadvantaged students, some community colleges, particularly in California, are becoming the sites of "early college high schools." These small schools (400 students or less), situated on the campuses of community colleges, offer a curriculum that leads to students simultaneously receiving both their high school diploma and an associate of arts degree (Bill and Melinda Gates Foundation 2003). This effort is targeted at low-income, first-generation, non-English-speaking, and minority students.

Several hundred community colleges offer a bachelor's degree in some capacity, mostly in partnership with a related university. Most of these degrees are concentrated in applied fields such as protective services and information technology (IT). As of July 2004, 17 community colleges in at least 9 states offered 1 or more baccalaureate degrees. Most of these baccalaureates are in education, nursing, or IT. Of the 130 degrees listed, the preponderance was in secondary science or mathematics education (30) or in applied fields such as IT or engineering (36) with a few degrees in mathematics or the sciences (9) (American Association of State Colleges and Universities 2004). States offering teacher education baccalaureates at community colleges include Nevada, Florida, Louisiana, Minnesota, Utah, and Arkansas. Most of these states, along with Vermont, New York, and Georgia, offer baccalaureate degrees in technical subjects (American Association of Community Colleges 2004b).

Community colleges are also responsive to newly emerging science fields that have a high demand for technologists. For example, the first 2-year multidisciplinary nanoscience technology program in the United States debuted in fall 2004 at Dakota County Technical College in Rosemont, Minnesota (American Association of Community Colleges 2004a).

Figure 2-1
Distribution of bachelor's and higher S&E degrees awarded by U.S. higher education institutions, by Carnegie type: 2002



SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-2.

Science and Engineering Indicators 2006

Certificate programs have become a popular means for students to gain particular skills, for universities to be flexible in a changing environment, and for industry to upgrade the skills of its workers in emerging and rapidly changing fields. General characteristics of certificate programs are a focus on practical skills (e.g., hazardous waste management and infection control); fewer course requirements than for a degree; and, in many cases, an interdisciplinary scope (e.g., geographic information science). In 2002, about 22,300 S&E certificates were awarded in U.S. colleges and universities, up from about 4,100 in 1983 (table 2-1). Most (77%) were in computer sciences. Education units of various corporations (e.g., Microsoft, Cisco, Oracle, and Novell) also offer certificate programs.

Private for-profit institutions are growing in numbers and becoming increasingly important degree-granting institutions in certain fields. In 2002, about 2,500 private for-profit institutions in the United States accounted for about 5% of higher education enrollment (NCES 2004b, 2005b). About two-thirds of those students are enrolled in nondegree-granting institutions. However, for-profit institutions are among the top schools in the United States awarding degrees in certain fields. For example, Nova Southeastern University is among the largest awarders of

Carnegie Classification of Academic Institutions

The classification used here is the 1994 version of the Carnegie Foundation for the Advancement of Teaching. Although the classification variables reflect the early 1990s, the 1994 classification system better describes the different institutional characteristics for S&E than the subsequent 2000 version, which uses more aggregate categories. A complete revision of the classification system is currently being developed for 2005.

Research I and II universities offered a full range of baccalaureate programs and graduate education through the doctorate level, awarded 50 or more doctoral degrees a year, and received at least $15.5 million in federal research support annually.

Doctorate I and II institutions offered a full range of baccalaureate programs and graduate education through the doctorate level, but in a narrower range than research universities. They awarded at least 20 doctoral degrees annually in at least 3 disciplines; no federal research funds criteria were applied.

Master's (comprehensive I and II) institutions offered a broad range of baccalaureate programs and, generally, graduate education through the master's degree. The latter often focused on occupational or professional disciplines such as engineering or business administration. Minimum enrollment was 1,500 students.

Baccalaureate (liberal arts I and II) colleges are mostly 4-year institutions focused on awarding bachelor's degrees. A small number of highly selective ones awarded more than 40% of their baccalaureate degrees in liberal arts and science fields.

Associate of arts (2-year) colleges offered certificate or degree programs through the associate degree level and (with a few exceptions) offered no bachelor's degrees.

Professional and other specialized schools offered various degrees including doctorates, but they specialized in areas such as religious training; medicine and health; law; engineering and technology; business and management; art, music, and design; or education. This category also included corporate-sponsored institutions.

doctoral degrees in psychology and education; DeVry Institute of Technology, Strayer College, and the University of Phoenix are among the largest awarders of bachelor's degrees in computer sciences; and the University of Phoenix is among the top awarders of master's degrees in business.

Various types of industrial learning centers, including corporate "universities," independent nonprofit institutions, and for-profit and nonprofit subsidiaries of institutions constitute another new institutional form delivering education in the United States. From 1988 to 2001, the number of corporate universities grew from 400 to 2,000 (National Research Council 2002). Most primarily offer noncredit, nondegree courses narrowly targeted at retraining the workforce and other company needs. However, some large industries have internal training at a higher education level in engineering and design, for example, Motorola University contracts with 1,200 faculty worldwide who teach business and engineering.

Table 2-1
Certificates awarded by U.S. academic institutions, by field: 1983–2002

Year	S&E	Agricultural sciences	Computer sciences	Engineering	Physical/ biological/ mathematical sciences	Social/ behavioral sciences
1983	4,126	943	2,657	94	136	296
1985	4,844	724	3,346	271	138	365
1987	5,089	422	3,005	236	481	945
1989	5,500	428	2,642	1,011	374	1,045
1991	8,117	659	5,551	364	415	1,128
1993	13,808	3,617	6,986	684	610	1,911
1995	15,235	3,057	8,073	799	861	2,445
1997	9,556	293	5,523	459	1,210	2,071
1998	9,915	305	6,469	593	706	1,842
2000	15,864	241	12,628	499	586	1,910
2001	19,889	802	15,691	540	648	2,208
2002	22,266	1,174	17,138	706	659	2,589

NOTE: Data not available for 1999.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2006

Independent nonprofit institutions also provide training geared specifically to corporate needs. These institutions offer credit courses and degree programs through IT and distance education. Institutions such as the Western Governors University and the United States Open University are recently formed examples. Since 1984, the National Technological University (NTU), a consortium of some 540 institutions, has been developing and offering courses and degree programs for engineering-oriented companies. The programs target engineering professionals interested in obtaining master's degrees in 1 of 18 engineering, technical, or business areas. All 1,300 academic courses offered by NTU are supplied by 52 leading engineering universities, including 25 of the top engineering schools in the country (National Research Council 2002).

For-profit and nonprofit subsidiaries of institutions and partnerships between 4-year institutions and private companies comprise another type of industry learning center. Duke Corporate Education and eCornell are examples of for-profit or nonprofit subsidiaries of postsecondary education institutions. Both offer credit and noncredit courses to individuals and corporate universities. Many of their courses are offered online and draw from a worldwide student base (Blumenstyk 2003). Motorola has partnerships with traditional institutions for sharing technology, faculty, and facilities. For example, Motorola is part of a doctoral program at the International Institute of Information Technology (formerly the Indian Institute of Information Technology) in Hyderabad, India, and degree programs at Morehouse College in Atlanta and Roosevelt University in Chicago (Wiggenhorn 2000).

Higher Education Enrollment in the United States

Recent higher education enrollments reflect the expanding U.S. college-age population. This section examines trends in undergraduate and graduate enrollment by type of institution, field, and demographic characteristics. It also examines graduate financial support patterns and data on retention rates. For information on enrollment rates of high school seniors, see "Transition to Higher Education" in chapter 1.

Overall Enrollment

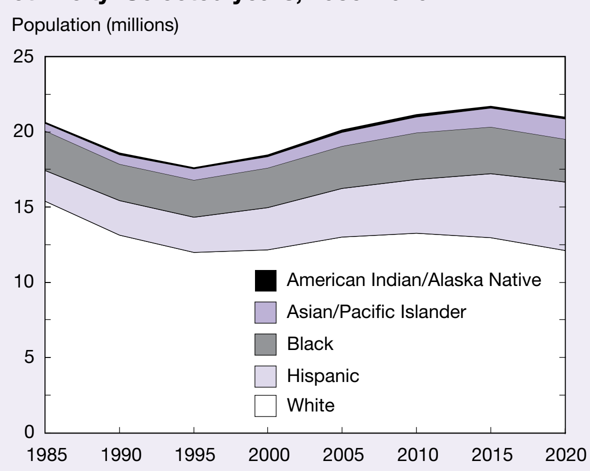
Over the past two decades, enrollment in U.S. institutions of higher education rose fairly steadily, from 12.6 million students in 1983 to 15.7 million in 2001 (the last year of available data), despite declines in the college-age population during much of that period (appendix tables 2-3 and 2-36). Of these, more than 6 million students (about 38% of all students enrolled in higher education institutions in the United States) were enrolled in 2-year institutions in 2001. The next two largest segments, research I universities and master's-granting I (or comprehensive) universities, together accounted for another 34% (5.3 million). (See sidebar "Carnegie Classification of Academic Institutions" for definitions of the types of academic institutions.)

Enrollment in higher education is projected to increase in the next decade because of increases in the college-age population. According to U.S. Census Bureau projections, the number of college-age (ages 20–24) individuals is expected to grow from 18.5 million in 2000 to 21.7 million by 2015, then decrease slightly to 21.0 million by 2020 (figure 2-2 and appendix table 2-4).

Increased enrollment in higher education is projected to come from minority groups, particularly Asians/Pacific Islanders and Hispanics. From 2000 to 2015, the Asian/Pacific Islander and Hispanic college-age populations are projected to increase by more than 50%, while the black and American Indian/Alaska Native college-age populations are projected to rise by 19% and 15%, respectively. The white college-age population is projected to increase slightly through 2010 and then decline (figure 2-2).

Changes in the demographic composition of the college-age population as a whole and increased enrollment rates of some racial/ethnic groups have contributed to changes in the demographic composition of the higher education student population in the United States.[1] From 1992 to 2001, overall enrollment increased by 7%, while underrepresented minority enrollment grew by 31% and Asian/Pacific Islander enrollment by 32%. Enrollment of foreign students (i.e., students on temporary visas) grew by 25% during that period. Almost half (47%) of underrepresented minority students and 42% of Asian/Pacific Islander students were enrolled in 2-year institutions compared with 36% of white students and 18% of foreign students.[2] Underrepresented minority students were less likely than other groups to be enrolled

Figure 2-2
U.S. population ages 20–24 years, by race/ethnicity: Selected years, 1985–2020



SOURCE: U.S. Census Bureau, Population Division, 1990 Census; and Population Projection Program, *Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100*. See appendix table 2-4.

Science and Engineering Indicators 2006

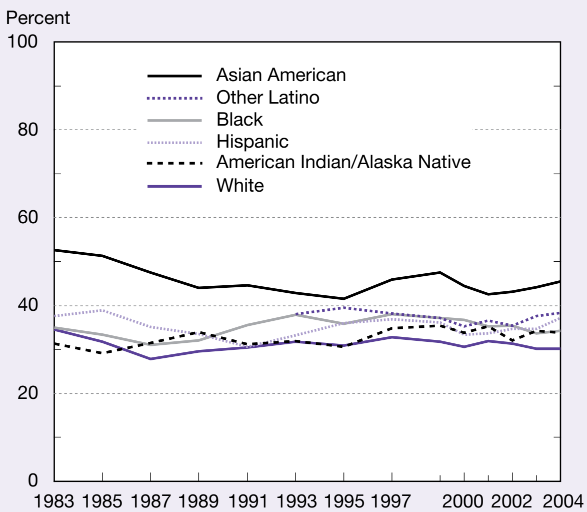
in research institutions (10% versus 20% of whites, 26% of Asians/Pacific Islanders, and 39% of foreign students.) For a breakout of enrollment trends in the 1990s by institutional type, race/ethnicity, and citizenship, see appendix table 2-5.

Undergraduate Enrollment in S&E

Freshmen Intentions to Major in S&E

Since 1972, the annual Survey of the American Freshman, National Norms, administered by the Higher Education Research Institute at the University of California at Los Angeles, has asked freshmen at a large number of universities and colleges about their intended majors. The data have provided a broadly accurate picture of degree fields several years later.[3] For at least the past two decades, about one-third of all freshmen planned to study S&E. In 2004, about one-third of white, black, Hispanic, and American Indian/Alaska Native freshmen and 46% of Asian/Pacific Islander freshmen reported that they intended to major in S&E (figure 2-3). The proportions planning to major in S&E were higher for men in every racial/ethnic group (appendix table 2-6). For most racial/ethnic groups, about 9%–14% planned to major in social/behavioral sciences, about 9% in engineering, about 8% in biological/agricultural sciences, 2%–5% in computer sciences, 2% in physical sciences, and 1% in mathematics or statistics. Higher proportions of Asian/Pacific Islander freshmen than of those from other racial/ethnic groups planned to major in biological/agricultural sciences (16%) and engineering (15%).

Figure 2-3
Freshmen intending S&E major, by race/ethnicity: Selected years, 1983–2004



NOTE: Data on "Other Latino" not collected before 1992.

SOURCE: Higher Education Research Institute, University of California at Los Angeles, Survey of the American Freshman: National Norms, special tabulations (2005).

Science and Engineering Indicators 2006

The demographic composition of students planning S&E majors has become more diverse over time. Women constituted 38% in 1983, rising to 45% in 2004. White students declined from 85% in 1983 to 72% in 2004. On the other hand, Asian/Pacific Islander students increased from 3% to 12%, Hispanic students increased from 1% to 8%, and American Indian/Alaska Native students increased from 1% to 2% (appendix table 2-7). Black students made up 10% of freshmen intending to major in S&E both in 1983 and in 2004.

In 2002, 20% of the respondents planning an S&E major reported needing remedial work in mathematics, and nearly 10% reported needing remediation in the sciences. These percentages are slightly higher than those of 1984 and vary by field and sex (appendix table 2-8). Fewer of those intending to major in mathematics, computer sciences, physical sciences, or engineering reported a need for remediation than did those intending to major in the social/behavioral or biological/agricultural sciences or in non-S&E fields. Within S&E fields and non-S&E fields, proportionately fewer male freshmen than female freshmen reported a need for remediation in mathematics or sciences. See "Transition to Higher Education" in chapter 1 for additional information on need of freshmen for remedial education.

Foreign Undergraduate Enrollment

The number of foreign undergraduates enrolled in U.S. academic institutions in all fields decreased almost 5% from academic year 2002–03 to 2003–04, the second consecutive decline after record increases during the 1990s. Decreases in foreign enrollments in recent years have been attributed to increased opportunity for higher education in the home country, competition from other countries for foreign students, rising U.S. tuition, and difficulties in obtaining U.S. visas (Institute of International Education 2004). (See sidebar "Price of Undergraduate Education.") Declines in particular fields may also be due to declining job opportunities in those fields. Among both undergraduate and graduate students, the number of foreign engineering students dropped 1% and the number of foreign computer sciences students dropped 7%. Other S&E fields, particularly the social sciences at 18%, experienced increases. Both physical and life sciences each registered small increases of 1%, and agricultural sciences rose 0.3%.

Japan and South Korea accounted for the largest numbers of foreign undergraduates in the United States in 2004 (appendix table 2-9). Although the number of undergraduates from China, Japan, and Taiwan was lower in 2004 than in 1999, enrollment of students from a number of other countries, including South Korea, Canada, India, and Mexico, increased.

Enrollment Trends in Engineering

For the most part, undergraduate enrollment data are not available by field. However, because engineering programs generally require students to declare a major in the first year of college, engineering enrollment data can serve as early indicators of both future undergraduate engineering degrees

Price of Undergraduate Education

Tuition increases at colleges and universities in the United States have outpaced inflation for the past two decades, although the net price to students has not increased as much as tuition. After adjusting for inflation, tuition and fees for in-state students at public 4-year colleges rose 51% in the 10-year period ending in the 2004–05 academic year (College Board 2004). Prices rose more at public 4-year colleges than they did at private 4-year or public 2-year colleges. Average tuition and fees rose the most in the Midwest and Southwest, and the least in the West and New England. (See chapter 8 for state indicators on average undergraduate tuition and state student aid expenditures.) The College Board's annual Survey of Colleges found that the rate of growth slowed in the 2004–05 academic year, when the price of attending a public 4-year college rose 10% compared with 14% in the 2003–04 academic year.

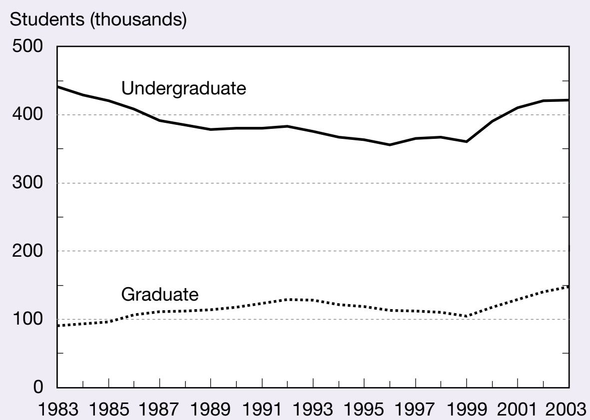
According to the U.S. Department of Education, National Center for Education Statistics, the single most important factor in the rise of tuition at public 4-year colleges and universities is the decline in state appropriations for higher education. Over the past two decades, the percentage of public institutions' revenue from state funding has decreased, thus the percentage from tuition and fees increased. State appropriations per full-time equivalent student at public higher education institutions declined in the late 1980s, rose through the end of the 1990s, and declined in recent years (College Board 2004). In FY 2005, total state appropriations for higher education rose 3.8% over FY 2004, slightly outpacing inflation (Hebel 2004). At private 4-year institutions, tuition increases were found to be related to declines in nontuition revenue (e.g., endowments), and increases in student aid and faculty compensation (NCES 2002).

Although tuition increased dramatically over the past decade, the net price to students did not increase as much and varied by family income. Students typically do not pay the full tuition amount, which averaged $5,132 for in-state students at public 4-year colleges and $20,082 for students at private 4-year colleges during the 2004–05 academic year. Student aid averaged $3,300 at public 4-year institutions and $9,400 at private 4-year institutions, making net tuition and fees about $1,800 at public 4-year institutions and about $10,700 at private 4-year institutions (College Board 2004). The net price of college for low-income students did not increase over the past decade, and the net price of college, after accounting for grants and loans, did not increase for middle-income students. Middle-income students, however, subsequently had higher levels of debt from educational loans. From 1993 to 2004, the percentage of degree recipients who borrowed and their median amount of debt increased (American Council on Education 2005). Increases in undergraduate debt for science and engineering students could potentially affect rates of graduate enrollment. See the sections later in this chapter titled "Retention in S&E" for graduate enrollment rates and "Undergraduate and Graduate Debt of S&E Doctorate Recipients" for data on trends in debt for undergraduate and graduate S&E education of doctorate recipients.

and student interest in an engineering career. The Engineering Workforce Commission administers an annual fall survey that tracks enrollment in undergraduate and graduate engineering programs (Engineering Workforce Commission 2004).

Undergraduate engineering enrollment declined through most of the 1980s and 1990s, then rose from 2000 through 2003.[4] From a 1983 peak of approximately 441,000 students, undergraduate engineering enrollment declined to about 361,000 students by 1999 before rebounding to about 422,000 in 2003 (figure 2-4; appendix table 2-10). Graduate engineering enrollment rose to about 129,000 in 1992, declined to approximately 105,000 by 1999, then soared to nearly 148,000 by 2003 (appendix table 2-11).

Figure 2-4
U.S. engineering enrollment, by level: 1983–2003



NOTE: Enrollment data include full- and part-time students.

SOURCE: Engineering Workforce Commission, *Engineering & Technology Enrollments, Fall 2003,* American Association of Engineering Societies (2004).

Science and Engineering Indicators 2006

Retention in S&E

The National Science Foundation (NSF) National Survey of Recent College Graduates tracks retention in S&E as measured through further S&E education and entry into S&E occupations. About 28% of those who graduated with an S&E bachelor's degree in 2001 or 2002 were continuing

in S&E graduate study (12%) or S&E employment (16%) in 2003. Retention rates in S&E declined from the 2001 and 1995 surveys (appendix table 2-12). However, many of those going into non-S&E occupations found employment in occupations with strong S&E components (see “U.S. S&E Labor Force Profile” in chapter 3).

Percentages of those going on for advanced study in S&E were higher for those with a high grade point average (GPA). About 18% of those with a 3.75–4.00 undergraduate GPA continued to study S&E. In contrast, relatively few (7%) of students with less than a 2.75 GPA continued to study S&E.

The retention rate in S&E after completion of a master’s degree was higher than the rate after completion of a bachelor’s degree. Around 44% of those who earned an S&E master’s degree in 2001 or 2002 were continuing in S&E in 2003, either in school (15%) or in employment (29%). Overall, the S&E retention rate after a master’s degree in 2003 was lower than the rate in either 1995 or 2001, with both a smaller percentage continuing advanced studies and a smaller percentage employed in S&E fields (appendix table 2-12).

Graduate Enrollment in S&E

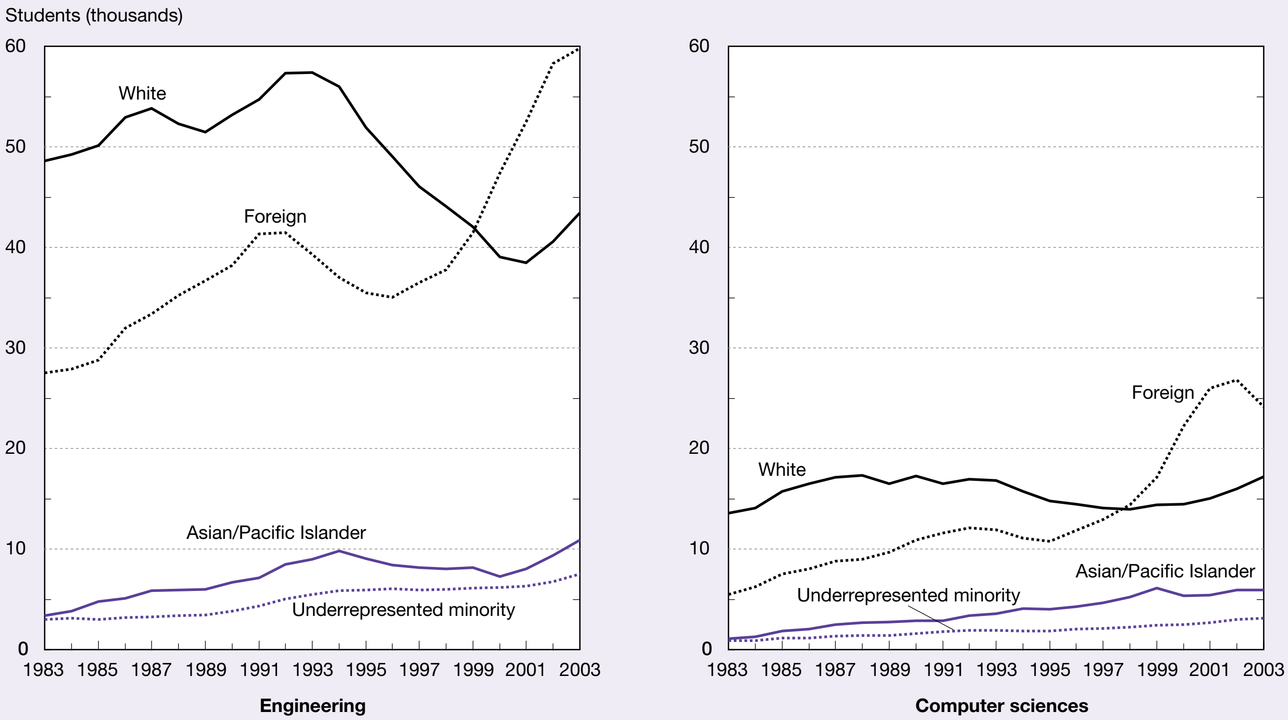
Graduate S&E educational institutions are a major source of both the high-skilled workers of the future and of the research needed for a knowledge-based economy. This section presents data on continuing key trends in graduate S&E enrollment, including trends in first-time enrollment of foreign students after September 11, 2001. Information is also included on patterns and trends in financial support for graduate education and in student debt.

Enrollment by Field

S&E graduate enrollment in the United States reached a new peak of 566,800 in fall 2003. Following a long period of growth that began in the 1970s, graduate enrollment in S&E declined in the latter half of the 1990s before rebounding in the past several years. Graduate enrollment in engineering and in life sciences drove most of the recent growth, although enrollment did increase in almost all major science fields.[5] Computer sciences enrollment rose rapidly from the mid-1990s through 2002 but declined in 2003. The increase in computer science through 2002 and the continuing increase in engineering mainly reflect an increase in the number of foreign graduate students in those fields (figure 2-5).

The number of full-time students enrolled for the first time in S&E graduate departments offers a good indicator of developing trends. It declined in the mid-1990s in all major S&E fields but increased in most fields in the late 1990s and early 2000s (appendix table 2-13). Between 2000 and 2003, first-time full-time S&E enrollment grew 14%. Growth was greatest in physical sciences; earth, atmospheric, and ocean sciences; mathematics; and social and behavioral sciences.

Figure 2-5
Graduate enrollment in computer sciences and in engineering, by citizenship and race/ethnicity: 1983–2003



NOTES: Foreign includes temporary residents only. Race/ethnicity includes U.S. citizens and permanent residents. Underrepresented minority includes black, Hispanic, and American Indian/Alaska Native.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-15.

Science and Engineering Indicators 2006

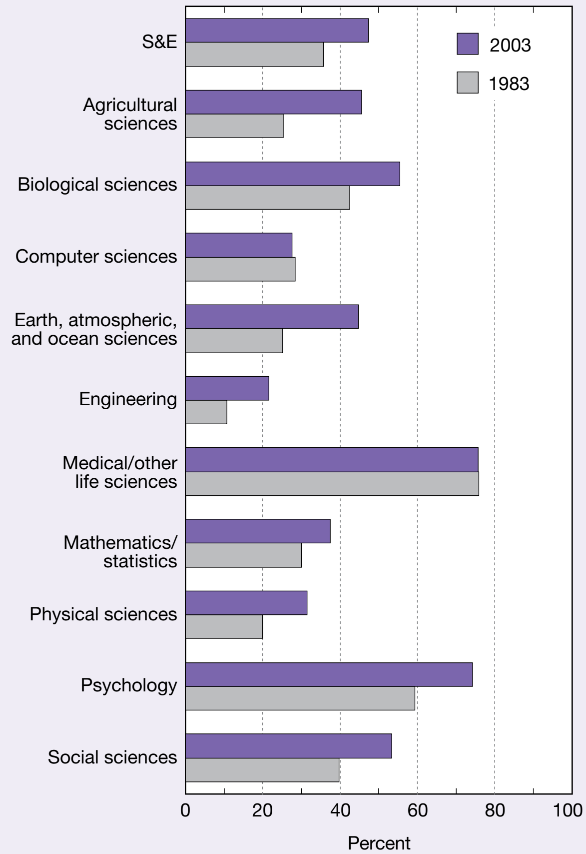
In only a few fields, such as computer sciences (down 3%) and materials engineering (down 5%), did first-time full-time graduate enrollment decline during the period.

Enrollment by Sex and Race/Ethnicity

The recent increase in S&E graduate enrollment overall occurred across all major demographic groups: women, minorities, and white men. The number of women enrolling in all S&E graduate programs has increased for the past two decades except for a decline in computer sciences in 2003. In contrast, the number of male S&E graduate students declined from 1993 through the end of the decade before increasing in recent years (appendix table 2-14).

The long-term trend of women's rising proportions in S&E fields also continued. Women made up 36% of S&E graduate students in 1983 and 47% in 2003, although large variations among fields persist. In 2003, women constituted the majority of graduate enrollment in psychology (74%), medical/other life sciences (76%), biological sciences (55%), and social sciences (53%). They constituted considerable proportions of graduate students in mathematics (37%), chemistry (39%), and earth, ocean, and atmospheric sciences (45%). Their percentage in computer sciences (28%) and engineering (22%) remains smaller (figure 2-6; appendix table 2-14).

Figure 2-6
Female U.S. graduate S&E enrollment, by field: 1983 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-14.

Science and Engineering Indicators 2006

The proportion of underrepresented minority students in graduate S&E programs increased from about 6% in 1983 to about 11% in 2003 (table 2-2). Increases occurred in all major science fields between 1983 and 2003. Only in engineering have enrollment increases apparently stalled in recent years: underrepresented minorities have been 6% of graduate enrollment since 1995 (appendix table 2-15). In 2003, blacks, Hispanics, and American Indians/Alaska Natives as a group made up about 6% of graduate enrollment in most S&E fields (engineering; mathematics; physical sciences; earth, atmospheric, and ocean sciences; and computer sciences), 17% in social sciences, and 19% in psychology.

The number of white S&E graduate students decreased from 1994 to 2001 in most S&E fields, then increased through 2003, whereas the number of underrepresented minority students has increased every year since 1985. The long-term rise in the number of underrepresented minority graduate students occurred in most S&E fields, with the exceptions of engineering and mathematics. In those two fields, underrepresented minority enrollment plateaued in the 1990s before rising again from 2000 through 2003. The number of Asian/Pacific Islander S&E graduate students increased every year since 1983, with the exception of 2000. Increases occurred in most science fields except for a drop in physical sciences and engineering enrollment in the 1990s. Asians/Pacific Islanders accounted for about 7% of S&E graduate enrollment in 2003 (appendix table 2-15).

Foreign Student Enrollment

Foreign graduate student enrollment in S&E grew from 73,200 in 1983 to 154,400 in 2003. For all S&E fields combined, the proportion of foreign students increased from 19% to 27% over the period (appendix table 2-15). Foreign enrollment was highest in engineering (47%), computer sciences (45%), physical sciences (41%), and mathematical sciences (38%).

First-time full-time enrollment of foreign S&E graduate students offers a mixed picture. It declined 5% in fall 2002, the first full academic year since September 11, 2001. Declines continued in fall 2003 (an 8% decrease in S&E overall) but were concentrated mainly in engineering (down 12%) and in computer sciences (down 23%), fields heavily favored by foreign students. First-time full-time foreign enrollment increased in physical sciences (up 9%) and in psychology (up 10%) and remained stable in the other major science fields in 2003 (appendix table 2-16). These trends may indicate developing trends in total graduate enrollment in future years. Foreign students' share of first-time full-time graduate enrollment dropped from 35% to 29% between 2000 and 2003, with most of the decrease in computer science (from 71% to 52%) and engineering (from 61% to 50%) (figure 2-7).

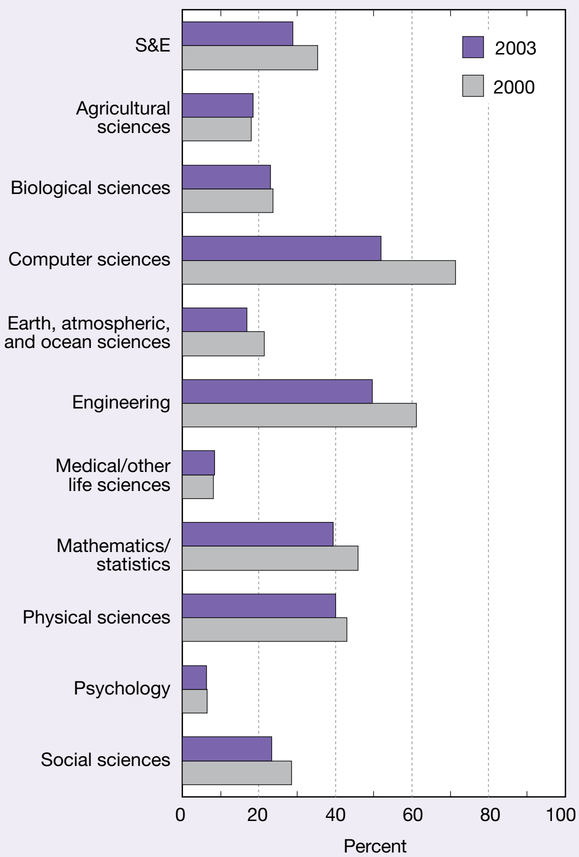
Table 2-2
Underrepresented minority share of S&E graduate enrollment, by field: 1983 and 2003

	1983		2003	
Field	Number	Percent	Number	Percent
S&E	24,099	6.2	60,298	10.6
Engineering	2,999	3.3	7,492	5.9
Science	21,100	7.1	52,806	12.0
Natural sciences	9,198	4.9	27,277	9.3
Agricultural sciences	395	3.1	1,035	7.8
Biological sciences	2,179	4.8	5,847	9.0
Earth, atmospheric, and ocean sciences	365	2.4	817	5.6
Computer sciences	875	3.8	3,148	5.9
Mathematics/statistics	764	4.4	1,287	6.6
Medical/other life sciences	3,437	7.9	13,028	14.1
Physical sciences	1,183	4.0	2,115	6.2
Social/behavioral sciences	11,902	10.6	25,529	17.4
Psychology	3,829	9.4	9,674	18.6
Social sciences	8,073	11.3	15,855	16.7

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2006

Figure 2-7
Foreign student share of U.S. first-time full-time graduate S&E enrollment, by field: 2000 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-16.

Science and Engineering Indicators 2006

According to data collected by the Institute of International Education, the overall number of foreign graduate students in all fields increased 2.4% from academic year 2002–03 to 2003–04. Graduate enrollment of students from India more than doubled between 1999 and 2004 and enrollment of students from China, South Korea, Taiwan, and Canada also increased (appendix table 2-17.) (See section "Global Higher Education in S&E" for degrees granted and enrollment of foreign students in other countries.)

Financial Support for S&E Graduate Education

About one-third of S&E graduate students are self-supporting; that is, they rely primarily on loans, their own funds, or family funds for financial support. The other two-thirds receive primary financial support from a wide variety of sources: the federal government, university sources, employers, nonprofit organizations, and foreign governments.

Support mechanisms include research assistantships (RAs), teaching assistantships (TAs), fellowships, and traineeships. Sources of funding include federal agency support, nonfederal support, and self-support. Nonfederal support includes state funds, particularly in the large public university systems; these funds are affected by the condition of overall state budgets. (See sidebar "Definitions and Terminology of Support.") Most graduate students, especially those who pursue doctoral degrees, are supported by more than one source or mechanism during their time in graduate school, and some receive support from several different sources and mechanisms in a given academic year. Self-support is derived from any loans obtained (including federal loans) or from personal or family contributions.

Other than self-support, RAs are the most prevalent primary mechanism of support for S&E graduate students. The

Definitions and Terminology of Support

Mechanisms of support: These may come from federal or nonfederal sources.

- Research assistantships (RAs) are given to students whose assigned duties are primarily research.
- Teaching assistantships (TAs) are given to students whose assigned duties are primarily teaching.
- Fellowships are competitive awards (often from a national competition) given to students for financial support of their graduate studies.
- Traineeships are educational awards given to students selected by an institution.

Other mechanisms of support include work-study programs, business or employer support, and support from foreign governments not in the form of a previously mentioned mechanism.

Sources of support: Except for self-support, funds may take the form of any mechanism; institutional support may take the form of tuition remission.

- Federal support is provided by federal agencies, chiefly in the form of RAs and traineeships. It also includes such items as tuition paid by the U.S. Department of Defense for members of the U.S. Armed Forces.
- Nonfederal support is provided by an institution of higher education, state and local governments, foreign sources, nonprofit institutions, or private industry.

percentage of S&E graduate students supported primarily by RAs increased in the late 1980s, rising from about 22% in the early 1980s to roughly 27%–29% of S&E graduate support from 1988 through 2003. Although the number of S&E graduate students relying primarily on fellowships, traineeships, and TAs rose over the past two decades, the percentage of students supported by these mechanisms stayed flat or declined. In 2003, 18% of S&E graduate students were primarily supported through TAs and 13% were primarily supported through either traineeships or fellowships. Self-support was the primary mechanism of support for roughly one-third of S&E graduate students over the past two decades (appendix table 2-18).

Primary mechanisms of support differ widely by S&E field of study. For example, in 2003, full-time students in physical sciences were supported mainly through RAs (44%) and TAs (39%). RAs also were important in agricultural sciences (58%), biological sciences (42%), and engineering (41%). In mathematics, however, primary student support is through TAs (54%) and self-support (19%). Full-time students in the social and behavioral sciences are mainly self-supporting (45%) or receive TAs (20%) (appendix table 2-19).

The federal government served as the primary source of support for about 20% of full-time S&E graduate students in 2003 (appendix table 2-20). This support was mostly in the form of RAs at 70%, up from 61% two decades earlier. The share of federally supported S&E graduate students receiving traineeships declined from 19% in 1983 to 12% in 2003. For students supported through nonfederal sources in 2003, TAs were the most prominent mechanism (40%), followed by RAs (32%) (appendix table 2-18).

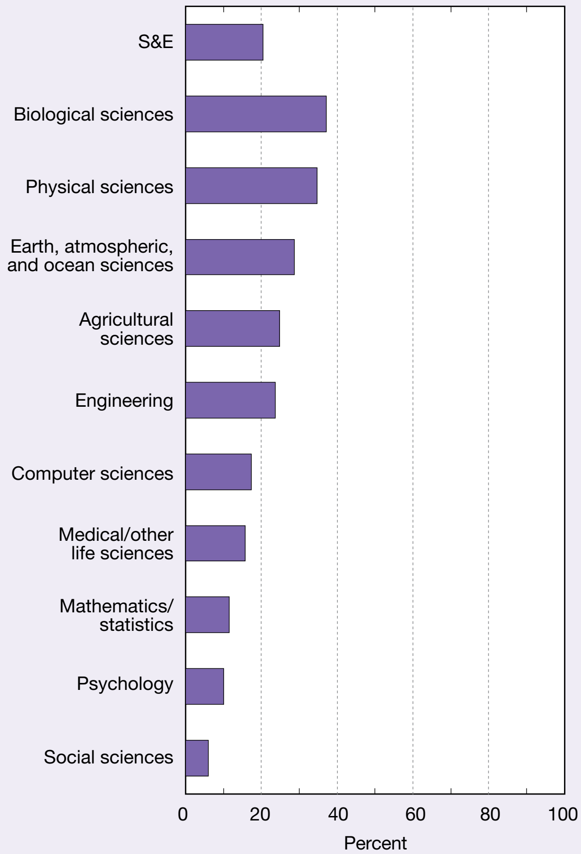
The federal government plays a substantial role in supporting S&E graduate students in some mechanisms and fields and a smaller role in others. For example, in 2003, the federal government funded 67% of S&E traineeships, 50% of RAs, and 22% of fellowships. Federal support reaches relatively more students in the physical sciences; earth, ocean, and atmospheric sciences; agricultural sciences; biological sciences; and engineering. However, relatively few students in mathematics, computer sciences, social sciences, psychology, and medical/other life sciences receive federal support (figure 2-8). Appendix table 2-20 gives detailed information by field and mechanism. (See section "Expenditures by Field and Funding Source" in chapter 5 for information on federal academic research and development funding by discipline.)

The National Institutes of Health (NIH) and NSF support most of the full-time S&E graduate students whose primary support comes from the federal government. In 2003, they supported about 24,300 and 19,300 students, respectively. Trends in federal agency support of graduate students show considerable increases from 1983 to 2003 in the proportion of students funded (NIH, from 23% to 30%; NSF, from 20% to 24%). Support from the U.S. Department of Defense declined during the 1990s from 15% to 11%, offsetting to some extent the increasing percentage that received NSF support (appendix table 2-21).

For doctoral degree students, notable differences exist in primary support mechanisms by sex, race/ethnicity, and citizenship. In 2003, male U.S. citizens were more likely to have been supported by RAs (29%) and female U.S. citizens were more likely to have supported themselves from personal sources of funds (27%). Among U.S. citizens, whites and Asians/Pacific Islanders were more likely than other racial/ethnic groups to have had primary support from RAs (26% and 28%, respectively), and underrepresented minorities depended more on fellowships (38%). The primary source of support for foreign doctoral degree students was an RA (46%) (appendix table 2-22).

U.S. citizen white and Asian/Pacific Islander men, as well as foreign doctoral degree students, are more likely than U.S. citizen white and Asian/Pacific Islander women, and underrepresented minority doctoral degree students, to receive doctorates in engineering and physical sciences, fields largely supported by RAs. Women and underrepresented minorities are more likely than other groups to receive doctorates in social sciences and psychology, fields in which

Figure 2-8
Full-time S&E graduate students with primary support from federal government, by field: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-20.

Science and Engineering Indicators 2006

self-support is prevalent. Differences in type of support by sex, race/ethnicity, or citizenship remain, however, even accounting for field of doctorate (NSF 2000a).

The amount of funding received by graduate students varies widely by source of support (e.g., federal, nonfederal), mechanism of support (e.g., RA, TA), field of study, type and location of school (public/private, urban/rural), and length of contract (12-month or 9- or 10-month). For example, one study showed that average stipends for history TAs on a 9- or 10-month contract were about $11,200 and those for biology RAs were about $19,000 for 12-month contracts (Smallwood 2004). Benefits associated with support mechanisms vary as well. Tuition and fees are waived for most, but not all, TAs and RAs. Most federally funded graduate student fellowship programs stipulate that institutions waive tuition and fees for awardees (NSF 2004c). Most (77%) institutionally supported TAs and RAs include health insurance coverage for students, and a few (21%) include coverage for dependents as well (Smallwood 2004).

Undergraduate and Graduate Debt of S&E Doctorate Recipients

At the time of doctoral degree conferral, about one-fourth of S&E doctorate recipients have some undergraduate debt and about one-third owe money directly related to graduate education.[6] In 2003, 27% of S&E doctorate recipients reported having undergraduate debt and 34% reported having graduate debt. For some, debt levels were high, especially for graduate debt: 2% reported high levels (more than $35,000) of undergraduate debt and 13% reported graduate debt of more than $35,000 (appendix table 2-23).

Levels of debt vary widely by doctorate fields. High levels of graduate debt were most common among doctorate recipients in psychology, social sciences, agricultural sciences, and medical/other health sciences. Psychology doctorate recipients are most likely to report graduate debt and high levels of debt. One-third of psychology doctoral degree recipients compared with 13% of all S&E doctoral degree recipients in 2003 reported graduate debt of more than $35,000.[7] Doctorate recipients in biological sciences; computer sciences; earth, atmospheric, and ocean sciences; engineering; mathematics; and physical sciences were least likely to report graduate debt.

Higher Education Degrees

S&E degrees accounted for almost two-thirds of all doctoral degrees and almost one-third of all bachelor's degrees awarded in 2002. However, S&E fields account for relatively few associate's or master's degrees. Both the number of degrees overall and the number in S&E fields have been increasing over the past two decades. For information on the labor market conditions for recent S&E graduates, see "Labor Market Conditions for Recent S&E Graduates" in chapter 3 (S&E labor force) and "Trends in Academic Employment of Doctoral Scientists and Engineers" in chapter 5 (academic research and development).

S&E Associate's Degrees

Community colleges are often an important and relatively inexpensive gateway for students entering higher education. Associate's degrees, largely offered by 2-year programs at community colleges, are the terminal degree for some people, but others continue their education at 4-year colleges or universities and subsequently earn higher degrees. About 13% of all associate's degrees are awarded in S&E or engineering technology.

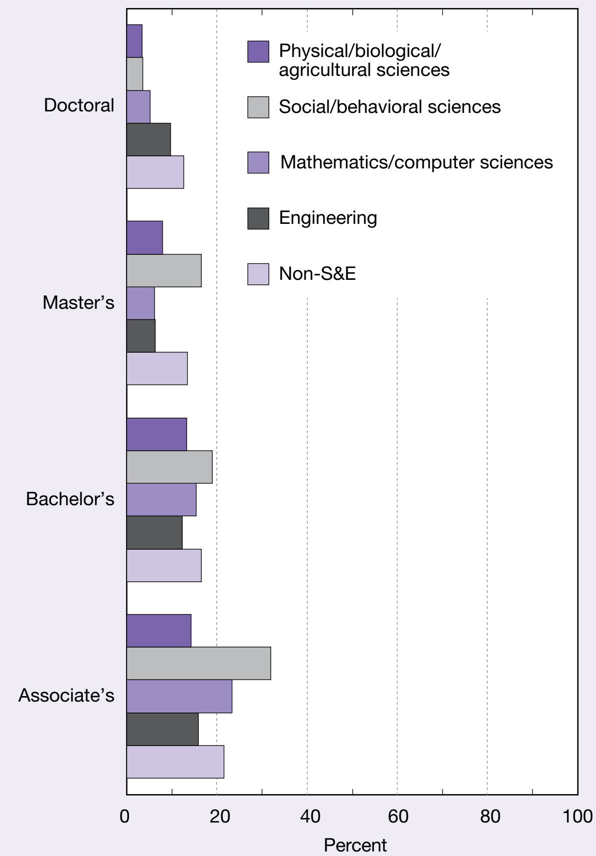
S&E associate's degrees from all types of academic institutions rose from 23,800 in 1983 to 42,200 in 2002. The increase in the late 1990s and the early 2000s was mainly attributed to computer sciences, which represented 64% of all S&E associate's degrees by 2002. In contrast, the number of associate's degrees awarded in engineering decreased. Degrees earned in engineering technology (not included in S&E degree totals because of their practice-focused nature)

declined from 51,300 in 1983 to 31,600 in 2002 (appendix table 2-24).

Women earned 45% of S&E associate's degrees in 2002, the same percentage they earned in 1983, and less than their percentage of S&E bachelor's degrees (51%). As is the case with men, computer sciences account for the majority of S&E associate's degrees earned by women (appendix tables 2-24 and 2-26).

Trends in the number of associate's degrees earned by students' race/ethnicity are shown in appendix table 2-25.[8] Students from underrepresented groups earn a considerably higher proportion of associate's degrees than they do of bachelor's or more advanced degrees (figure 2-9). In 2002, they earned 32% of associate's degrees in social and behavioral sciences and 23% in mathematics and computer sciences. The percentage of computer sciences associate's degrees earned by these students has almost doubled since 1983.

Figure 2-9
Underrepresented minority share of S&E degrees, by degree level and field: 2002 or 2003



NOTES: Doctoral degrees are 2003 data; other degrees are 2002 data. Underrepresented minority includes black, Hispanic, and American Indian/Alaska Native.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-25, 2-27, 2-29, and 2-31.

Science and Engineering Indicators 2006

S&E Bachelor's Degrees

The baccalaureate is the most prevalent degree in S&E, accounting for 77% of all degrees awarded. S&E bachelor's degrees have consistently accounted for roughly one-third of all bachelor's degrees for the past two decades. Except for a brief downturn in the late 1980s, the number of S&E bachelor's degrees has risen steadily, from 317,600 in 1983 to 415,600 in 2002 (appendix table 2-26).

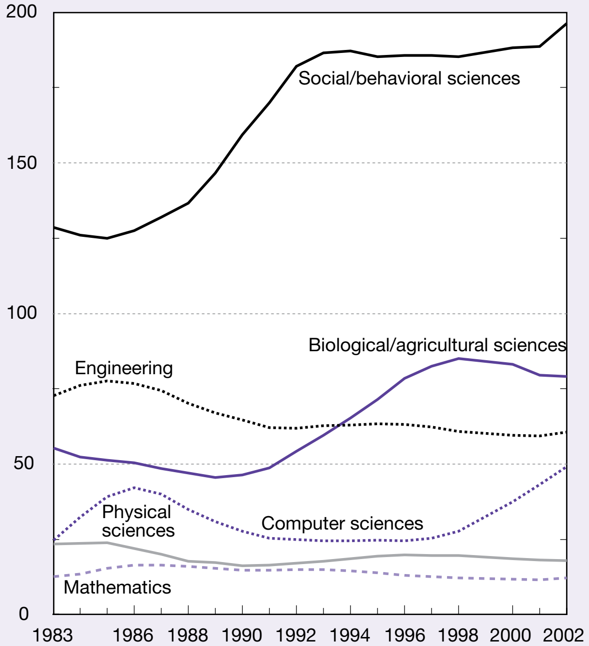
Trends in the number of S&E bachelor's degrees vary widely among fields (figure 2-10). The number of bachelor's degrees earned in engineering peaked in 1985, then dropped before leveling off in the 1990s. Bachelor's degrees in biological and agricultural sciences steadily increased in the 1990s before declining slightly in the 2000s. The number of social and behavioral sciences degrees awarded has been increasing since the mid-1990s. The number of bachelor's degrees earned in computer sciences dropped through the mid-1990s, then increased sharply from 1998 to 2002 to reach a new peak (appendix table 2-26).

S&E Bachelor's Degrees by Sex

Women have outnumbered men in undergraduate education since 1982 and earned 58% of all bachelor's degrees in 2002. They have earned at least half of all S&E bachelor's degrees since 2000. Within S&E, men and women tend to study different fields. Men earned a majority of bachelor's degrees awarded in engineering, computer sciences, and physical sciences (79%, 73%, and 57%, respectively). Women earned more than half of the bachelor's degrees in psychology (78%), biological/agricultural sciences (59%), and social sciences (55%), and close to half in mathematics (47%) (figure 2-11; appendix table 2-26). The share of bachelor's degrees awarded to women increased in almost all major S&E fields during the past two decades. One notable exception, however, is computer sciences: in this field, the number of awards dropped for both men and women from the mid-1980s to the mid-1990s, then increased thereafter. The earlier decline for women was greater than that for men, and the subsequent increase for women was less than that for men. From 1983 through 2002, the proportion of computer sciences bachelor's degrees awarded to women dropped from 36% to 27%.

The number of bachelor's degrees awarded to women rose from 1983 through 2002 in all fields and in S&E as a whole, with a brief drop in numbers of engineering and natural sciences degrees in the late 1980s and early 1990s. In contrast, the number of bachelor's degrees awarded to men in all fields and in S&E plateaued in the 1990s but increased in 2002. Within S&E, the number of engineering, physical sciences, and social and behavioral sciences degrees awarded to men dropped in the 1990s, whereas the number of bachelor's degrees in biological sciences generally increased.[9]

Figure 2-10
S&E bachelor's degrees, by field: 1983–2002

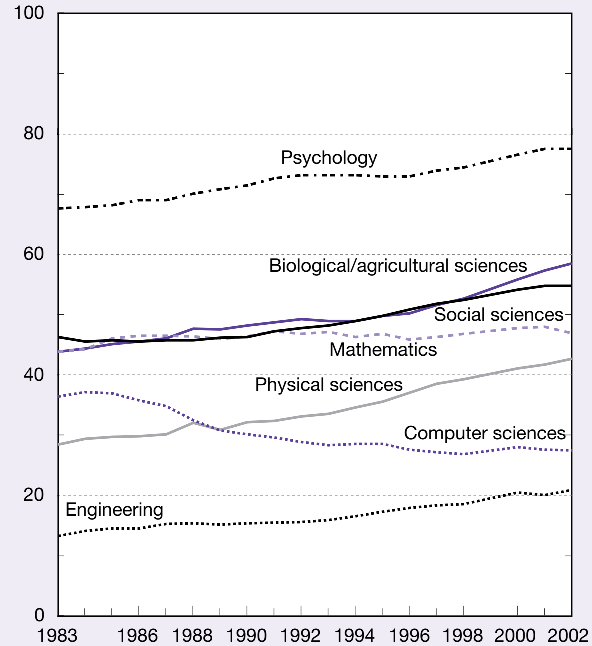


NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-26.

Science and Engineering Indicators 2006

Figure 2-11
Female share of S&E bachelor's degrees, by field: 1983–2002



NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-26.

Science and Engineering Indicators 2006

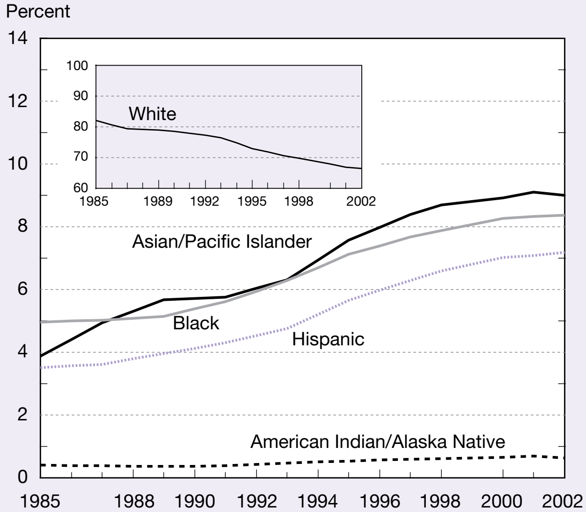
S&E Bachelor's Degrees by Race/Ethnicity

In the past two decades, the racial/ethnic composition of those earning S&E bachelor's degrees has changed, reflecting both population change and increasing college attendance by members of minority groups.[10] Between 1983 and 2002, the proportion of S&E degrees awarded to Asians/Pacific Islanders increased from 4% to 9%, and the proportion awarded to members of underrepresented minority groups grew from 9% to 16% (figure 2-12). Conversely, the proportion of S&E bachelor's degrees earned by white students declined from 82% in 1983 to 66% in 2002. During the 1990s, the number of S&E bachelor's degrees earned by white students decreased but rose again in 2002.

Despite considerable progress for underrepresented minority groups between 1983 and 2002 in earning bachelor's degrees in any field, the gap in educational attainment between young minorities and whites continues to be wide. The percentage of blacks ages 25 to 29 with a bachelor's or higher degree rose from 13% in 1983 to 18% in 2003, whereas the percentage of Hispanics ages 25 to 29 with a bachelor's or higher degree was 10% in 1983 and 2003 (NCES 2005a). For whites ages 25 to 29, this percentage rose from 25% in 1983 to 34% in 2003. Differences in completion of bachelor's degrees in S&E by race/ethnicity reflect differences in high school completion rates, college enrollment rates, and college persistence and attainment rates. In general, blacks and Hispanics are less likely than whites and Asians/Pacific Islanders to graduate from high school, to enroll in college, and to graduate from college (see "Transition to Higher Education" in chapter 1 for information on immediate post-high school college enrollment rates). Among high school graduates, the percentages of blacks and Hispanics ages 25 to 29 with a bachelor's or higher degree were 21% and 15%, respectively, in 2000, compared to 36% for whites (NCES 2001). Among those who do enroll in or graduate from college, however, blacks, Hispanics, and American Indians/Alaska Natives are about as likely as whites to choose S&E fields; Asians/Pacific Islanders are more likely than members of other racial/ethnic groups to choose these fields. For Asians/Pacific Islanders, almost half of all bachelor's degrees received are in S&E, compared with about one-third of all bachelor's degrees earned by each of the other racial/ethnic groups.

The contrast in field distribution among whites, blacks, Hispanics, and American Indians/Alaska Natives on the one hand and Asians/Pacific Islanders on the other is apparent within S&E fields as well. White, black, Hispanic, and

Figure 2-12
Minority share of S&E bachelor's degrees, by race/ethnicity: 1985–2002



NOTE: Data not available for 1999.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-27.

Science and Engineering Indicators 2006

American Indian/Alaska Native S&E baccalaureate recipients share a similar distribution across broad S&E fields. In 2002, between 9% and 11% of all baccalaureate recipients in each of these racial/ethnic groups earned their degrees in the social sciences, 4% to 5% in the biological sciences, and 3% to 4% in engineering and in computer sciences. Asian/Pacific Islander baccalaureate recipients earned higher proportions of their baccalaureates in the biological sciences, computer sciences, and engineering (appendix table 2-27).

Trends in bachelor's degrees over the past 20 years are similar in many ways for most racial/ethnic groups. For all racial/ethnic groups, the number of bachelor's degrees in engineering, physical sciences, and mathematics generally dropped or flattened out, especially since the mid-1990s. Degrees in biological sciences generally increased through the late 1990s, then dropped in recent years. Degrees in computer sciences fell in the early 1990s but increased steeply from 1998 through 2002. All racial/ethnic groups, except for whites, generally show an increase in total bachelor's degrees and in social/behavioral sciences bachelor's degrees. The total number of bachelor's degrees awarded in all fields and in social/behavioral sciences to white students was fairly flat from 1993 through 2001, then increased slightly in 2002 (appendix table 2-27).

Bachelor's Degrees by Citizenship

Students on temporary visas in the United States earned a small share (4%) of S&E degrees at the bachelor's level. However, they earned 8% of bachelor's degrees awarded in computer sciences in 2002 and 7% of those awarded in engineering. The number of S&E bachelor's degrees awarded to students on temporary visas increased over the past two decades from about 14,100 in 1983 to 16,300 in 2002. Trends in the number of degrees by field generally followed the pattern noted above for all racial/ethnic groups except whites (appendix table 2-27).

S&E Master's Degrees

Master's degrees in S&E fields increased from 67,700 in 1983 to about 99,200 in 2002 (appendix table 2-28). Engineering, social sciences, computer sciences, and psychology accounted for most of the growth (figure 2-13). In recent years, computer sciences was the only field to experience substantial growth.

Master's Degrees by Sex

Since 1983, the number of S&E master's degrees earned by women has more than doubled, rising from 21,000 to 43,500 (figure 2-14). In contrast, the number of master's degrees that men earned grew only marginally, from 46,700 in 1983 to 55,700 in 2002. As a result, the percentage of women earning master's degrees rose steadily during the past two decades. In 1983, women earned 31% of all S&E master's degrees; by 2002, they earned 44%. In addition to earning increasing numbers of degrees in both social sciences and psychology, fields with a history of strong female representation, women also showed strong growth in engineering and computer sciences (appendix table 2-28).

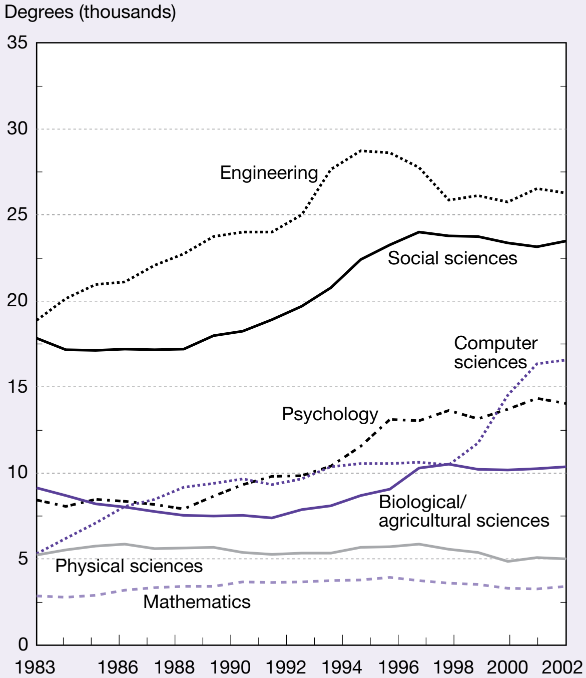
Women's share of S&E master's degrees varies by field. In 2002, women earned a majority of master's degrees in psychology (76%), biological sciences (58%), and social sciences (54%); they earned their lowest share in engineering (21%) (appendix table 2-28). The number and percentage of master's degrees awarded to women in all major S&E fields have increased since 1983.

Master's Degrees by Race/Ethnicity

The number of S&E master's degrees awarded increased for all racial/ethnic groups from 1985 to 2002 (figure 2-15).[11] The proportion of master's degrees in S&E fields earned by U.S. citizen and permanent resident racial and ethnic minorities increased over the past two decades. Asians/Pacific Islanders accounted for 7% of master's degrees in 2002, up from 5% in 1983. Underrepresented minorities also registered gains, increasing from 5% to 11% during this period. The number of S&E master's degrees awarded to whites decreased from 1995 through 2002. The percentage of S&E master's degrees awarded to white students fell from 68% in 1985 to 49% in 2002 (appendix table 2-29).

Trends in the number of master's degrees by field were similar for most racial/ethnic groups. The number of master's degrees in physical sciences rose through the mid-1990s, then dropped through 2002. For all groups, the number of master's degrees in biological sciences and agricultural sciences generally rose through at least the late 1990s, and for

Figure 2-13
S&E master's degrees, by field: 1983–2002

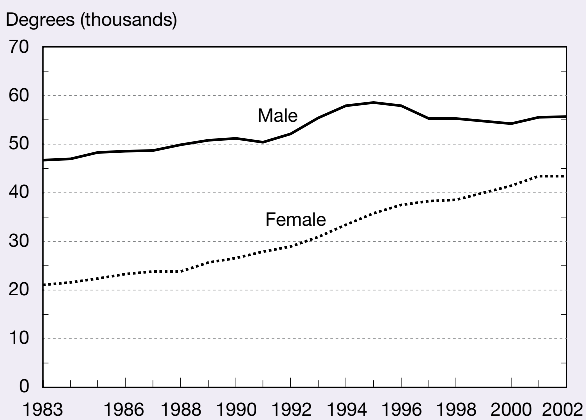


NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-28.

Science and Engineering Indicators 2006

Figure 2-14
S&E master's degrees, by sex: 1983–2002

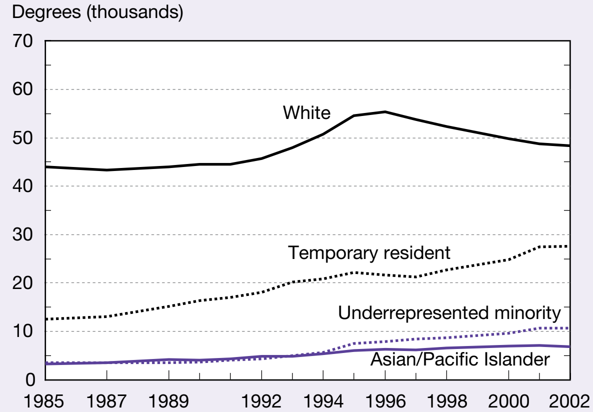


NOTE: Data not available for 1999.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-28.

Science and Engineering Indicators 2006

Figure 2-15
S&E master's degrees, by race/ethnicity and citizenship: 1985–2002



NOTES: Race/ethnicity includes U.S. citizens and permanent residents. Underrepresented minority includes black, Hispanic, and American Indian/Alaska Native. Data not available for 1999.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-29.

Science and Engineering Indicators 2006

all groups but whites and Asians/Pacific Islanders, master's degrees in engineering generally increased. Also, for all groups except white students, master's degrees in social and behavioral sciences and in computer sciences generally increased from 1983 through 2002. For white and Asian/Pacific Islander students, the number of engineering master's degrees dropped after the mid-1990s. For white students, the number of social and behavioral sciences master's degrees dropped from 1995 through 2002, and master's degrees in computer sciences dropped through 1997, then increased (appendix table 2-29).

Master's Degrees by Citizenship

S&E master's degrees awarded to students on temporary visas rose from approximately 12,500 in 1983 to about 27,600 in 2002, and increased in most S&E fields during that period. The sole exception was physical sciences. During that period, the share of S&E master's degrees earned by temporary residents rose from 19% to 28%. Foreign students make up a much higher proportion of S&E master's degree recipients than they do of bachelor's or associate's degree recipients. Their degrees are heavily concentrated in computer sciences and engineering, where they earned 46% and 41%, respectively, of master's degrees in 2002 (appendix table 2-29). These two fields accounted for 29% of all master's degrees earned by students on temporary visas, compared with 6% of all master's degrees earned by U.S. citizens and permanent residents. Men constitute a higher proportion of S&E master's degree recipients with temporary visas (66%) than they do of those earned by U.S. citizens and permanent residents (52%) (NSF 2004b).

New Directions in Graduate Education

New directions in graduate education, including professional master's programs, the growth of certificate programs, and distance education, parallel those in undergraduate education. Professional master's degree programs often stress interdisciplinary training for work in emerging S&E fields. (See sidebar "Professional Master's Degree Programs.") Professional certificate programs at the graduate level are typically amenable to distance delivery at corporate sites. These programs include a coherent set of courses for a specialty, such as engineering management.

S&E Doctoral Degrees

Global economic competition and the spreading conviction that highly educated workforces are key to successfully building growth economies have increased interest both in the United States and abroad in the supply of foreign and domestic doctorate recipients and their migration across borders.

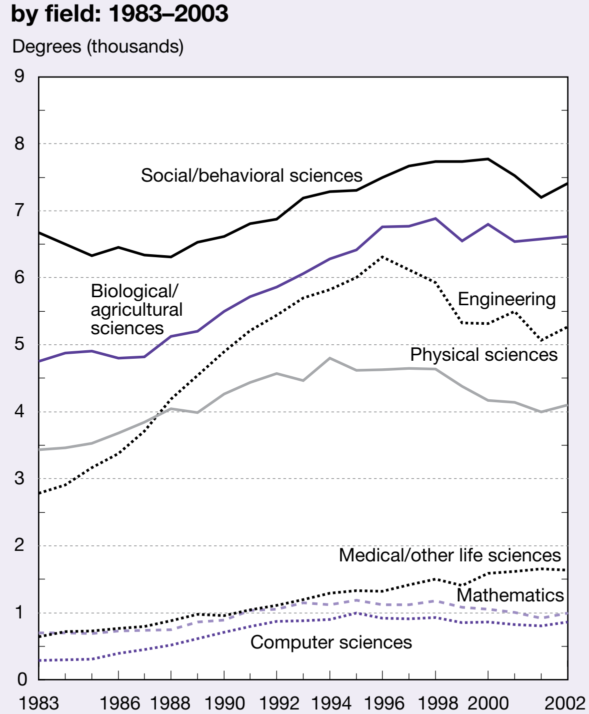
The number of S&E doctorates conferred annually by U.S. universities rose from the mid-1980s through the mid-1990s, peaked in 1998, and then declined for the remainder of the 1990s. In 2003, the number of S&E doctorates increased slightly over the previous year. (For information on employment of recent doctorate recipients, see "Labor Market Conditions for Recent S&E Graduates" in chapter 3 [S&E labor force] and "Trends in Academic Employment of Doctoral Scientists and Engineers" in chapter 5 [academic research and development.]) The increase through 1998 largely reflected growth in the number of foreign degree recipients. The largest increases were in engineering, biological/agricultural sciences, and social and behavioral sciences degrees (figure 2-16). The post-1998 decline in earned doctorates reflects fewer degrees earned by both U.S. citizens and permanent residents (see "Foreign S&E Doctorate Recipients").

Doctoral Degrees by Sex

Among U.S. citizens, the proportion of S&E doctoral degrees earned by women has risen considerably in the past two decades, reaching a record high of 45% in 2003 (appendix table 2-30). During this period, women made gains in all major field groups. However, as figure 2-17 shows, considerable differences by field continue. Women earn half or more of doctorates in non-S&E fields and in social/behavioral sciences, and 19% of doctorates in engineering (appendix table 2-30).

The increase in the proportion of S&E doctoral degrees earned by women has been due to both an increase in the number of women and a decrease in the number of men earning such degrees. The number of U.S. citizen women earning doctorates in S&E increased from 4,325 in 1983 to 7,131 in 2003 (appendix table 2-30). Meanwhile, the number of S&E doctorates earned by U.S. citizen men declined

Figure 2-16
S&E doctoral degrees earned in U.S. universities, by field: 1983–2003



NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-30.

Science and Engineering Indicators 2006

Professional Master's Degree Programs

As subdisciplines within sciences emerge and industry expresses needs for people with particular skills, universities are turning to professional master's degree and certificate programs as a means of preparing a needed workforce or as a means of mid-career change for professionals in such fields as biotechnology, nanotechnology, and computer sciences. Because of this rise of interest, particularly in the sciences, the Sloan Foundation launched a Professional Master's Degree project in 1997, limiting its focus to the natural sciences and mathematics. The program has grown to more than 1,100 students enrolled in 97 programs distributed among 45 universities (CPST 2005). These programs tend to be more interdisciplinary than traditional doctoral or master's degree programs and provide an alternative to doctoral education for students who enroll in them. Interdisciplinary fields within the biological sciences (e.g., bioinformatics, applied biotechnology, applied genomics) account for more than half of the students enrolled. A similar effort by the Council of Graduate Schools promotes the development of professional master's degree programs in the humanities and social sciences.

from 9,808 in 1983 to 8,605 in 2003. The increase in the number of S&E doctorates earned by women occurred in most major S&E fields. A decrease in the number of S&E doctorates earned by men after 1995 occurred in most major S&E fields except biological sciences.

Doctoral Degrees by Race/Ethnicity

Although the proportion of S&E doctoral degrees earned by white U.S. citizens decreased in the past two decades, the number of S&E doctorates earned remained relatively stable, fluctuating from around 12,000 to 14,000 degrees awarded annually. Doctoral S&E degrees earned by whites peaked at 14,166 in 1995, then declined slightly each year since, mainly in the fields of engineering, physical sciences, mathematics, and computer sciences. The share of all doctoral S&E degrees earned by white U.S. citizens decreased from 66% in 1983 to 47% in 2003. Their share of degrees awarded to all U.S. citizens declined from 90% to 79% (appendix table 2-31).

The number of doctoral S&E degrees earned by white male U.S. citizens declined from a peak of more than 11,000 in 1975 to less than 7,000 in 2002 and 2003, accounting for most of the drop in doctoral S&E degrees earned by white U.S. citizens (figure 2-18). The number of degrees earned by white U.S. females generally increased over much of the past three decades, but lately has begun to decline.

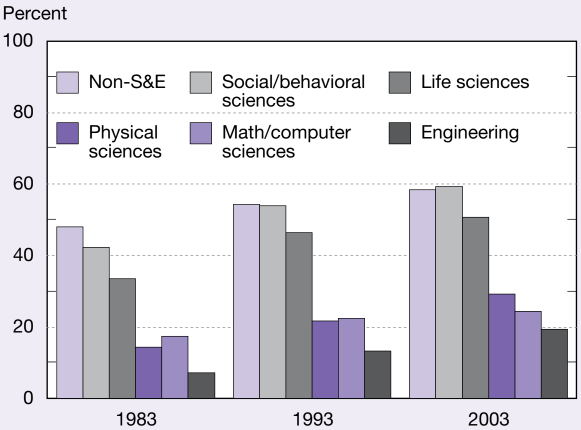
The number and proportion of doctoral degrees in S&E fields earned by U.S. citizen underrepresented minorities also increased over the past two decades. Blacks, Hispanics, and American Indians/Alaska Natives together earned about 1,500 S&E doctorates in 2003, accounting for 5% of all S&E doctorate degrees earned that year and up from 3% in 1983 (figure 2-19). (Their share of degrees earned by all U.S. citizens rose from 4% to 9% in the same period.) Gains by all groups contributed to this rise, as the number of S&E degrees earned by blacks, Hispanics, and American Indians/Alaska Natives more than doubled. Their largest gains came in social sciences and psychology. In 2003, the percentage of the doctoral degrees earned by underrepresented minorities in psychology was 11%, up from 6% in 1983, while the percentage of doctorates earned in the social sciences increased from 5% in 1983 to 8% in 2003 (appendix table 2-31).

In the mid-1990s, the number of doctoral degrees earned by Asian/Pacific Islander U.S. citizens showed a steep increase. Asians/Pacific Islanders earned just over 4% of S&E doctorates in 2003, up from 2% in 1983.

Foreign S&E Doctorate Recipients

Noncitizens, primarily those with temporary visas, account for the bulk of the growth in S&E doctorates awarded by U.S. universities from 1983 through 2003. The number of S&E doctorate recipients with temporary visas rose dramatically in the 1980s and 1990s, accounting for almost one-third of S&E doctorate recipients in 2003.

Figure 2-17
Doctoral degrees earned by female U.S. citizens in U.S. institutions, by field: 1983, 1993, and 2003

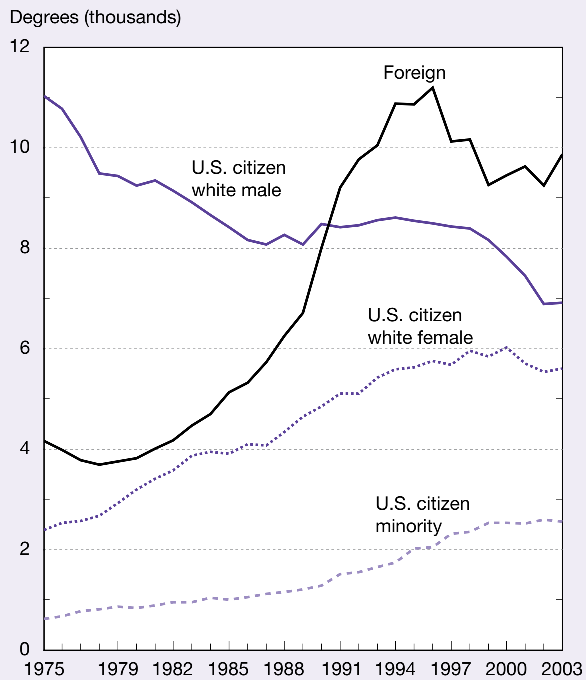


NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Life sciences include biological sciences, agricultural sciences, and medical/other life sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-30.

Science and Engineering Indicators 2006

Figure 2-18
U.S. S&E doctoral degrees, by sex, race/ethnicity, and citizenship: 1975–2003

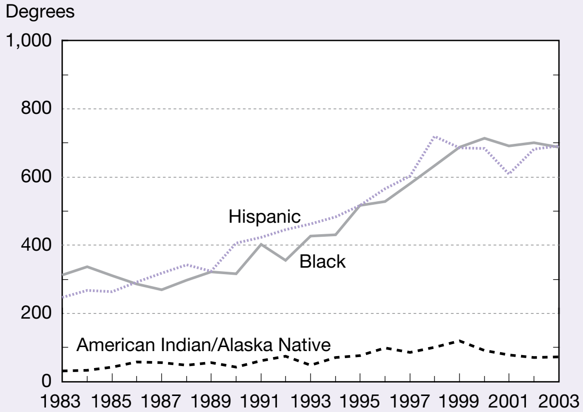


NOTES: Foreign includes permanent and temporary residents. Minority includes Asian/Pacific Islander, black, Hispanic, and American Indian/Alaska Native. Degree recipients with unknown citizenship omitted.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-31.

Science and Engineering Indicators 2006

Figure 2-19
U.S. citizen underrepresented minority S&E doctoral degrees, by race/ethnicity: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-31.

Science and Engineering Indicators 2006

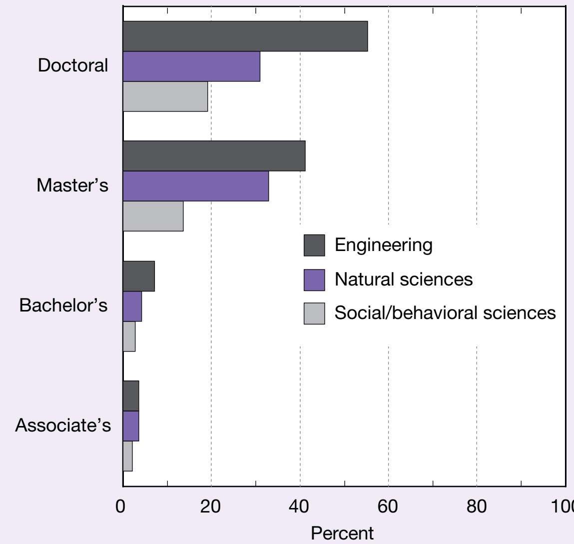
During this period, the number of S&E doctorates earned by U.S. citizens fluctuated from approximately 14,000 to about 17,000, and the number earned by temporary residents rose from 3,500 to a peak of 8,700 in 2003. The temporary resident share of S&E doctorates rose from 18% in 1983 to 32% in 2003. The number of S&E doctorates earned by U.S. permanent residents increased from about 900 in 1983 to a peak of 3,614 in 1995 before falling to about 1,200 in 2003 (appendix table 2-32). (In the mid-1990s, the number of doctorates awarded to U.S. permanent residents showed a steep increase when a large number of Chinese doctoral degree students on temporary visas shifted to permanent resident status under the 1992 Chinese Student Protection Act.)

Foreign students on temporary visas earn a larger proportion of degrees at the doctoral level than at any other level (figure 2-20). Their proportion in some fields is considerably higher: in 2003, foreign students on temporary visas earned 43% to 44% of doctoral degrees awarded in mathematics, computer sciences, and agricultural sciences, along with 55% of those awarded in engineering (appendix table 2-31).

Countries/Economies of Origin

The top 10 foreign countries/economies of origin of foreign S&E doctorate recipients together accounted for 64% of all foreign recipients of a U.S. S&E doctorate from 1983 to 2003 (table 2-3). More than half of those top 10 countries are located in Asia. The major Asian countries/economies sending doctoral degree students to the United States have been, in descending order, China, Taiwan, India, and South Korea. Canada and Mexico were also among the top 10. Major European countries of origin (not in the top 10) were Germany, the United Kingdom, Greece, Italy, and France, in that order.

Figure 2-20
Foreign share of U.S. S&E degrees, by degree and field: 2002 or 2003



NOTES: Doctoral degree data are for 2003; other data are for 2002. Foreign includes temporary residents only. Natural sciences include physical, biological, agricultural, computer, earth, atmospheric, and ocean sciences and mathematics.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-25, 2-27, 2-29, and 2-31.

Science and Engineering Indicators 2006

Table 2-3
Foreign recipients of U.S. S&E doctorates, by country/economy of origin: 1983–2003

Country/economy	Number	Percent
All foreign recipients	176,019	100.0
Top 10 total	111,959	63.6
China	35,321	20.1
Taiwan	19,711	11.2
India	17,515	10.0
South Korea	17,112	9.7
Canada	5,832	3.3
Iran	3,807	2.2
Turkey	3,413	1.9
Thailand	3,102	1.8
Japan	3,100	1.8
Mexico	3,046	1.7
All others	64,060	36.4

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2003).

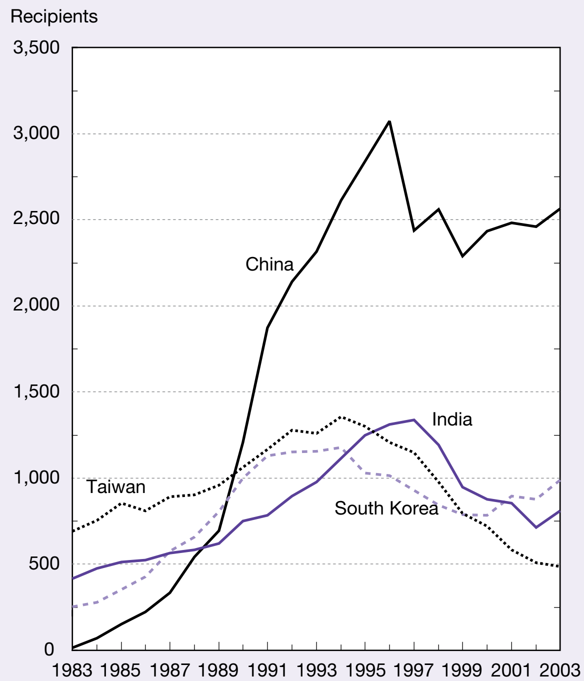
Science and Engineering Indicators 2006

Asia. The number of U.S. S&E doctorates earned by students from Asia increased from the mid-1980s until the mid- to late 1990s, followed by a decline (figure 2-21). Most of these degrees were awarded in engineering and biological and physical sciences (table 2-4). From 1983 to 2003, students from four Asian countries/economies (China, Taiwan, India, and South Korea) earned more than 50% of U.S. S&E doctoral degrees awarded to foreign students (89,700 of 176,000), almost four times more than students from Europe (23,000).

China had the largest number of students earning U.S. S&E doctorates during the 1983–2003 period. These students received more than 35,300 S&E doctoral degrees from U.S. universities, mainly in biological and physical sciences and engineering (table 2-4). The number of S&E doctorates earned by Chinese nationals increased from 16 in 1983 to more than 3,000 in 1996 (figure 2-21). After this peak year, their number of doctorates earned from U.S. institutions declined and leveled off to about 2,500 in recent years.[12]

Students from Taiwan received the second-largest number of S&E doctorates at U.S. universities. Between 1983 and 2003, students from Taiwan earned more than 19,700 S&E doctoral degrees, mainly in engineering and biological and physical sciences (table 2-4). In 1983, they earned more U.S. S&E doctoral degrees than students from India and China combined. The number of U.S. S&E doctoral degrees earned by students from Taiwan increased rapidly for almost a decade, from 691 in 1983 to more than 1,300 at its peak in 1994. However, as universities in Taiwan increased their capacity for advanced S&E education in the 1990s, the number of students from Taiwan earning S&E doctorates from U.S. universities declined to 485 in 2003 (figure 2-21).[13]

Figure 2-21
U.S. S&E doctoral degree recipients, by selected Asian country/economy: 1983–2003



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

Science and Engineering Indicators 2006

Students from India earned more than 17,500 S&E doctoral degrees at U.S. universities over the period. Like students from China and Taiwan, they mainly earned doctorates in engineering and biological and physical sciences. They also earned by far the largest number of U.S. doctoral degrees awarded to any foreign group in computer sciences (table 2-4). The more than decade-long increase in U.S. S&E doctorates earned by students from India ended in 1997, followed by 5 years of decline (figure 2-21). The number of S&E doctoral degrees earned by students from India increased slightly in 2003.

Students from South Korea earned more than 17,000 U.S. S&E doctorates, mainly in engineering and biological, social, and physical sciences. The number of S&E doctoral degrees earned by South Korean students increased from about 250 in 1983 to about 1,200 in 1994, declined to a low of about 800 in the late 1990s, and increased slightly to almost 1,000 in 2003.

Europe. European students earned far fewer U.S. S&E doctorates than did Asian students, and they tended to focus less on engineering than did their Asian counterparts (table 2-5). Western European countries whose students earned the largest number of S&E doctorates from 1983 to 2003 were Germany, the United Kingdom, Greece, Italy, and France, in that order. From 1983 to 1993, Greece and the United Kingdom were the primary European countries of origin; thereafter, their numbers of doctoral degree recipients declined. The numbers of U.S. S&E doctorate recipients from Germany, Italy, and France generally increased over the past two decades (figure 2-22). Scandinavians received fewer U.S. doctorates than did students from the other European regions, with a field distribution roughly similar to that for other Western Europeans (table 2-5).

The number of Eastern European students earning S&E doctorates at U.S. universities increased from fewer than 50 in 1983 to more than 700 in 2003 (figure 2-23). A higher proportion of Central and Eastern Europeans (89%) than Western Europeans (73%) earned U.S. doctorates in S&E fields. Within S&E, Western Europeans were more likely to study psychology and social sciences, and Eastern Europeans were more likely to study physical sciences and mathematics (table 2-5).

North America. The Canadian and Mexican shares of U.S. S&E doctoral degrees were small compared with those from Asia and Europe. The number of U.S. S&E degrees earned by students from Canada increased from less than 200 in 1983 to 350 in 2003. In all, 62% of Canadian doctoral degree students in U.S. universities earned S&E doctorates, mainly in social and biological sciences (figure 2-24; table

Table 2-4
Asian recipients of U.S. S&E doctorates, by field and country/economy of origin: 1983–2003

Field	Asia	China	Taiwan	India	South Korea
All fields	141,826	37,510	23,045	20,382	21,810
S&E	120,698	35,321	19,711	17,515	17,112
Engineering	44,213	10,202	9,156	7,685	6,469
Science	76,485	25,119	10,555	9,830	10,643
Agricultural sciences	5,142	1,148	745	411	670
Biological sciences	19,020	8,728	2,661	2,330	1,898
Computer sciences	5,169	993	958	1,399	674
Earth, atmospheric, and ocean sciences	2,832	1,221	418	236	340
Mathematics	5,823	2,372	773	570	740
Medical/other life sciences	3,547	678	697	628	353
Physical sciences	18,613	7,855	2,429	2,459	2,261
Psychology	1,871	254	276	224	288
Social sciences	14,468	1,870	1,598	1,573	3,419
Non-S&E	21,128	2,189	3,334	2,867	4,698

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2003).

Science and Engineering Indicators 2006

Table 2-5
European and North American recipients of U.S. S&E doctorates, by field and region/country of origin: 1983–2003

	Europe[a]				North America		
Field	Total	Western	Scandinavia	Central and Eastern	Total	Mexico	Canada
All fields	29,882	21,119	1,873	6,890	12,905	3,562	9,343
S&E	22,983	15,422	1,426	6,135	8,878	3,046	5,832
Engineering	4,807	3,281	266	1,260	1,465	680	785
Science	18,176	12,141	1,160	4,875	7,413	2,366	5,047
Agricultural sciences	694	536	61	97	779	527	252
Biological sciences	3,231	2,198	189	844	1,684	510	1,174
Computer sciences	1,071	688	64	319	232	72	160
Earth, atmospheric, and ocean sciences	905	642	76	187	335	142	193
Mathematics	2,351	1,204	104	1,043	456	167	289
Medical/other life sciences	511	419	53	39	523	84	439
Physical sciences	4,644	2,677	217	1,750	972	266	706
Psychology	894	733	81	80	828	88	740
Social sciences	3,875	3,044	315	516	1,604	510	1,094
Non-S&E	7,410	5,697	447	755	4,027	516	3,511

[a]See figure 2-23 for countries included in Western Europe, Scandinavia, and Eastern Europe.

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2003).

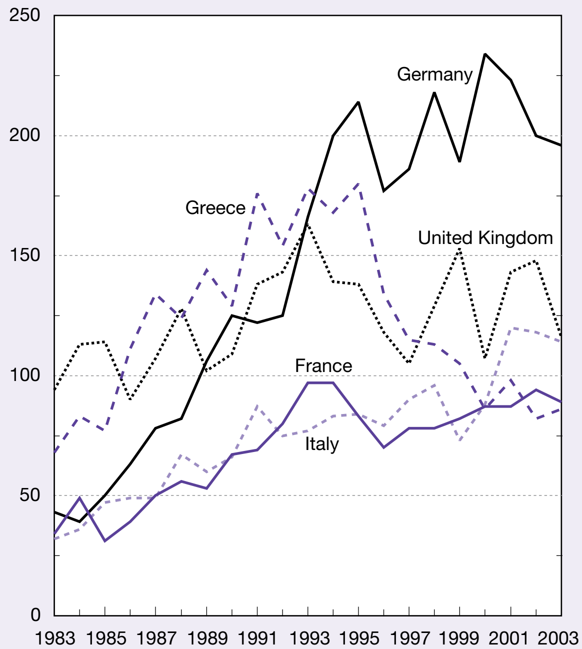
Science and Engineering Indicators 2006

2-5). Mexican doctoral degree students in U.S. universities are more concentrated in S&E fields than are Canadian students: 86% of doctoral degrees earned by Mexican students at U.S. universities were in S&E fields, mainly engineering, agricultural, biological, and social sciences. The number of doctoral degree recipients from Mexico increased from 100 in 1983 to more than 200 in 2003.

Stay Rates

Almost 30% of employed S&E doctorate recipients in the United States are foreign born (see chapter 3), as are more than half of postdocs (appendix table 2-35). The majority of those working in the United States (excluding postdocs) obtained their doctorates from U.S. universities. Stay rates based on stated plans at receipt of doctorate indicate how much the

Figure 2-22
U.S. S&E doctoral degree recipients, by selected Western European country: 1983–2003

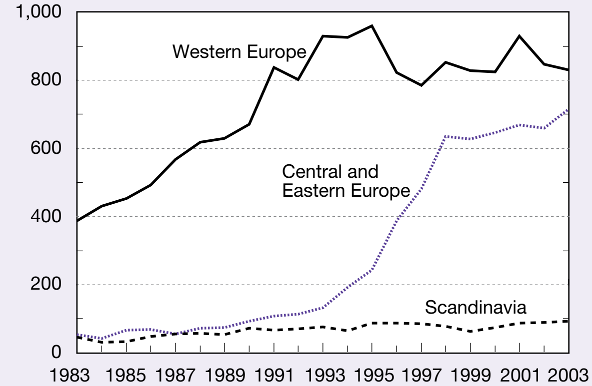


NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

Science and Engineering Indicators 2006

Figure 2-23
U.S. S&E doctoral degree recipients from Europe, by region: 1983–2003

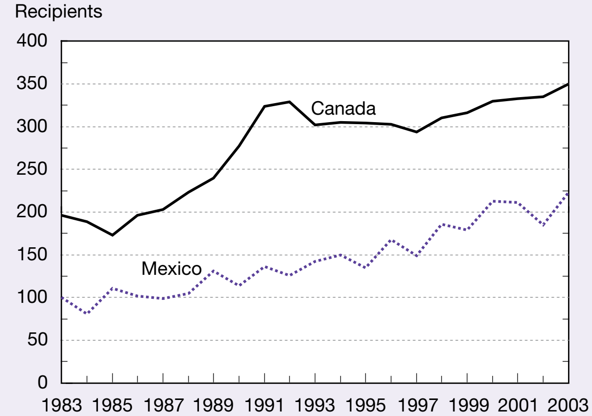


NOTES: Degree recipients include permanent and temporary residents. Western Europe includes Andorra, Austria, Belgium, France, Germany, Gibraltar, Greece, Ireland, Italy, Luxembourg, Malta, Monaco, the Netherlands, Portugal, Spain, and Switzerland. Eastern Europe includes Albania, Bulgaria, Czech Republic, Slovakia, Hungary, Poland, Romania, Russia, Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgystan, Latvia, Lithuania, Moldova, Tadjikistan, Turkmenistan, Ukraine, Uzbekistan, Yugoslavia, Bosnia-Herzogovina, Croatia, Macedonia, and Serbia-Montenegro. Scandinavia includes Denmark, Finland, Iceland, Norway, and Sweden.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

Science and Engineering Indicators 2006

Figure 2-24
U.S. S&E doctoral degree recipients from Canada and Mexico: 1983–2003



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

Science and Engineering Indicators 2006

United States relies on inflow of doctorate holders from different countries and whether working in the United States remains an attractive option for foreign students who obtain U.S. doctorates. (See chapter 3 for an analysis using an alternative stay-rate measure based on examination of Social Security records several years after earning a doctorate.)

Until the early 1990s, about half of foreign students who earned S&E degrees at U.S. universities reported that they planned to stay in the United States after graduation, and about one-third said they had firm offers for postdoctoral study or employment (NSB 1998). In the 1990s, however, these percentages increased substantially. In the 1992–95 period, for example, of the foreign S&E doctoral degree recipients who reported their plans, 68% planned to remain in the United States after receiving their degree and 35% already had firm offers. By 2000–03, 74% of foreign doctoral recipients in S&E fields with known plans intended to stay in the United States and 51% had firm offers to do so (appendix table 2-33). Foreign doctorate recipients in physical sciences and mathematics/computer sciences were more likely, and those in social/behavioral sciences, less likely, to have firm plans to stay. Although the number of S&E doctoral degrees earned by foreign students declined after 1996,

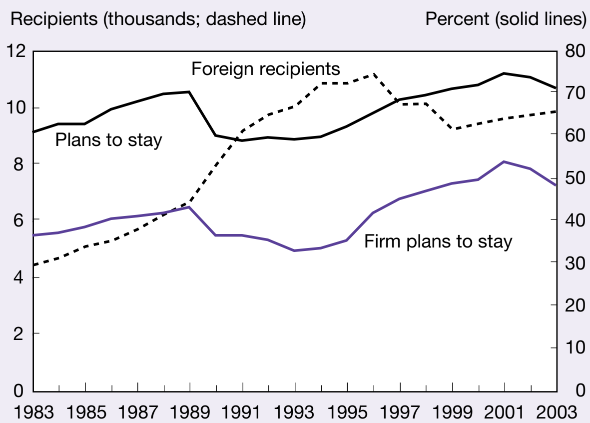
the percentage of students who had firm plans to remain in the United States continued to increase through 2001 before declining in 2002 and 2003 (figure 2-25).

Stay rates vary by place of origin. In the 2000–03 period, 64% of U.S. S&E doctoral recipients from China and 67% of those from India reported accepting firm offers for employment or postdoctoral research in the United States, up from 47% and 53%, respectively, in the period from 1992 to 1995 (figure 2-26; appendix table 2-33). Recipients from Taiwan, Japan, and South Korea were less likely to stay in the United States. Over the same 2000–03 period, 41% of S&E doctoral degree recipients from Taiwan, 42% of those from Japan, and 46% of those from South Korea reported accepting firm offers to remain in the United States. Although the number of S&E doctorate students from Taiwan and South Korea fell in the late 1990s (and in the case of Taiwan, into the 2000s), the percentage who intended to stay in the United States after receipt of their degree increased. Among U.S. S&E doctoral degree recipients from Europe, a relatively high percentage from the United Kingdom planned to stay, whereas relatively small percentages from France, Italy, and Spain (compared with other Western European countries) planned to stay after graduation. The percentage of 2000–03 doctoral degree students who had firm plans to stay in the United States was higher for Canada (54%) than for Mexico (30%) (appendix table 2-33).

Doctoral Degrees by Time to Degree

The NSF Survey of Earned Doctorates tracks patterns and trends in the time it takes to earn an S&E doctorate. The survey measures time to degree in several ways, including median number of years between baccalaureate receipt and doctorate receipt (also known as *total time to degree*)

Figure 2-25
Plans of foreign U.S. S&E doctoral degree recipients to stay in United States: 1983–2003

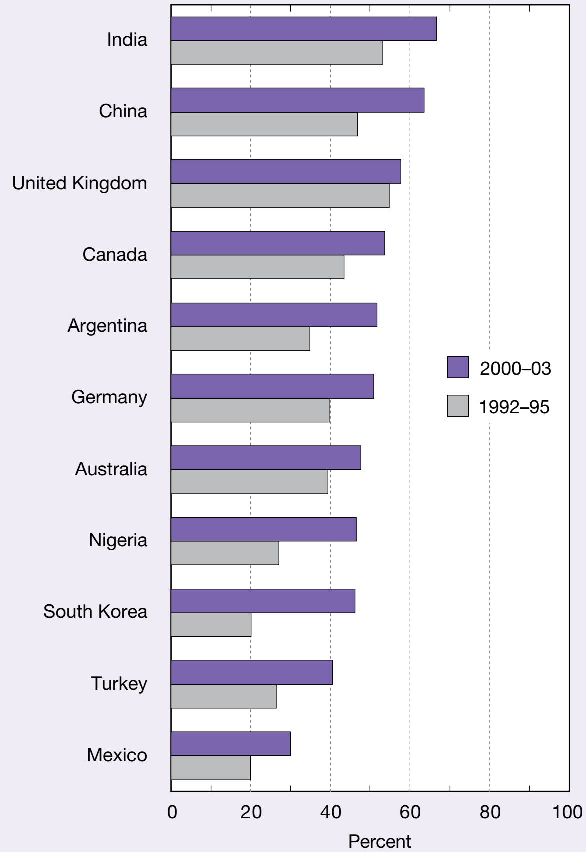


NOTES: Degree recipients include permanent and temporary residents. Appendix table 2-33 includes plans to stay by country of origin and field of study in 3-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005). See appendix table 2-33.

Science and Engineering Indicators 2006

Figure 2-26
Short-term stay rates of foreign U.S. S&E doctoral degree recipients, by place of origin: 1992–95 and 2000–03



NOTES: Short-term stay rates are those with firm commitments of postaward or postdoctoral employment. Longer-term stay rates may differ. Appendix table 2-33 includes plans to stay by place of origin and field of study in 3-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

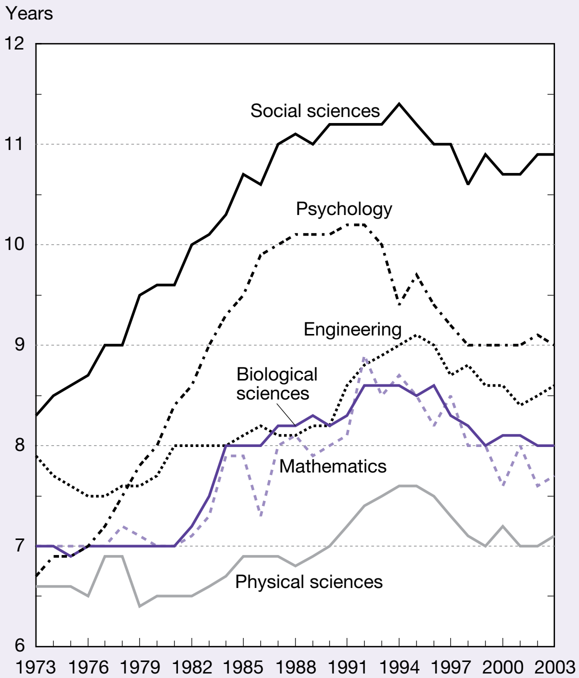
Science and Engineering Indicators 2006

and median number of years registered in graduate school between graduate entry and doctorate receipt (also known as *registered time to degree*).

Data on the time from baccalaureate to doctorate show increases from 1973 through the early 1990s, followed by declines in all S&E fields. Over the past three decades, increases ranged from about 6 months longer in engineering, physical sciences, and mathematics to nearly 3 years longer in social sciences (figure 2-27). Total time to degree (as measured by elapsed time from baccalaureate) was longest in each of the S&E fields in the early to mid-1990s. By 2003, it had shortened considerably. Physical sciences had the shortest time to degree at 7.1 years, and social sciences, the longest at 10.9 years (appendix table 2-34).

Median registered time to degree, as measured by number of years registered in graduate school between entry and doctorate receipt, also followed a similar pattern of increase over the past 30 years for all fields. It averaged about 1 year

Figure 2-27
Time from bachelor's to S&E doctoral degree, by doctoral degree field: 1973–2003



NOTE: Median years between award of bachelor's degree and award of doctoral degree.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005). See appendix table 2-34.

Science and Engineering Indicators 2006

longer in most S&E fields and almost 2 years longer in agricultural sciences, psychology, and social sciences. Among S&E fields in 2003, registered time to degree was shortest in the physical sciences (6.4 years) and longest in the social sciences (8.3 years).

Postdocs

Postdoctoral fellowships provide recent doctorate recipients with "an opportunity to develop further the research skills acquired in their doctoral programs or to learn new research techniques" (Association of American Universities 1998). Typically, postdoctoral fellows or *postdocs* have temporary appointments involving full-time research or scholarship whose purpose is to further their education and training. The titles associated with these positions and the conditions of employment vary widely. The status of postdoctoral fellows within the academic hierarchy is not well defined and varies among institutions, although the concept that the postdoctoral experience represents the last step on a person's training for becoming an independent investigator and faculty member is generally accepted (COSEPUP 2000, 2004).

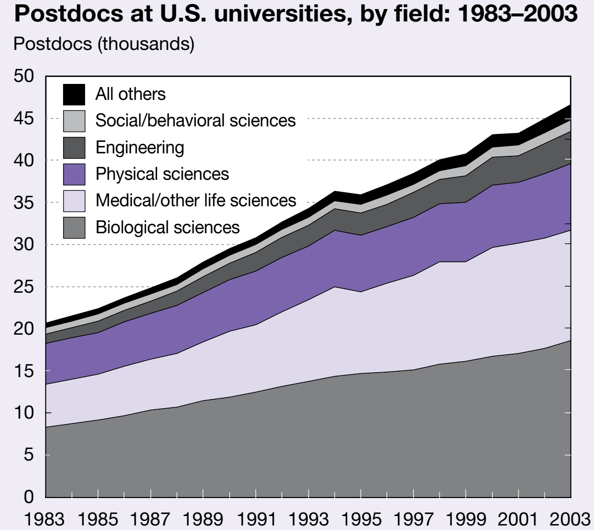
Since 1983, the number of doctoral degree recipients with science, engineering, and health postdoctoral appointments at U.S. universities more than doubled from 20,700 in 1983 to 46,700 in 2003. Approximately two-thirds of those were in biological, medical, and other life sciences (figure 2-28).

Noncitizens account for much of the increase in the number of S&E postdocs, especially in biological sciences and medical and other life sciences. The number of S&E postdocs with temporary visas at U.S. universities increased from approximately 7,500 in 1983 to 27,000 in 2003. The number of U.S. citizen and permanent resident S&E postdocs at these institutions increased more modestly from approximately 13,200 in 1983 to 19,700 in 2003 (figure 2-29 and appendix table 2-35). Noncitizens accounted for 58% of S&E postdocs in 2003.

An increasing share of academic S&E postdocs are funded through federal research grants. In fall 2003, 56% of S&E postdocs at U.S. universities were funded through this mechanism, up from 48% in 1983. Federal fellowships and traineeships fund a declining share of S&E postdocs—14% in 2003, down from 24% in 1983. In 2003, the remainder (about 30%) of S&E postdocs were funded through non-federal sources (table 2-6).

Although the majority of postdocs are employed in academic institutions, federal agencies and federally funded research and development centers (FFRDCs) also employ sizable numbers of postdocs. NIH, for example, employed approximately 2,600 intramural postdocs in 2004 (NIH, Office of the Director, internal report). In 2003, almost 3,000 postdocs were employed in FFRDCs, which are federally funded but administered by universities and colleges, industrial firms, or nonprofit organizations. Most (16) of the 22 FFRDCs employing postdocs are funded by the U.S. Department of Energy. The largest FFRDC postdoc employers were Aerospace FFRDC (almost 700 postdocs) and Los Alamos National

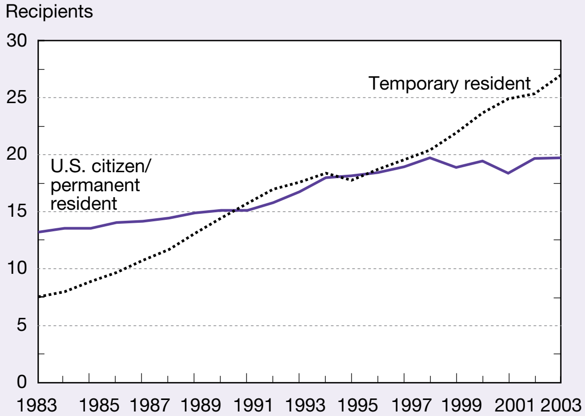
Figure 2-28
Postdocs at U.S. universities, by field: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-35.

Science and Engineering Indicators 2006

Figure 2-29
Postdocs at U.S. universities, by citizenship status: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-35.

Science and Engineering Indicators 2006

Table 2-7
Postdocs at federally funded research and development centers: 2003

Center	Postdocs
All FFRDCs	2,908
The Aerospace Corporation	696
Los Alamos National Laboratory	406
Lawrence Berkeley National Laboratory	303
Lawrence Livermore National Laboratory	222
Argonne National Laboratory	178
Stanford Linear Accelerator Center	171
Oak Ridge National Laboratory	150
Pacific Northwest National Laboratory	136
Sandia National Laboratory	127
Brookhaven National Laboratory	119
Jet Propulsion Laboratory	82
Ames Laboratory	77
National Center for Atmospheric Research	66
Fermi National Accelerator Laboratory	47
National Renewable Energy Laboratory	45
National Radio Astronomy Observatory	23
Idaho National Engineering and Environmental Laboratory	19
Savannah River Technology Center	11
Thomas Jefferson National Accelerator Facility	11
National Optical Astronomy Observatories	9
Princeton Plasma Physics Laboratory	7
National Astronomy and Ionosphere Center	3

FFRDC = federally funded research and development center

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, special tabulations (2003).

Science and Engineering Indicators 2006

Laboratories (about 400). Other large FFRDC postdoc employers include Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Argonne National Laboratory, and Stanford Linear Accelerator Center Research Division (table 2-7).

Chapter 3 provides more detail on postdoctoral employment, including reasons for postdoc, length of postdoc, salaries, and subsequent employment. See sidebar "Postdoctoral Appointments."

Global Higher Education in S&E

The 1990s saw a tremendous increase in international migration of students and highly skilled workers. In particular, migration of students occurred from developing countries to the more developed countries, and from Europe and Asia to the United States. Some migrate temporarily for education and others remain permanently. Some of the factors that influence the decision to migrate are economic opportunities, research opportunities, research funding, and climate for innovation in the country of destination (OECD 2002). The population of individuals ages 18 to 23 (a proxy for college-age population) decreased in Europe, the United States, China, and Japan in the 1990s and is projected to continue decreasing in Europe and Japan (appendix table 2-36). This decrease is an incentive for countries to encourage in-migration of students from other countries or to increase enrollment proportions of their own college-age population. New efforts are underway to better measure international migration. See sidebar "Developing

Table 2-6
Source of funding of S&E postdocs: 1994–2003
(Percent distribution)

Source	1983	1985	1987	1989	1991	1993	1995	1997	1999	2000	2001	2002	2003
All sources	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Federal fellowships	11.9	10.6	9.5	9.4	9.0	8.5	8.8	9.0	9.4	9.1	8.3	8.7	8.1
Federal traineeships	12.5	11.3	10.6	8.9	8.8	8.5	7.6	7.2	6.6	6.0	5.7	6.0	5.7
Federal research grants	48.0	50.0	50.9	51.6	51.8	52.1	51.9	51.7	53.2	54.5	54.7	55.8	56.0
Nonfederal sources	27.6	28.1	29.1	30.1	30.5	30.9	31.6	32.1	30.7	30.3	31.3	29.5	30.2

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2006

Postdoctoral Appointments

Since the 2000 Committee on Science, Engineering and Public Policy (COSEPUP) report on the postdoctoral experience, postdoc associations, funding agencies, and employers of postdocs have sought ways to standardize the postdoc experience and improve employment conditions (COSEPUP 2000). Postdocs are paid less than other doctoral degree recipients: in 2003, the median salary for postdocs 1–5 years after completing their doctorate (across all S&E fields) was $40,000, and the median salary of nonpostdocs ranged from $48,500 to $80,000, depending on employment sector (see chapter 3). In addition, these positions often lack health insurance, retirement benefits, access to grievance procedures, pay raises, and annual reviews. Nevertheless, many doctoral degree recipients view postdocs as critical to their careers. Among postdocs in 2003 who earned their doctorate at U.S. universities, the most commonly cited reasons for taking a postdoc were that it was expected in their field (31%), to obtain additional training in their field (22%), and to work with a specific person or in a specific place (18%). Only 12% reported that they took a postdoc because no other employment was available.

Internationally Comparable Data on Mobility and Careers of Doctorate Holders."

The United States has, by far, the largest number of foreign students (undergraduate and graduate) of all Organisation for Economic Co-operation and Development (OECD) countries (figure 2-30), although other countries have higher percentages of students who are foreign. In Australia, Switzerland, New Zealand, Austria, Belgium, France, Germany, and the United Kingdom, 10% or more of students enrolled in higher education are foreign compared with about 4% in the United States (OECD 2004).

First University Degrees in S&E Fields

In 2002, more than 9 million students worldwide earned a first university degree.[14] Students earned more than 3 million of these in S&E fields (appendix table 2-37). These worldwide totals include only countries for which recent data are available (primarily countries in the Asian, European, and American regions) and therefore are an underestimation. Asian universities accounted for almost 1.5 million of the world's S&E degrees in 2002, more than 600,000 of them in engineering (figure 2-31). Students across Europe (including Eastern Europe and Russia) earned about 930,000, and students in North and Central America earned almost 600,000 S&E degrees in 2002.

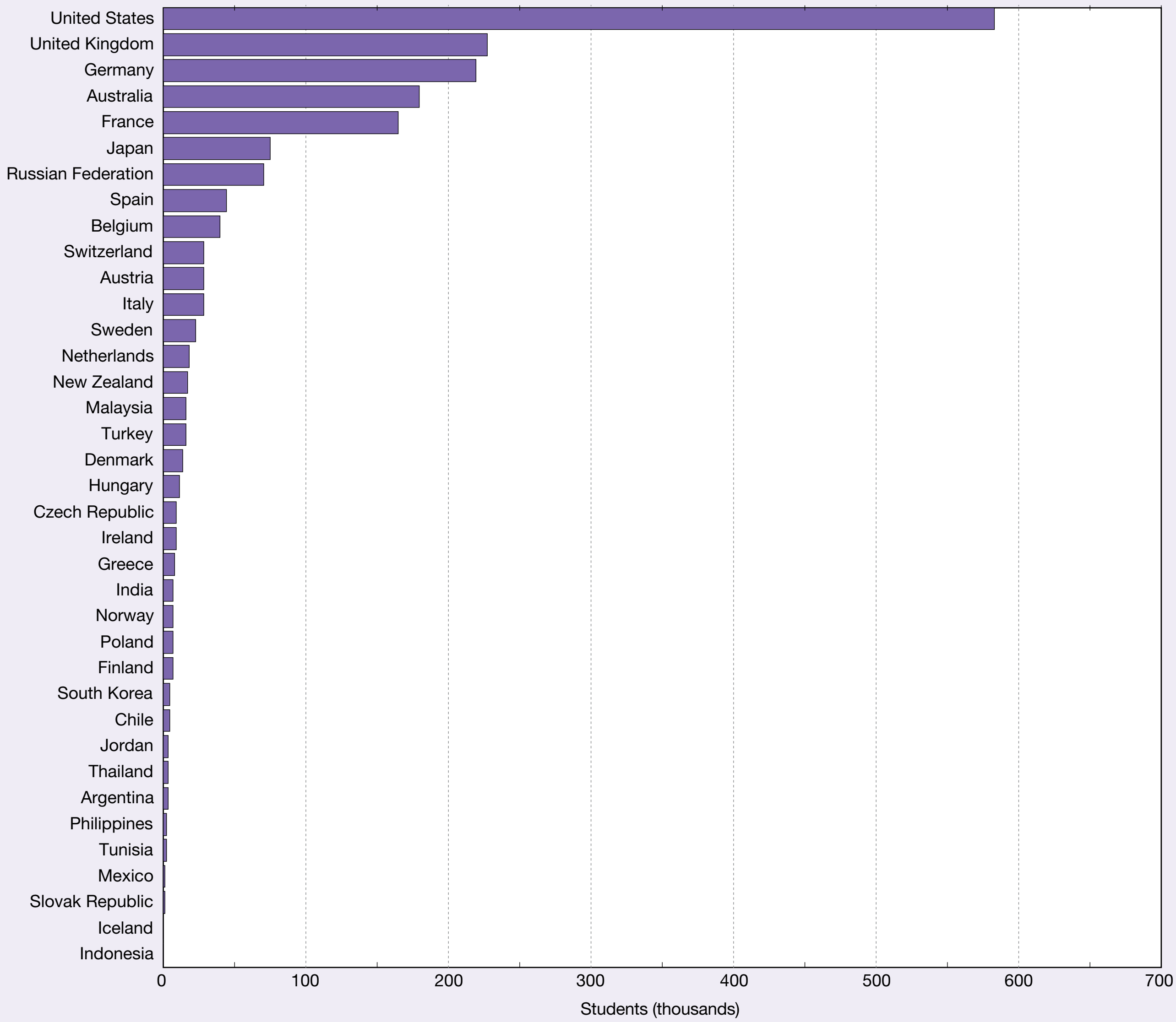
Developing Internationally Comparable Data on Mobility and Careers of Doctorate Holders

A highly educated workforce contributes to economic growth, particularly in knowledge-based economies. Yet, little internationally comparable data exist on the link between education and careers of highly educated professionals and on the mobility of doctorate holders across borders. Currently available international data have been collected from surveys that have different objectives, perspectives, and methodologies, and thus have limited use in international comparisons. A project underway by the Organisation for Economic Co-operation and Development (OECD), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and Eurostat endeavors to bring about standardization of questions asked, methodologies used, and output measures of surveys of doctorate holders. Internationally coordinated data collections about doctorate holders would build on the existing work currently being conducted by numerous countries (e.g., the United States, Canada, France, and the United Kingdom), which does not currently yield comparable information across countries. Work on standardizing survey frames, data collection methods, quality standards, questions, and tabular output for such internationally comparable surveys is under way.

The United States has historically been a world leader in providing broad access to higher education. The ratio of bachelor's degrees earned in the United States to the population of the college-age cohort remains relatively high at 33.9 per 100 in 2002. However, a number of other countries/economies, mainly in Europe, also provide a college education to approximately one-third or more of their college-age population. Costa Rica, Denmark, France, Finland, Iceland, Portugal, the Netherlands, Sweden, the United Kingdom, Bulgaria, Latvia, Lithuania, Mongolia, Australia, New Zealand, and Taiwan all have a high proportion of bachelor's degrees to the college-age population (appendix table 2-37).

For the past three decades, S&E degrees have constituted about one-third of U.S. bachelor's degrees. In several countries/economies around the world, the proportion of first degrees in S&E fields is higher than in the United States. In the most recent data available, the corresponding figures in Japan (64%), China (57%), and South Korea (47%) were considerably higher. Indonesia, Laos, Malaysia, Singapore, Taiwan, Iran, Israel, Eritrea, Ghana, Mauritius, Austria, Finland, France, Germany, Czech Republic, Canada, and Chile also have high proportions of first degrees in S&E fields. Many of these countries/economies, especially in Europe and Asia, have traditionally awarded a large proportion of their first degrees in engineering.

Figure 2-30
Foreign students enrolled in tertiary education, by country: 2002



SOURCE: Organisation for Economic Co-operation and Development, *Education at a Glance 2002* (2002).

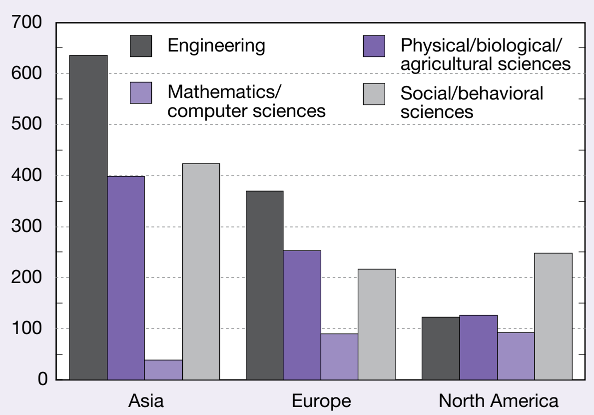
Science and Engineering Indicators 2006

Over the past two decades, the number of first university S&E degrees awarded in China, South Korea, and the United Kingdom more than doubled, and those in the United States and Japan generally increased (appendix table 2-38). In Germany, first university S&E degrees increased gradually through 1997 and then declined.[15] Engineering first university degrees have trebled over the past two decades in China and South Korea, and increased greatly in Japan and the United Kingdom, far outpacing growth in engineering degrees in the United States (figure 2-32). (See sidebar "Educational Reforms in China.") In natural sciences, the number of first university degrees in the United States has been increasing since 1989 and far exceeds the rising numbers of natural sciences degrees awarded in China, the United Kingdom, Japan, and South Korea.

Global Comparison of Participation Rates by Sex

Among Western countries for which degree data are available by sex, Canada and the United States show relatively high percentages of first university degrees in S&E awarded to women. In many Asian countries, women generally earn about one-third or less of the first university degrees awarded in S&E fields. In 2002, women earned half or more of the S&E first university degrees in the United States, Canada, Portugal, Albania, Bulgaria, Estonia, Latvia, Poland, Slovenia, Mongolia, Bahrain, Israel, Lebanon, and Qatar (appendix table 2-39).

Figure 2-31
First university S&E degrees in Asia, Europe, and North America, by field: 2002



NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCES: Organisation for Economic Co-operation and Development, Education database, http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics database, www.unesco.org/statistics; and national sources. See appendix table 2-37 for countries/economies included in each region.

Science and Engineering Indicators 2006

In the United States, Canada, Japan, and many European countries, over half of the S&E first university degrees earned by women are in the social and behavioral sciences.

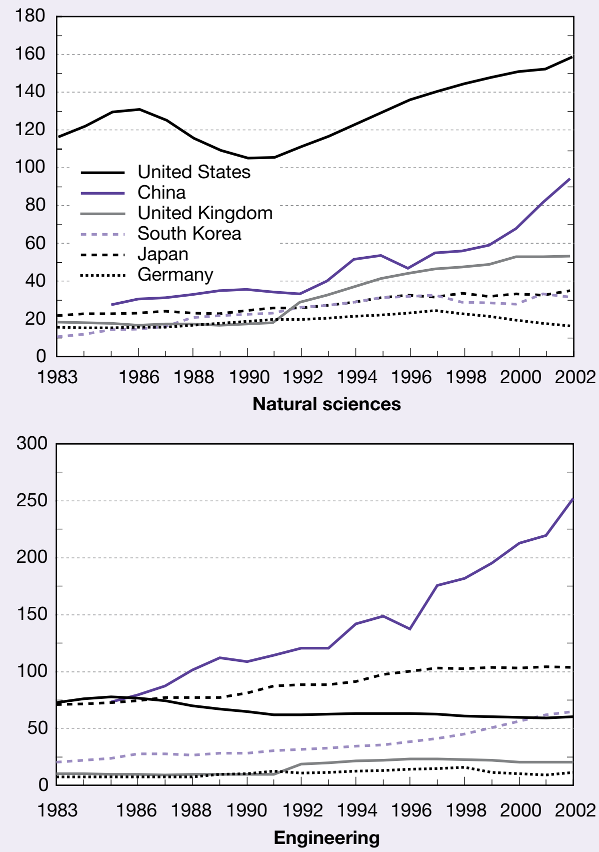
Global Comparison of S&E Doctoral Degrees

Of the more than 125,000 S&E doctoral degrees earned worldwide in 2002, 98,000 (78%) were earned outside the United States (appendix table 2-40). Figure 2-33 shows the breakdown of S&E doctoral degrees by major region and selected fields.

In 2003, women earned 39% of S&E doctoral degrees awarded in the United States. The percentage of S&E doctoral degrees earned by women in other countries and areas of the world varied widely. In Western Europe, the percentages earned by women varied from 27% in Germany to 45% in Italy. In Asia, women earned roughly one-fifth of all S&E doctoral degrees (appendix table 2-41).

For most of the past two decades, momentum in doctoral S&E programs has been strong in the United States and some Asian and European countries. By 2001, China was the largest producer of S&E doctoral degrees (more than 8,000) in the Asian region. The numbers of natural sciences and engineering (NS&E) doctoral degrees awarded in China, South Korea, and Japan have continued to rise.[16] (Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences, and mathematics.) (See appendix tables 2-42 and 2-43.) However, in the late 1990s and early 2000s, NS&E doctoral degrees leveled off or declined in the United States, the United Kingdom, and Germany (figure 2-34).

Figure 2-32
First university natural sciences and engineering degrees, by selected countries: 1983–2002 or most recent year



NOTES: Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences and mathematics. German degrees include only long university degrees required for further study.

SOURCES: China—National Bureau of Statistics of China, China Statistical Yearbook, annual series (Beijing) various years; Japan—Government of Japan, *Monbusho Survey of Education;* South Korea—Organisation for Economic Co-operation and Development, Education Online Database, http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp; United Kingdom—Higher Education Statistics Agency; Germany—Federal Statistical Office, *Prüfungen an Hochschulen;* United States—National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-38.

Science and Engineering Indicators 2006

Global Student Mobility

International migration of students and highly skilled workers has expanded in the past two decades and countries are increasingly competing for foreign students. The U.S. share of foreign students declined in recent years while Australia's and the United Kingdom's shares have increased.[17] The United States remains, however, the predominant destination for foreign students, accounting for 40% of internationally mobile students in 2004. The United

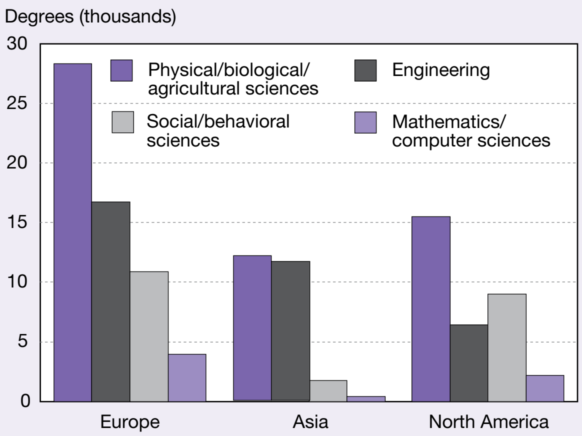
Educational Reforms in China

In 1998, China began an effort to consolidate institutions, increase funding, and reorganize its educational system, resulting in more efficient administration, reduction of competing programs, a more flexible curriculum, and rapid expansion of enrollment (Hsiung 2005). As a result of this effort, natural sciences (science, agriculture, and medicine) and engineering enrollment in Chinese universities grew from roughly 1.8 million students in 1995 to 5.8 million in 2003. More than half of all undergraduate students were enrolled in these fields in 2003. Despite reforms, several challenges remain, including increased class sizes, lack of autonomy from the government, and little academic freedom for faculty.

Kingdom accounted for 18%, Germany for 15%, France for 12%, and Australia for 6% (Institute of International Education 2004).

In addition to the United States, a number of countries worldwide have increased foreign student enrollment in recent years. Foreign student enrollment in the United Kingdom increased in the past decade. The proportion of foreign students studying S&E fields in the United Kingdom has increased, especially at the graduate level, with increasing flows of students from China and India. From 1994 to 2004, foreign graduate students studying S&E

Figure 2-33
S&E doctoral degrees earned in Europe, Asia, and North America, by field: 2001 or most recent year

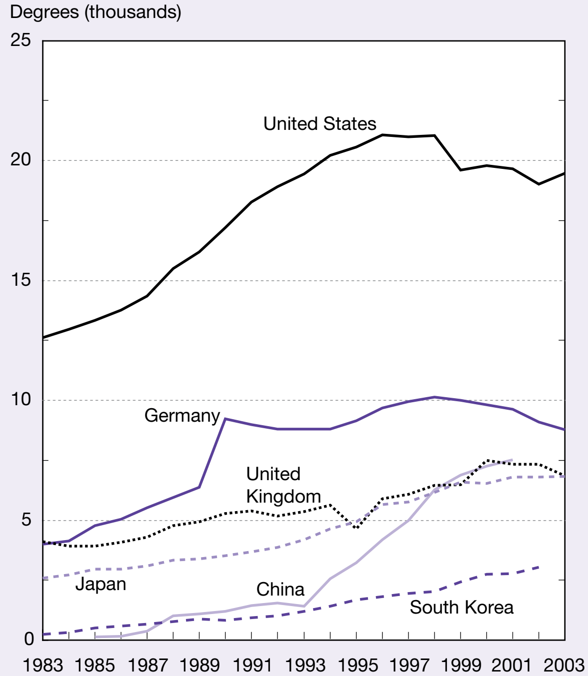


NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Asia includes China, India, Japan, South Korea, and Taiwan. Europe includes Western, Central, and Eastern Europe; see appendix table 2-40 for countries/economies included within each region.

SOURCES: Organisation for Economic Co-operation and Development, Education Online Database; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics database, http://www.unesco.org/statistics; and national sources. See appendix table 2-40.

Science and Engineering Indicators 2006

Figure 2-34
Natural sciences and engineering doctoral degrees, by selected country: 1983–2003



NOTE: Natural sciences and engineering include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences; mathematics; and engineering.

SOURCES: China—National Research Center for Science and Technology for Development; United States—National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; Japan—Government of Japan, *Monbusho Survey of Education;* South Korea—Organisation for Economic Co-operation and Development, Education Online database, http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp; United Kingdom—Higher Education Statistics Agency; and Germany— Federal Statistical Office, *Prüfungen an Hochschulen*. See appendix tables 2-42 and 2-43.

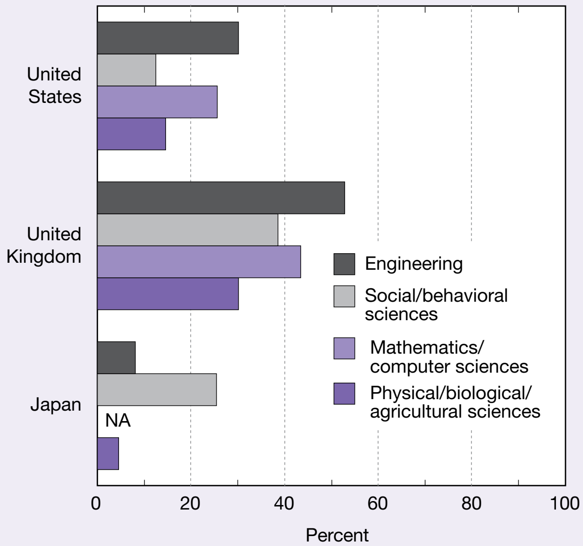
Science and Engineering Indicators 2006

in the United Kingdom increased from 29% to 41%. In graduate engineering, foreign student enrollment more than doubled from 9,300 (35% of enrollment) to 20,500 (53% of enrollment) (figure 2-35; appendix table 2-44). Students from China, Greece, India, and Malaysia accounted for most of the increase in foreign graduate engineering enrollment.

Foreign students accounted for about 27% of the French S&E graduate enrollment in 2003. About half of the 30,000 foreign S&E graduate students in France come from Africa, and Asian students account for another 20%. Although educational reforms in the European Union (EU) are encouraging student mobility among countries, only 3% of all S&E graduate students and 10% of foreign S&E graduate students in France come from other EU countries (appendix table 2-45). (See sidebar "Education Reforms in Europe.")

In Japanese universities, more than 84,000 foreign students, mainly from the Asian region, were enrolled at the undergraduate and graduate levels in 2004. More than 50,000 of these students were enrolled in S&E fields. Foreign S&E

Figure 2-35
S&E foreign graduate student enrollment, by selected country and field: 2003



NA = not available

NOTES: Japanese data include mathematics in natural sciences and computer sciences in engineering. Foreign graduate enrollment in U.S. data includes temporary residents only; U.K. and Japanese data include permanent and temporary residents.

SOURCES: United States—National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov; United Kingdom—Higher Education Statistics Agency, special tabulations; Japan—Government of Japan, Division of Higher Education, special tabulations (2005). See appendix tables 2-31, 2-44, and 2-46.

Science and Engineering Indicators 2006

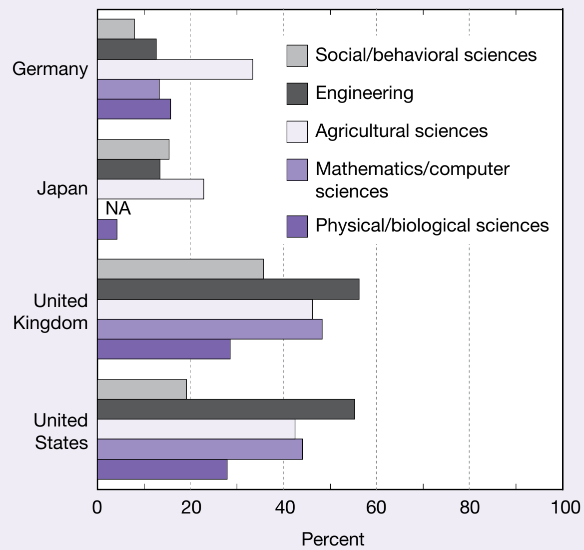
student enrollment in Japan was concentrated at the undergraduate level (34,000), mostly in the social and behavioral sciences.[18] About 17,000 foreign S&E students were enrolled in Japanese universities at the graduate level, representing 12% of the graduate students in S&E fields. Foreign S&E graduate students in Japan come mainly from China and South Korea (appendix table 2-46).

Foreign S&E students accounted for about 6% of undergraduate and 21% of graduate S&E enrollment in Canada in 2001. At both the undergraduate and graduate levels, foreign S&E students are concentrated in mathematics/computer sciences and engineering. Asian countries/economies were the top places of origin of foreign S&E graduate and undergraduate students in Canada. The United States is also among the top countries of origin of foreign students, accounting for 6% of foreign S&E graduate students and 2% of foreign S&E undergraduate students in Canada (appendix table 2-47).

International Comparison of Foreign Doctoral Degree Recipients

Like the United States, the United Kingdom and France have many foreign students among their S&E doctoral degree recipients. In 2003, 39% of S&E doctorates from the United Kingdom and 37% of S&E doctorates from U.S. universities were awarded to foreign students (both permanent and temporary visa holders). In both countries, foreign students accounted for more than half of the doctorates awarded in engineering. Foreign students account for about 14% of S&E doctorate recipients in Japan and Germany (figure 2-36; appendix table 2-48).

Figure 2-36
S&E doctoral degrees earned by foreign students, by selected country and field: 2003 or most recent year



NA = not available

NOTES: Japanese data for university-based doctorates only; excludes *ronbun hakase* doctorates awarded for research within industry. Japanese data include mathematics in natural sciences and computer sciences in engineering. For each country, data are for doctoral recipients with foreign citizenship, including permanent and temporary residents.

SOURCES: Germany—Federal Statistical Office, *Prüfungen an Hochschulen 2003*; Japan—Government of Japan, Division of Higher Education, special tabulations; United Kingdom—Higher Education Statistics Agency, special tabulations (2005); United States— National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-48.

Science and Engineering Indicators 2006

Education Reforms in Europe

In 1999, 29 European countries, through the Bologna Declaration, initiated a system of reforms in higher education in Europe. The goal of the Bologna Process is to harmonize certain aspects of higher education within participating countries by 2010 so that degrees are comparable, credits are transferable, and students, teachers, and researchers can move freely from institution to institution across national borders. Its aim is to replace the varied degree programs in existence that typically took 5 or more years to earn, with a standard 3-year bachelor's degree and a 2-year master's degree with a standardized credit system. The reform process has now been extended to more than 40 countries. It is not clear whether these new 3-year bachelor's degrees will be accepted in U.S. graduate programs. A survey of admissions officers at 90 U.S. institutions by Educational Credential Evaluators, Inc., in 2004 found that most would not consider applicants who had degrees from 3-year undergraduate programs (Bollag 2004). It is also not clear yet what effect the Bologna Process will have on the flow of foreign students into Europe.

Conclusion

The United States continues to be a world leader in S&E higher education. American freshmen continue to show interest in S&E fields. The number of S&E bachelor's degrees has held steady at about one-third of all bachelor's degrees in the United States. Meanwhile, the number of bachelor's degrees awarded in all fields and in S&E fields has continued to increase. Graduate enrollment in S&E fields is also increasing, reaching a new peak in 2003. The number of S&E doctorates awarded also increased in 2003.

Women now earn half of bachelor's degrees in S&E, although they earn much lower shares in some fields. Minority students from all groups are earning growing shares of S&E degrees at all levels. Underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives) do not participate in higher education in the same proportion as whites, but among those who complete bachelor's degrees, similar percentages of underrepresented minorities and whites earn their degrees in S&E fields.

Foreign students continue to be a large presence in U.S. S&E graduate education. Foreign student enrollment in graduate S&E programs continues to increase. Students on temporary visas earned about one-third of S&E doctorates in the United States in 2003 and more than half of the engineering doctorates. An increasing fraction of them stay in the United States: about three-quarters of foreign doctoral degree recipients in 2003 planned to stay in the United States after graduation.

However, many other countries are now increasing their capacity for higher education and many attract large numbers of foreign students. In recent years, universities in other countries, including Australia, the United Kingdom, Canada, Japan, and Germany, expanded their enrollment of foreign S&E graduate students. And, although total foreign graduate enrollment in the United States is still increasing, first-time enrollment of foreign students has decreased in some fields in the past several years as a result of visa restrictions after the events of September 11, 2001, growth in non-U.S. higher education institutions, or declines in U.S. demand for engineers and computer scientists.

Notes

1. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

2. Higher percentages of Hispanic and American Indian/Alaska Native students are enrolled in 2-year institutions compared with students from other racial/ethnic groups. The percentage of black students enrolled in 2-year institutions is roughly similar to that of white students (NSF 2003).

3. The number of S&E degrees awarded to a particular freshmen cohort is lower than the number of students reporting such intentions and reflects losses of students from S&E, gains of students from nonS&E fields after their freshman year, and general attrition from bachelor's degree programs. (See "Retention in S&E" later in this chapter.)

4. White, Asian, and Hispanic U.S. citizens and permanent residents accounted for most of the gains in undergraduate engineering enrollment in recent years. For data by race/ethnicity, see http://www.nsf.gov/statistics/wmpd/pdf/tabb-9.pdf.

5. For more detailed information by field, see *Graduate Students and Postdoctorates in Science and Engineering: Fall 2002* at http://www.nsf.gov/statistics/pubseri.cfm?TopID=2&SubID=18&SeriID=9#recentpub/.

6. Debt is measured in discrete categories ranging from none to $35,001 or more.

7. Levels of debt vary within psychology as well. Psychology doctorates who earned PsyDs, those who graduated from professional psychology schools, and those in clinical psychology had higher levels of debt. Despite differences by field, doctorate recipients from most psychology subfields had higher levels of debt than doctorate recipients from other S&E fields (NSF 2000b).

8. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

9. See the NSF report series *Science and Engineering Degrees* (http://www.nsf.gov/statistics/showpub.cfm?TopID=2&SubID=5) for longer degree trends and *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2004* (http://www.nsf.gov/statistics/pubseri.cfm?TopID=2&SubID=45&SeriID=6#recentpub) for more detail on enrollments and degrees by sex and by race/ethnicity.

10. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

11. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

12. The number of doctoral S&E degrees earned by Chinese students within Chinese universities continued to increase throughout the decade, from 1,069 in 1990 to 6,788 in 1999 (NSB 2002).

13. A current science and technology policy debate in Taiwan focuses on whether to encourage more Taiwanese to study at U.S. universities for the subsequent benefits of networking between Taiwanese and U.S. scientists and engineers.

14. A first university degree refers to the completion of a terminal undergraduate degree program. These degrees are classified as level 5A in the International Standard Classification of Education, although individual countries use different names for the first terminal degree: for example, *laureata* in Italy, *diplome* in Germany, *maitrise* in France, and *bachelor's degree* in the United States and in Asian countries.

15. Poor labor market conditions for engineers in Germany in the 1990s contributed to the decline in degrees. Since 1999, the number of students enrolled in engineering increased and is expected to result in increased degrees in the future.

16. Doctoral degree recipients in Japan have faced high unemployment rates in recent years as the number of doctoral degrees has increased (Brender 2004). Similarly, Chinese college graduates are facing high unemployment rates. In 2004, roughly 30% of 2003 Chinese college graduates remained unemployed even as the number of 2004 graduates was expected to increase by 32% (Hsiung 2005).

17. Limited university capacity for foreign students in the United Kingdom and Australia may restrict the amount of future growth in foreign enrollment, whereas Japan and Germany have greater capacity to expand (OECD 2004).

18. At the undergraduate level, about 20% of foreign students are permanent residents in Japan. In contrast, at the graduate level, only a small percentage of foreign students (5%) are permanent residents.

Glossary

Bologna Process: An effort initiated by the 1999 Bologna Declaration to harmonize higher education within participating European countries by the year 2010 so that degrees are comparable; credits are transferable; and students, teachers, and researchers can move freely from institution to institution across national borders.

Distance education: Situations where students are not located with their teachers/learning institutions and therefore require specialized instructional techniques, technologies, and means of communication to promote learning.

Early college high school: Small school situated on the campus of a community college with a curriculum that leads to simultaneous award of both a high school diploma and an associate of arts degree.

Federally funded research and development center: R&D-performing organizations exclusively or substantially financed by the federal government either to meet particular R&D objectives or, in some instances, to provide major facilities at universities for research and associated training purposes; each FFRDC is administered either by an industrial firm, a university, or a nonprofit institution.

First university degree: completion of a terminal undergraduate degree program; these degrees are classified as level 5A in the International Standard Classification of Education, although individual countries use different names for the first terminal degree.

Industrial learning centers: Corporate "universities," independent nonprofit institutions, and for-profit and nonprofit subsidiaries of institutions; most offer noncredit, nondegree courses narrowly targeted at retraining the workforce and addressing other company needs.

Institutional control: Whether an academic institution is public or private.

Stay rate: The proportion of students on temporary visas who have plans to stay in the United States immediately after degree conferral.

Time to degree: the time it takes to earn an S&E doctorate; can be measured either as **total time to degree**—the median number of years between baccalaureate receipt and doctorate receipt—or **registered time to degree**—the median number of years registered in graduate school between graduate entry and doctorate receipt.

Underrepresented minority: blacks, Hispanics, and American Indians/Alaska Natives are considered to be underrepresented in S&E.

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Chapter 3
Science and Engineering Labor Force

List of Sidebars

List of Tables

List of Figures

Highlights

The science and engineering workforce in the United Sates has grown rapidly, both over the last half century and the last decade.

- From 1950 to 2000, employment in S&E occupations grew from fewer than 200,000 to more than 4 million workers, an average annual growth rate of 6.4%.
- Between the 1990 and 2000 censuses, S&E occupations continued to grow at an average annual rate of 3.6%, more than triple the rate of growth of other occupations.
- Between 1980 and 2000, the total number of S&E degrees earned grew at an average annual rate of 1.5%, which was faster than labor force growth, but less than the 4.2% growth of S&E occupations. S&E bachelor's degrees grew at a 1.4% average annual rate, and S&E doctorates at 1.9%.

The S&E labor force does not include just those in S&E occupations. S&E skills are needed and used in a wide variety of jobs.

- Approximately 12.9 million workers say they need at least a bachelor's degree level of knowledge in S&E fields in their jobs. However, only 4.9 million were in occupations formally defined as S&E.
- Twelve million workers have an S&E degree as their highest degree and 15.7 million have at least one degree in an S&E field.
- Sixty-six percent of S&E degree holders in non-S&E occupations say their job is related to their degree, including many in management and marketing occupations.

S&E occupations have generally had low unemployment, but were unusually affected by the most recent recession.

- Unemployment in S&E occupations reached 4.6% in 2003, the highest level in the 22 years for which it has been calculated.
- The difference between the S&E unemployment rate and the unemployment rate for all workers fell to just 1.4 percentage points in 2003, compared with 6.9 percentage points in 1983.

Increases in median real salary for recent S&E graduates between 1993 and 2003 indicate relatively high demand for S&E skills during the past decade.

- The median real salary for recent S&E bachelor's degree recipients increased more than that of recipients of non-S&E bachelor's degrees, in all broad S&E fields.
- The largest increases for recent bachelor's degree recipients were in engineering (34.1%), computer and mathematical sciences (28.0%), and life sciences (24.5%). Smaller increases were found for recent bachelor's degree recipients in social sciences (15.8%), physical sciences (9.5%), and non-S&E fields (7.7%).
- For all broad S&E fields, median real salaries grew faster over the decade for master's degree recipients than for bachelor's in the same field. This ranged from a 31.8% increase in median real earnings for recipients of physical science master's degrees to a 54.8% increase for recipients of master's degrees in computer and mathematical sciences. At the master's level, however, non-S&E degrees also enjoy large increases in real median salary, growing by 52.7%.
- Median salary increased by only 0.3% for recent doctoral degree recipients in life sciences over the past 10 years. This reflects in part the increased participation in postdoc positions, which provide further training but traditionally pay low salaries.

Retirements from the S&E labor force are likely to become more significant over the next decade.

- Twenty-nine percent of all S&E degree holders in the labor force are age 50 or over. Among S&E doctorate holders in the labor force, 44% are age 50 or over.
- By age 62, half of S&E bachelor's degree holders had left full-time employment. Doctorate degree holders work slightly longer, with half leaving full-time employment by age 66.

The importance of foreign-born scientists and engineers to the S&E enterprise in the United States continues to grow.

- Twenty-five percent of all college-educated workers in S&E occupations in 2003 were foreign born.
- Forty percent of doctorate degree holders in S&E occupations in 2003 were foreign born.
- Among all doctorate holders resident in the United States in 2003, a majority in computer science (57%), electrical engineering (57%), civil engineering (54%), and mechanical engineering (52%) were foreign born.

The proportions of women, blacks, and Hispanics in S&E occupations have continued to grow over time, but are still less than their proportions of the population.

- Women were 12% of those in S&E occupations in 1980 and 25% in 2000. However, the growth in representation between 1990 and 2000 was only 3 percentage points.
- The representation of blacks in S&E occupations increased from 2.6% in 1980 to 6.9% in 2000. The representation of Hispanics increased from 2.0% to 3.2%. However, for Hispanics, this is proportionally less than their increase in the population.

Introduction

Chapter Overview

Although workers with science and engineering skills still make up only a fraction of the total U.S. civilian labor force, their effect on society belies their numbers. These workers contribute enormously to technological innovation and economic growth, research, and increased knowledge. Workers with S&E skills include technicians and technologists, researchers, educators, and managers. In addition, many others with S&E training use their skills in a variety of nominally non-S&E occupations (such as writers, salesmen, financial managers, and legal consultants), and many niches in the labor market require them to interpret and use S&E knowledge.

In the last half century, the size of the S&E labor force has grown dramatically—with employment in S&E occupations growing 2,510% between 1950 and 2000 (albeit from a small base of 182,000 jobs). Although the highest growth rates occurred in the 1950s, employment in S&E occupations in the 1990s continued to grow by 3 to 4 times the growth of other jobs.

This growth in the S&E labor force was largely made possible by three factors: (1) increases in S&E degrees earned by both native and foreign-born students, (2) both temporary and permanent migration to the United States of those with foreign S&E education, and (3) the relatively small numbers of scientists and engineers old enough to retire. Many have expressed concerns (see National Science Board 2003) that changes in each of these factors may limit the future growth of the S&E labor force in the United States.

Chapter Organization

This chapter has four major sections. First is a general profile of the U.S. S&E labor force. This includes demographic characteristics (population size, sex, and race/ethnicity). It also covers educational backgrounds, earnings, places of employment, occupations, and whether the S&E labor force makes use of S&E training. Much of the data in this section comes from the National Science Foundation's (NSF) 2003 National Survey of College Graduates (NSCG) and the 2003 Survey of Doctorate Recipients.

Second is a look at the labor market conditions for recent S&E graduates—graduates whose labor market outcomes are most sensitive to labor market conditions. For recent S&E doctoral degree recipients, the special topics of academic employment and postdoc appointments are also examined.

Third is the age and retirement profile of the S&E labor force. This is key to gaining insights into the possible future structure and size of the S&E-educated population.

The last section focuses on the global S&E labor force, both its growth abroad and the importance of the international migration of scientists and engineers to the United States and to both sending and destination countries elsewhere in the world.

U.S. S&E Labor Force Profile

This section profiles the U.S. S&E labor force, providing specific information about its size, recent growth patterns, projected labor demand, and trends in sector of employment. It also looks at workers' use of their S&E training, educational background, and salaries.

Section Overview

The S&E labor force includes both individuals in S&E occupations and many others with S&E training who may use their knowledge in a variety of jobs. Employment in S&E occupations has grown rapidly over the past two decades and is currently projected to continue to grow faster than general employment through the next decade. Although most individuals with S&E degrees do not work in occupations with formal S&E titles, most of them, even at the bachelor's degree level, report doing work related to their degree even in mid- and late-career. The proportion of women and ethnic minorities in the S&E labor force continues to grow, but with the exception of Asians/Pacific Islanders, remains smaller than their proportion of the overall population.

How Large Is the U.S. S&E Workforce?

Estimates of the size of the U.S. S&E workforce vary based on the criteria used to define scientist or engineer. Education, occupation, field of degree, and field of employment are all factors that may be considered. (See sidebar, "Who Is a Scientist or an Engineer?")

The size of the S&E workforce in 2003 varies between approximately 4 million and 15 million individuals, depending on the definition and perspective used (see table 3-1).

In 2003, 15.7 million individuals had at least one degree in an S&E field. This broader definition of the S&E workforce may be most relevant to many of the ways science and technical knowledge is used in the United States. A slightly smaller number, 11.9 million, has an S&E degree as its highest degree.

If the labor force definition is limited to those in S&E occupations with at least a bachelor's degree, the 2003 NSF Scientists and Engineers Statistical Data System (SESTAT) data estimated 4.9 million workers, whereas the U.S. Census Bureau's 2003 American Community Survey estimated 4.0 million. Occupation-based estimates not limited to college graduates include 5.0 million in November 2003 from the Bureau of Labor Statistics (BLS) Occupational Employment Statistics Survey and 5.6 million from the 2003 American Community Survey.

A third measure, based on self-reported need for S&E knowledge, is available from the 2003 SESTAT for workers with degrees from all fields of study. An estimated 12.9 million workers reported needing at least a bachelor's degree level of S&E knowledge—with 9.2 million reporting a need for knowledge of the natural sciences and engineering and 5.3 million a need for knowledge of the social sciences. That the need for S&E knowledge is more than double the number in

Who Is a Scientist or an Engineer?

The terms scientist and engineer have many definitions, none of them perfect. (For a more thorough discussion, see *SESTAT and NIOEM: Two Federal Databases Provide Complementary Information on the Science and Technology Labor Force* [NSF/SRS 1999b] and "Counting the S&E Workforce—It's Not That Easy" [NSF/SRS 1999a]). This chapter uses multiple definitions for different analytic purposes; other reports use even more definitions. The three main definitions used in this chapter are:

- **Occupation.** The most common way to count scientists and engineers in the workforce is to include individuals having an occupational classification that matches some list of S&E occupations. Although considerable questions can arise regarding how well individual write-ins or employer classifications are coded, the occupation classification comes closest to defining the work a person performs. (For example, an engineer by occupation may or may not have an engineering degree.) One limitation of classifying by occupation is that it will not capture individuals using S&E knowledge, sometimes extensively, under occupational titles such as manager, salesman, or writer.* It is common for individuals with an S&E degree in such occupations to report that their work is closely related to their degree and, in many cases, to also report R&D as a major work activity.
- **Highest degree.** Another way to classify scientists and engineers is to focus on the field of their highest (or most recent) degree. For example, classifying as "chemist" a person who has a bachelor's degree in chemistry but who works as a technical writer for a professional chemists' society magazine may be appropriate. Using this "highest degree earned" classification does not solve all problems, however. For example, should a person with a bachelor's degree in biology and a master's degree in engineering be included among biologists or engineers? Should a person with a bachelor's degree in political science be counted among social scientists if he also has a law degree? Classifying by highest degree earned in situations similar to the above examples may be appropriate, but one may be uncomfortable excluding an individual who has both a bachelor's degree in engineering and a master's degree in business administration from an S&E workforce analysis.
- **Need for S&E knowledge.** Many individuals identify their jobs as requiring at least a bachelor's degree level of knowledge in S&E—not all of whom have such a degree.

*For example, in most collections of occupation data a generic classification of postsecondary teacher fails to properly classify many university professors who would otherwise be included by most definitions of the S&E workforce. The Scientists and Engineers Statistical Data System (SESTAT) data mostly avoids this problem through use of a different survey question, coding rules, and respondent followups.

Table 3-1
Concepts and counts of S&E labor force: 2003

Concept	Education coverage	Source	Number
Occupation			
Employment in S&E occupations	All	2003 BLS Occupations and Employment Survey	4,962,000
Employment in S&E occupations	Bachelor's and above	2003 NSF SESTAT data	4,928,000
Employment in S&E occupations	Bachelor's and above	2003 American Community Survey	4,014,000
Employment in S&E occupations	All	2003 American Community Survey	5,604,000
Education			
Highest degree in S&E field	Bachelor's and above	2003 NSF SESTAT data	11,891,000
Any degree in S&E field	Bachelor's and above	2003 NSF SESTAT data	15,689,000
Need for S&E knowledge			
At least bachelor's degree-level knowledge in S&E	Bachelor's and above	2003 NSF SESTAT data	12,851,000
At least bachelor's degree-level knowledge in natural sciences and engineering	Bachelor's and above	2003 NSF SESTAT data	9,211,000
At least bachelor's degree-level knowledge in social sciences	Bachelor's and above	2003 NSF SESTAT data	5,333,000

BLS = Bureau of Labor Statistics; NSF = National Science Foundation

SOURCES: NSF, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov; U.S. Department of Labor, BLS, Occupations and Employment Survey (2003); and U.S. Census Bureau, American Community Survey (2003).

Science and Engineering Indicators 2006

formal S&E occupations suggests the pervasiveness of technical knowledge in the modern workplace.

S&E Workforce Growth

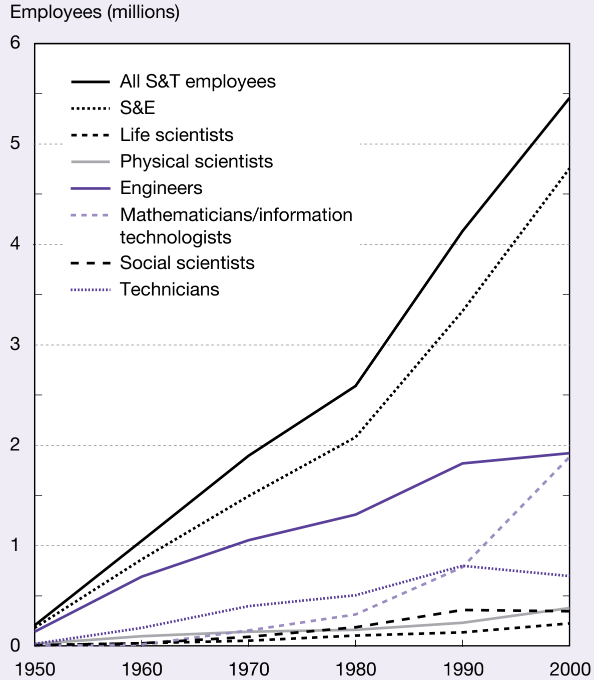
Despite some limitations in measuring the S&E labor force, occupation classifications allow examination of growth in at least one measure of scientists and engineers over extended periods. According to data from the decennial censuses, the number of workers in S&E occupations grew to 4.0 million, at an average annual rate between 1950 and 2000 of 6.4%—compared with a 1.6% average annual rate for the whole workforce older than age 18. By a broader definition of the science and technology (S&T) occupations (including technicians and programmers) S&T occupations grew to 5.5 million at a 6.8% average annual rate (figures 3-1 and 3-2).

The growth rate of S&E employment continued to be greater than for the full workforce in the 1990s (see figure 3-2, done with a log scale to better compare growth rates). S&E employment grew between 1990 and 2000 at a 3.6% average annual rate (and S&T employment at a 2.8% average annual rate) compared with 1.1% for the whole workforce. Social scientist and technician occupations experienced declines in employment in the 1990s.

In all broad categories of S&E fields, employment in the occupations directly associated with the field has grown faster than new degree production (see chapter 2 for a fuller discussion of S&E degrees). Average annual growth rates of employment and degree production are shown in figure 3-3 for 1980–2000. Although employment grew at an average annual rate of 4.2%, total S&E degree production grew by a smaller 1.5%. With the exception of the social sciences, there was greater growth in the number of graduate degrees in each field, with total S&E master's degrees granted growing at an average annual rate of 2.0% and doctoral degrees at 1.9%.

Using data from the monthly Current Population Survey (CPS) from 1993 to 2004 to look at employment in S&E occupations across all sectors and education levels creates a very similar view, albeit with some significant differences. The 3.1% average annual growth rate in all S&E employment is almost triple the rate for the general workforce. This is reflected in the growing proportion of total jobs in S&E occupations, which increased from 2.6% in 1983 to 3.9% in 2004. Also noteworthy are the decreases in employment in

Figure 3-1
Science and technology employment: 1950–2000



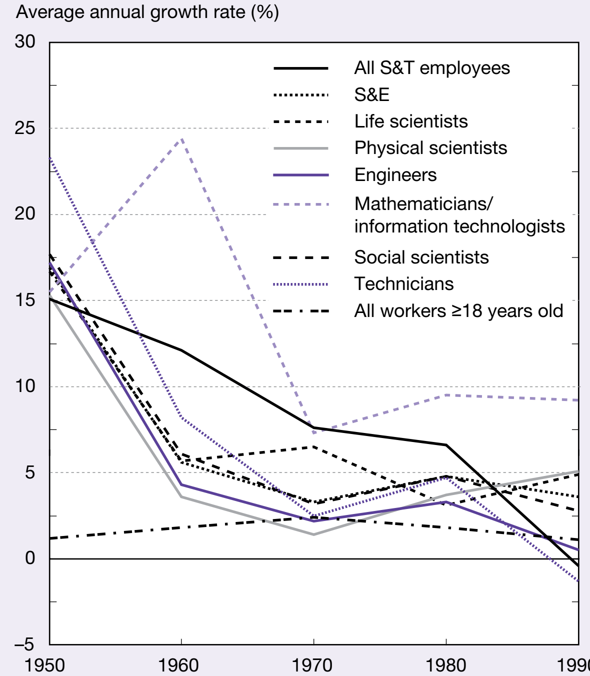
S&T = science and technology

NOTE: Data include those with bachelor's degrees or higher in science occupations, some college and above in engineering occupations, and any education level for technicians and computer programmers.

SOURCE: B.L. Lowell, Estimates of the Growth of the Science and Technology Workforce, Commission on Professionals in Science and Technology (forthcoming). See appendix table 3-1.

Science and Engineering Indicators 2006

Figure 3-2
Annual growth rate in science and technology employment, by decade: 1950–90



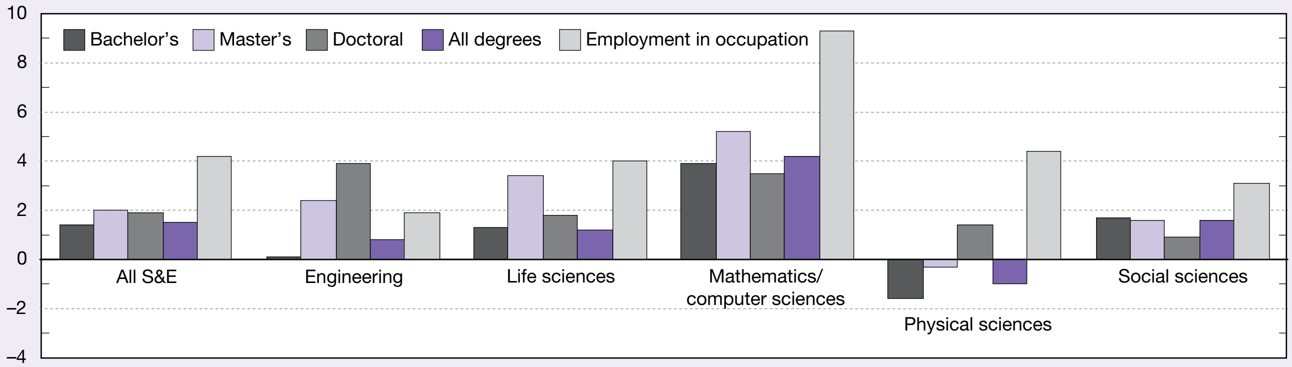
S&T = science and technology

NOTE: Data include those with bachelor's degrees or higher in science occupations, some college and above in engineering occupations, and any education level for technicians and computer programmers.

SOURCE: B.L. Lowell, Estimates of the Growth of the Science and Technology Workforce, Commission on Professionals in Science and Technology (forthcoming). See appendix table 3-1.

Science and Engineering Indicators 2006

Figure 3-3
Annual average growth rate of degree production and occupational employment, by S&E field: 1980–2000



SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), special tabulations from U.S. Census Bureau, Public-Use Microdata Sample (PUMS) (1980–2000); and NSF/SRS data on degree production. See appendix table 3-2.

Science and Engineering Indicators 2006

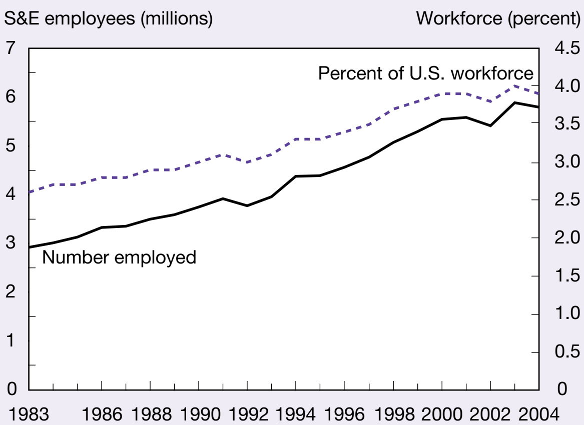
S&E occupations between 1991 and 1992 and between 2001 and 2002—evidence that S&E employment is not exempt from economic downturns (see figure 3-4).

Projected Demand for S&E Workers

The most recent occupational projections from BLS, for 2002–12, forecast that employment in S&E occupations will increase about 70% faster than the overall growth rate for all occupations (figure 3-5). It is worth noting that these projections involve only the demand for strictly defined S&E occupations, and do not include the wider range of jobs in which S&E degree holders often use their training.

S&E occupations are projected to grow by 26% from 2002 to 2012, while employment in all occupations is projected to grow 15% over the same period (BLS 2004). This is a revision of BLS projections for 2000 to 2010 that projected a 47% increase in S&E employment (BLS 2001).

Figure 3-4
U.S. workforce in S&E occupations: 1983–2004



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations from U.S. Census Bureau, Current Population Survey Monthly Outgoing Rotation files (1983–2004). See appendix table 3-3.

Science and Engineering Indicators 2006

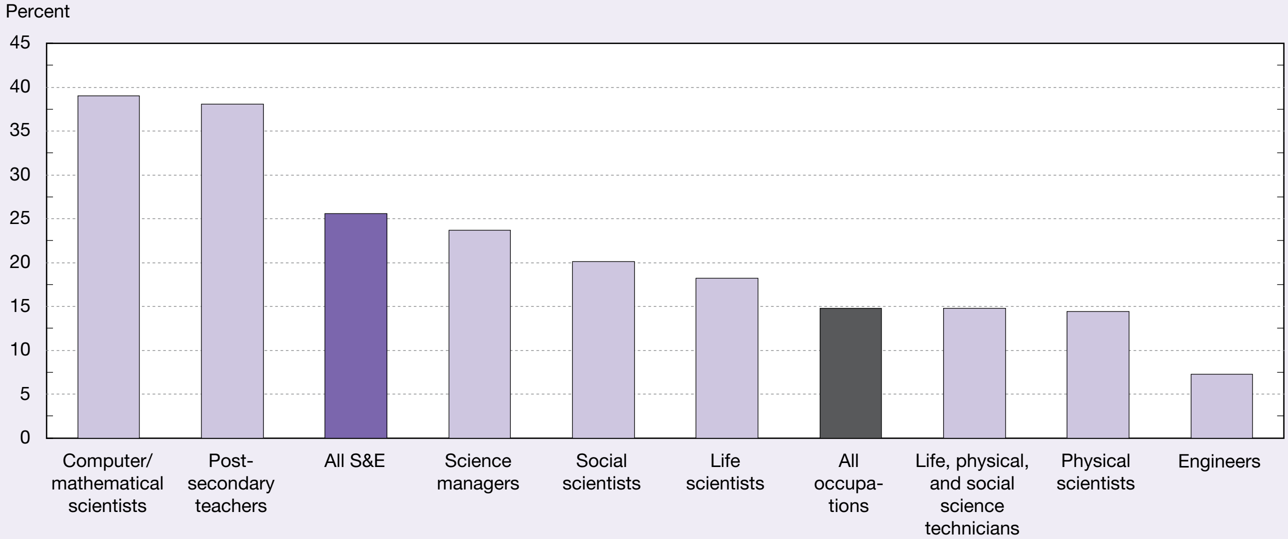
Although BLS labor force projections often do a reasonable job of forecasting employment in many occupations (see Fullerton, 2003), S&E occupations may be particularly difficult to forecast. Many spending decisions on research and development by corporations and governments are difficult or impossible to anticipate. In addition, R&D money increasingly crosses borders in search of the best place to have particular research performed. (The United States may be a net recipient of these R&D funds; see discussion in chapter 4). Finally, it may be difficult to anticipate new products and industries that may be created via the innovation processes that are most closely associated with scientists and engineers.

Approximately 78% of BLS's projected increase in S&E jobs is in computer-related occupations (see table 3-2). Aside from computer-related occupations, faster than average growth is projected for life scientists, social scientists, and for the S&E-related occupation of science manager. An occupation of interest, "postsecondary teacher" (which includes all fields of instruction), is projected to grow almost as fast as computer occupations, rising from 1.6 to 2.2 million over the decade between 2002 and 2012.

Overall engineering employment is forecasted by BLS to grow only about 7% over the decade. Within engineering occupations, industrial engineering is projected to have the biggest relative employment gains, increasing by 20%, followed by civil engineering and environmental engineering, each projected to increase by about 18%.

BLS also forecasts that job openings in S&E occupations over the 2002–12 period will be a slightly greater proportion of current employment than for all occupations: 43% versus 39% (see figure 3-6). Job openings include both growth in total employment and openings caused by attrition. One big reason that S&E job openings are not much higher than average job growth is retirements (see the discussion later in this

Figure 3-5
Projected increase in S&E employment, by occupation: 2002–12



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections. See appendix table 3-4.

Science and Engineering Indicators 2006

chapter). Although retirements in S&E may be expected to increase rapidly in coming years and increase in percentage terms faster than retirements from other employment, scientists and engineers are still on average younger than the labor force as a whole. Retirement is also the likely reason that S&E job openings are less dominated by computer-related occupations, which have younger age distributions than other S&E areas.

Salary Changes as an Indicator of Labor Market Conditions

Sometimes discussions of S&E labor markets use difficult-to-define words like "surplus" or "shortage" that imply a close matching between particular types of educational credentials and particular jobs. As discussed previously in this chapter, individuals with a particular S&E degree may use their training in occupations nominally associated with different S&E fields or in occupations not considered S&E. They may also work in various sectors of employment such as private industry, academia, government, or K–12 education. All of this makes any "simple" comparison of supply and demand estimates impossible.

One indicator of the level of labor market demand for a set of skills is the changes observed over time in the pay received by individuals with those skills, regardless of what occupations they may be in.[1] The changes between 1993 and 2003 in real (inflation-adjusted) median salary for recent graduates in S&E and non-S&E fields are shown in figure 3-7. Among bachelor's degree recipients in non-S&E fields 1–5 years after degree, median real salaries grew by only 7.7% over 10 years. In contrast, recent bachelor's degree recipients in all S&E fields enjoyed greater increases in median real salary: 24.5% in the life sciences, 28.0% in

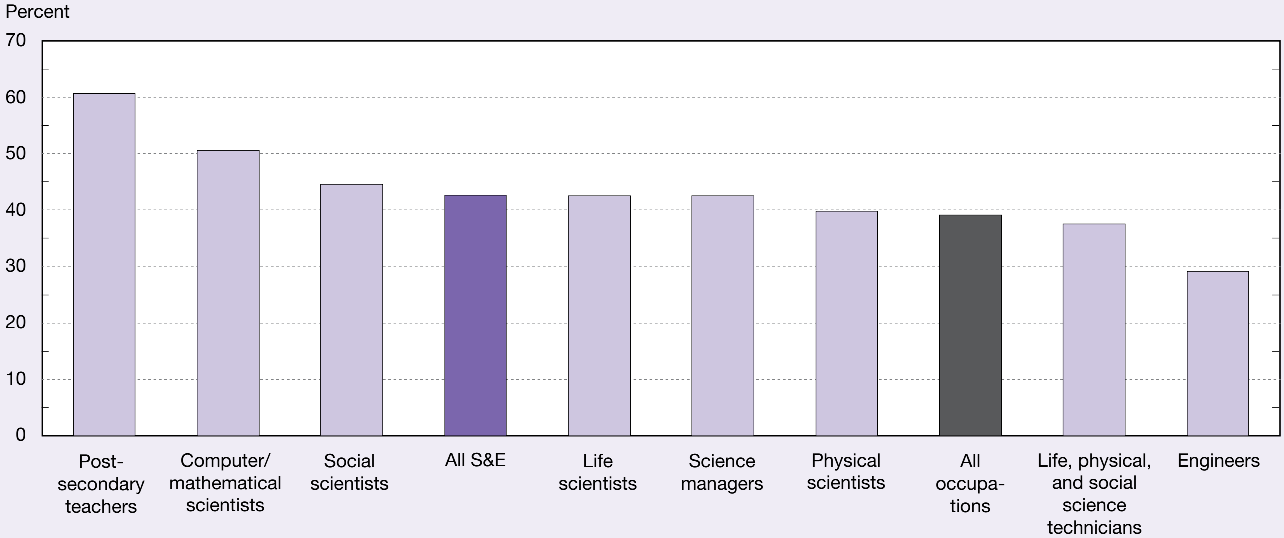
Table 3-2
S&E jobs: 2002 and projected 2012
(Thousands)

Occupation	2002	2012	Change
All occupations	144,014	165,319	21,305
S&E	4,873	6,119	1,246
Computer/mathematical scientists	2,504	3,480	976
Engineers	1,478	1,587	109
Life scientists	214	253	39
Physical scientists	251	287	36
Social scientists/related occupations	426	512	86

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections, *National Industry-Occupation Employment Projections 2002–2012* (2004).

Science and Engineering Indicators 2006

Figure 3-6
Projected job openings as percentage of 2002 employment, by occupation: 2002–12



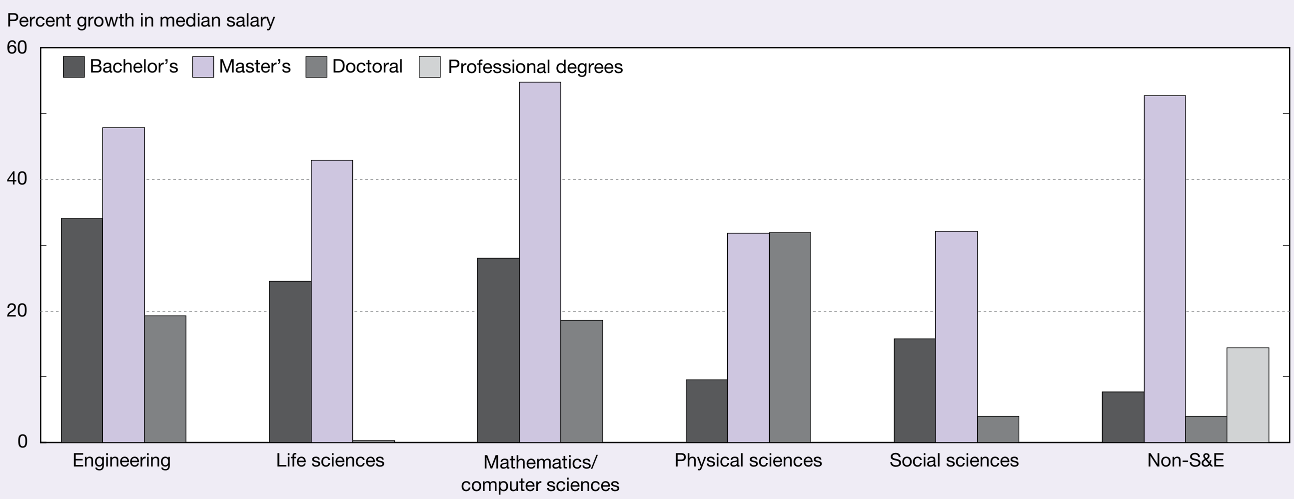
SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections. See appendix table 3-4.

Science and Engineering Indicators 2006

computer and mathematical sciences, and 34.1% in engineering. The smallest increase at the S&E bachelor's degree recipient level was in the physical sciences at 9.5%.

Among recent master's degree recipients, all fields, including non-S&E, showed increases in median real salaries between 1993 and 2003. Non-S&E master's degree recipients experienced a 52.7% increase in median real salary, surpassed only by master's degrees in computer and mathematical science (54.8% increase). Real median earnings for other recent S&E master's degree recipients grew by 47.9% in engineering, 42.9% in the life sciences, 32.1% in the social sciences, and 31.8% in the physical sciences. These high growth rates in earnings for recent master's degree recipients in all fields are indicative of the increasing returns to high skills throughout the U.S. economy during this period.

Figure 3-7
Inflation-adjusted change in median salary 1–5 years after degree, by field and level of highest degree: 1993–2003



NOTE: Non-S&E fields include the SESTAT categories "non-S&E" and "S&E related."

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates (1993) and preliminary estimates (2003).

Science and Engineering Indicators 2006

Among recent doctoral degree recipients, the increase in median real salary was greatest for those in the physical sciences (31.9%) and smallest was in the life sciences (0.3%). Recent non-S&E doctorate recipients increased real earnings by only 4.0%, the same rate as recent doctorates in social sciences. Real earnings for recent doctoral degree recipients increased by 19.3% in engineering and 18.6% in mathematical and computer sciences. In all fields except the physical sciences, earnings increased less in percentage terms than at the master's level. This may reflect the greater proportion of doctorate holders in academia and, particularly in the case of life sciences, in postdoc positions.

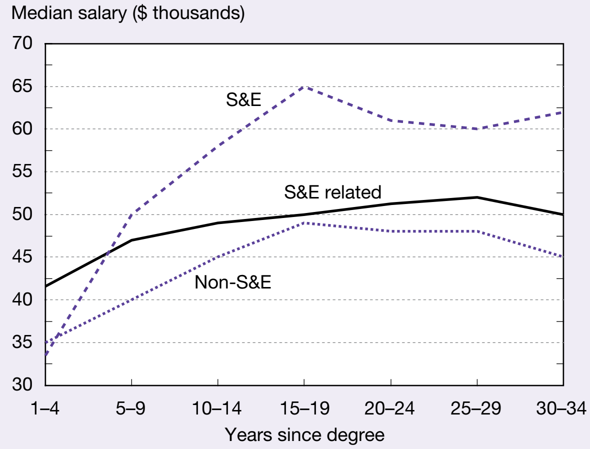
Evaluation of recent doctoral degree recipient salaries is made more difficult by the earnings differentials between academic and nonacademic employment, as well as the increasing prevalence of postdocs. As shown in figure 3-8, recent doctoral degree recipients in engineering, life sciences, and mathematical and computer sciences actually had lower median salaries than recent master's degree recipients in the same fields.

The median salary for recent non-S&E master's degree recipients was higher than for either those with non-S&E doctorates or non-S&E professional degrees (law, medicine, and other professional degrees).

Salaries Over a Person's Working Life

Estimates of median salary at different points in a person's working life are shown in figure 3-9 for individuals with bachelor's degrees in a variety of fields. At all years since degree, holders of S&E bachelor's degrees earn more than those with non-S&E degrees. Median salaries for S&E bachelor's degree holders in 2003 peaked at $65,000 at 15–19 years after degree, compared to $49,000 for those with non-S&E bachelor's degrees. Those with bachelor's degrees in S&E-related fields (such as technology, architecture, or health) also earned more than non-S&E bachelor's holders at most years since degree, peaking at $52,000 25–29 years after degree—much less than for S&E graduates.

Figure 3-9
Median salaries for bachelor's degree holders, by years since degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates, preliminary estimates (2003).

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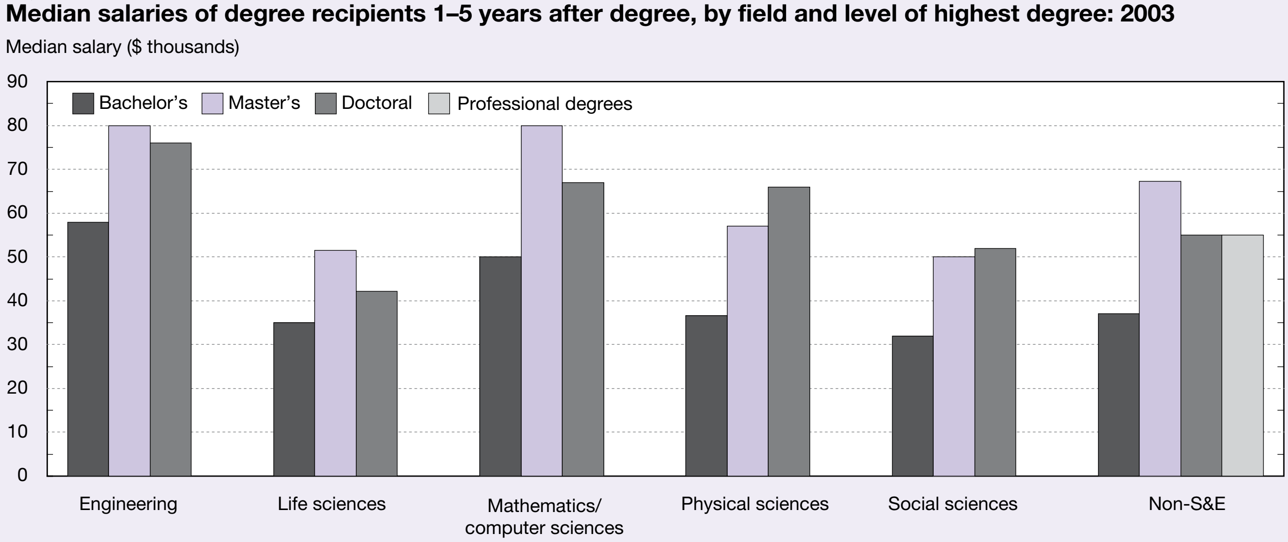
Figure 3-8
Median salaries of degree recipients 1–5 years after degree, by field and level of highest degree: 2003



NOTE: Non-S&E fields include the SESTAT categories of "non-S&E" and "S&E-related."

SOURCE: National Science Foundation. Division of Science Resources Statistics, National Survey of College Graduates, preliminary estimates (2003)

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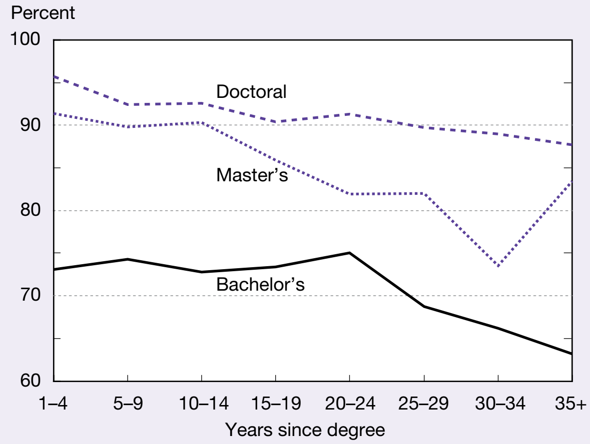
How Are People With an S&E Education Employed?

Although the majority of S&E degree holders do not work in S&E occupations, this does not mean they do not use their S&E training. In 2003, of the 6.0 million individuals whose highest degree was in an S&E field and who did not work in S&E occupations, 66% indicated that they worked in a job either closely or somewhat related to the field of their highest S&E degree (table 3-3).

One to four years after receiving their degrees, 96% of S&E doctoral degree holders say that they have jobs closely or somewhat related to the degrees they received compared with 91% of master's degree recipients and 73% of bachelor's degree recipients (figure 3-10). This relative ordering of relatedness by level of degree holds across all periods of years since recipients received their degrees. However, at every degree level, the relatedness of job to degrees tends to fall with time since degree, with some exceptions for older workers, who may be more likely to still work when their jobs are related to their education. There are many good reasons for this trend: individuals may change their career interests over time, gain skills in different areas while working, take on general management responsibilities, or forget some of their original college training (or some of their original college training may become obsolete). Given these possibilities, the career-cycle decline in the relevance of an S&E degree is only modest. When a somewhat weaker criterion is used such as are jobs "closely" or "somewhat" related to an individual's field of highest degree, even higher proportions of S&E graduates report their jobs being related to their degrees. More than 70% of S&E bachelor's degree holders report their jobs are at least somewhat related to their field of degree until 25–29 years after their degrees. Even 30–34 years after their degree, only 11% of S&E doctoral degree holders report their jobs are not related to their field of degree, and only one-third of S&E bachelor's degree holders (figure 3-10).

Figure 3-10
Employed individuals with S&E highest degrees in jobs closely or somewhat related to highest degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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Figure 3-11 shows differences in a stricter criterion for relatedness: the percentages of individuals who reported their job as closely related to their field of degree, by major S&E disciplines for bachelor's degree holders. From 1 to 4 years after receiving their degrees, the percentage of S&E bachelor's degree holders who reported their jobs are closely related to their field of degree ranged from 28% for individuals with degrees in social sciences to 59% for individuals with degrees in engineering. Between these extremes, most other S&E fields showed similar percentages for recent graduates: 57% for computer and mathematical sciences, 54% for physical sciences, and 48% for life sciences. As with relatedness in general, this stricter definition of relatedness of job and degree declines only slowly with years since degree.

Table 3-3
Individuals with S&E as highest degree employed in non-S&E occupations, by highest degree and relation of degree to job: 2003
(Percent)

Highest degree	*n* (thousands)	Degree related to job: Closely	Somewhat	Not
All degree levels[a]	6,022	33.3	32.9	33.8
Bachelor's	4,868	29.8	33.6	36.7
Master's	972	48.3	30.0	21.6
Doctoral	303	42.3	36.6	21.2

[a]Includes professional degrees.

NOTES: Non-S&E occupations include the SESTAT categories "non-S&E" and "S&E related." Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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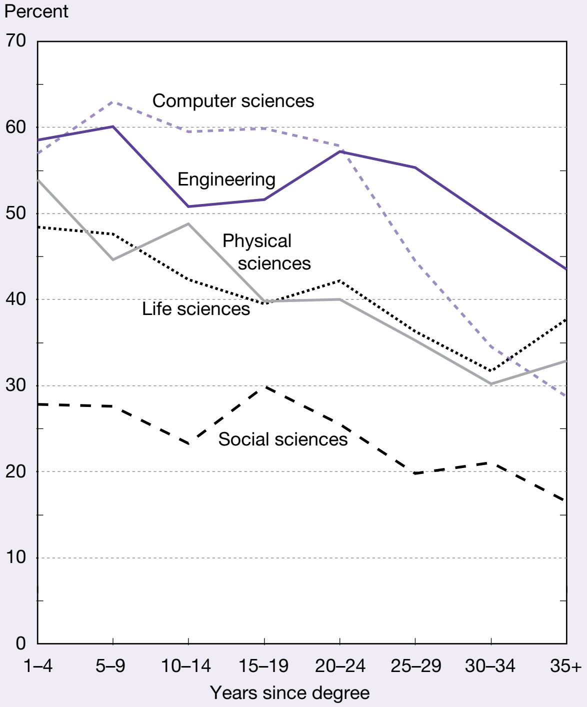
Figure 3-11
S&E bachelor's degree holders employed in jobs closely related to degree, by field and years since degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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Employment in Non-S&E Occupations

About 6.0 million individuals whose highest degree is in S&E worked in non-S&E occupations in 2003. Of these, two-thirds said that their job was at least somewhat related to their degree (table 3-4). This included 1.6 million in management and management-related occupations, of whom 33% said their jobs were closely related and 40% said somewhat related to their S&E degrees. In the next largest occupation category for S&E-degreed individuals in non-S&E jobs, sales and marketing, slightly over half, 51%, said their S&E degrees were relevant to their jobs. Among K–12 teachers whose highest degree is in S&E, 78% say their job is closely related to their degrees.

Unemployment

A two-decades-long view of unemployment trends in S&E occupations, regardless of education level, comes from the CPS data for 1983–2004. During this 22-year period, the unemployment rate for all individuals in S&E occupations ranged from a low of 1.4% in 1999 to a high of 4.6% in 2003. Overall, the S&E occupational unemployment rate was both lower and less volatile than either the rate for all U.S. workers (ranging from 3.9% to 9.9%) or for S&E technicians (ranging from 2.0% to 6.1%). During most of the period, computer programmers had a similar unemployment rate as those in S&E occupations, but greater volatility (ranging from 1.2% to 6.7%). The most recent recession in 2002–03 appears to have had a strong effect on S&E employment, with the differential between S&E and general unemployment falling to only 1.4 percentage points in 2003, compared with 6.9 percentage points in 1983 (figure 3-12). This may

Table 3-4
Individuals with S&E as highest degree employed in non-S&E occupations, by occupation and relation of degree to job: 2003
(Percent)

Occupation	*n* (thousands)	Degree related to job: Closely	Somewhat	Not
All non-S&E	6,022	33.3	32.9	33.8
Sales and marketing	950	16.3	34.9	48.8
Management related	842	26.1	40.1	33.8
Non-S&E managers	545	34.8	43.5	21.7
Health related	402	53.3	30.4	16.3
Social services	340	67.1	24.8	8.1
Technologists and technicians	289	47.4	35.4	17.2
K–12 teachers (other than S&E)	275	54.2	29.3	16.5
S&E K–12 teachers	190	78.4	18.2	3.4
Management of S&E	188	57.1	35.2	7.7
Arts and humanities	163	20.7	36.7	42.6
Non-S&E postsecondary teachers	52	62.9	24.9	12.2
Other non-S&E	1,743	20.7	28.8	50.5

NOTES: Non-S&E occupations include the SESTAT categories "non-S&E" and "S&E related." Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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be due to the unusually strong reductions in R&D in the information and related technology sectors (see chapter 4).

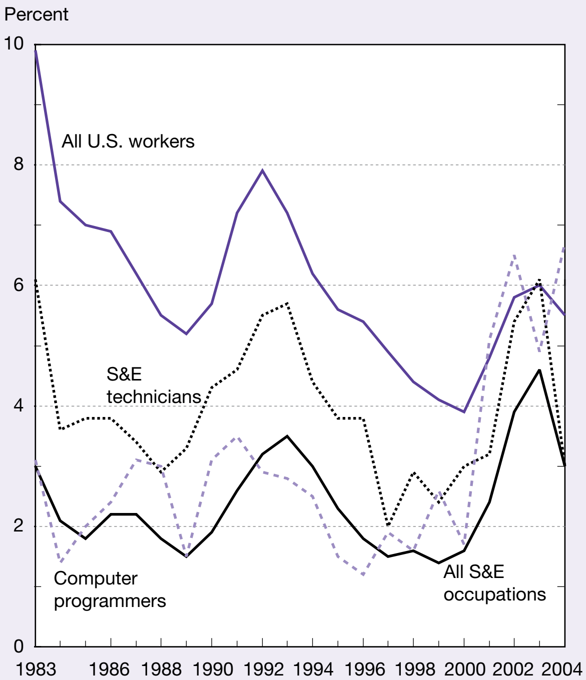
Figure 3-13 compares unemployment rates over career cycles for bachelor's and doctoral degree holders in 1999 and in 2003. Looking at field of degree rather than occupation includes both individuals who might have left an S&E occupation for negative economic reasons and individuals who moved into other careers due to more positive factors. The generally weaker 2003 labor market had its greatest effect on bachelor's degree holders: for individuals at various points in their careers, the unemployment rate increased by between 1.6 and 3.5 percentage points between 1999 and 2003. Although labor market conditions had a lesser effect on doctoral degree holders' unemployment rates, some increases in unemployment rates between 1999 and 2003 did occur for those individuals in most-years-since-degree groups.

Similarly, labor market conditions from 1999 to 2003 had a greater effect on the portion of bachelor's degree holders who said they were working involuntarily out of the field (IOF) of their highest degree than on doctoral degree holders (figure 3-14). For doctoral degree holders, IOF rates changed little between 1999 and 2003. IOF rates actually dropped for recent doctorate degree graduates, while increasing slightly for those later in their careers. However, in both 1999 and 2003, the oldest doctoral degree holders actually had the lowest IOF rates—which may partially reflect lower retirement rates for individuals working in their fields. Taken together with the unemployment patterns shown in figure 3-13, this finding implies that more highly educated S&E workers are less vulnerable to changes in economic conditions than individuals who hold only bachelor's degrees.

Metropolitan Areas

United States metropolitan areas are ranked in table 3-5 according to the proportion of the entire metropolitan area workforce that is employed in S&E occupations, and in table 3-6 by the total number of workers employed in S&E

Figure 3-12
Unemployment rate, by occupation: 1983–2004



SOURCE: National Bureau of Economic Research, Merged Outgoing Rotation Group Files, from U.S. Department of Labor, Bureau of Labor Statistics, Current Population Survey. See appendix table 3-8.

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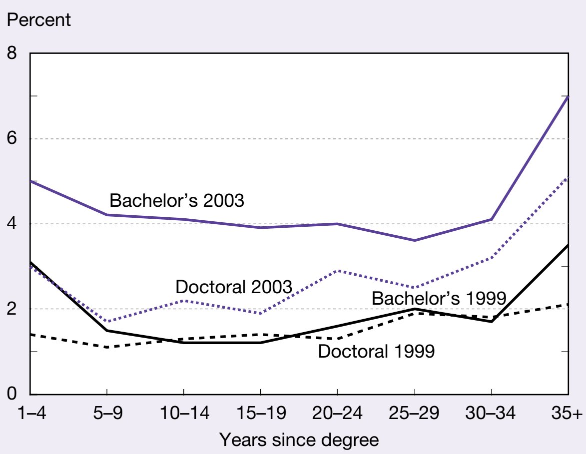
Figure 3-13
Unemployment rates for individuals with S&E highest degrees, by years since highest degree: 1999 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1999) and preliminary estimates (2003), http://sestat.nsf.gov.

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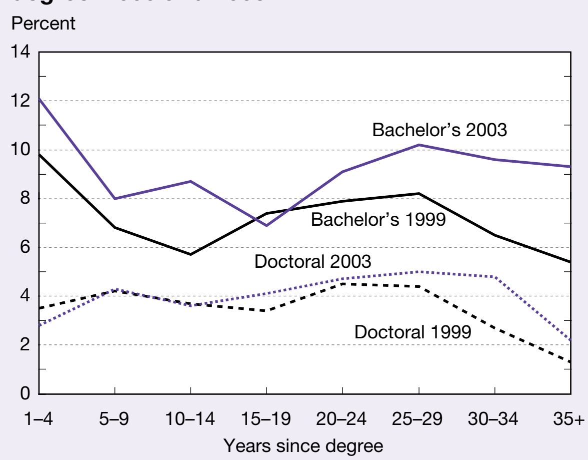
Figure 3-14
Involuntarily out-of-field rates of individuals with S&E highest degrees, by years since highest degree: 1999 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1999) and preliminary estimates (2003), http://sestat.nsf.gov.

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Table 3-5
S&E employment by metropolitan area, by S&E percentage of total employment: 2003

Rank	Metropolitan area	Workforce (%)	S&E employees (*n*)
	United States	3.9	4,961,540
1	Boulder-Longmont, CO PMSA	13.1	20,110
2	Corvallis, OR MSA	12.7	4,470
3	San Jose, CA PMSA	12.0	102,700
4	Huntsville, AL MSA	11.6	20,580
5	Washington, DC-MD-VA-WV PMSA	9.4	253,410
6	Raleigh-Durham-Chapel Hill, NC MSA	8.9	59,710
7	Rochester, MN MSA	8.7	8,590
8	Melbourne-Titusville-Palm Bay, FL MSA	8.5	16,080
9	Seattle-Bellevue-Everett, WA PMSA	8.3	106,200
10	Lowell, MA-NH PMSA	7.9	9,680
11	Richland-Kennewick-Pasco, WA MSA	7.8	6,220
12	Austin-San Marcos, TX MSA	7.6	51,760
13	Charlottesville, VA MSA	7.5	6,280
14	Madison, WI MSA	7.5	20,950
15	Boston, MA-NH PMSA	7.2	136,530
16	Colorado Springs, CO MSA	7.1	16,380
17	Fort Collins-Loveland, CO MSA	6.8	8,060
18	Olympia, WA PMSA	6.8	5,840
19	San Francisco, CA PMSA	6.8	65,330
20	Middlesex-Somerset-Hunterdon, NJ PMSA	6.8	42,090

MSA = metropolitan statistical area; PMSA = primary metropolitan statistical area

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics Survey (2003).

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Table 3-6
S&E employment by metropolitan area, by total number of workers employed in S&E occupations: 2003

Rank	Metropolitan area	Workforce (%)	S&E employees (n)
	United States	3.9	4,961,540
1	Washington, DC-MD-VA-WV PMSA	9.4	253,410
2	Chicago, IL PMSA	4.2	164,650
3	Los Angeles-Long Beach, CA PMSA	3.9	156,340
4	Boston, MA-NH PMSA	7.2	136,530
5	New York, NY PMSA	3.2	126,730
6	Atlanta, GA MSA	5.3	111,610
7	Seattle-Bellevue-Everett, WA PMSA	8.3	106,200
8	San Jose, CA PMSA	12.0	102,700
9	Detroit, MI PMSA	5.2	102,500
10	Houston, TX PMSA	4.9	100,030
11	Dallas, TX PMSA	5.3	99,780
12	Philadelphia, PA-NJ PMSA	4.2	97,410
13	Minneapolis-St. Paul, MN-WI MSA	5.4	90,390
14	Orange County, CA PMSA	5.0	71,640
15	Denver, CO PMSA	6.2	69,370
16	Phoenix-Mesa, AZ MSA	4.2	67,020
17	San Francisco, CA PMSA	6.8	65,330
18	San Diego, CA MSA	5.1	64,220
19	Baltimore, MD PMSA	5.1	63,000
20	Oakland, CA PMSA	6.1	60,750

MSA = metropolitan statistical area; PMSA = primary metropolitan statistical area

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics Survey (2003).

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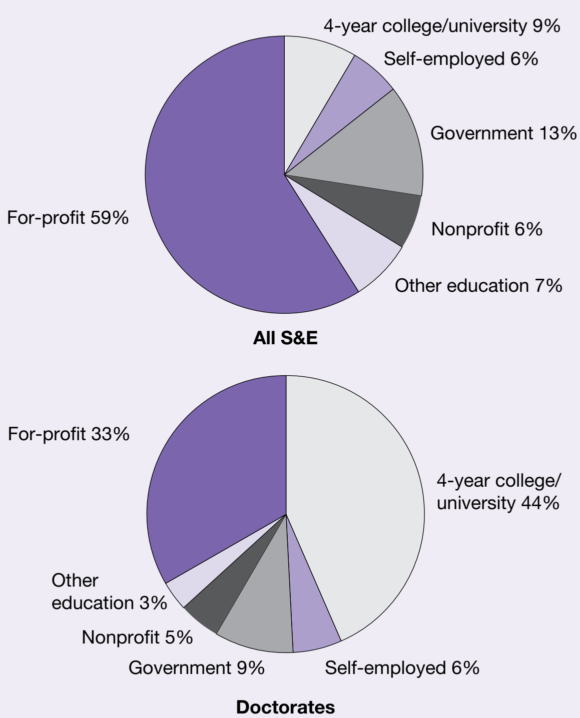
occupations. The Boulder-Longmont, Colorado metropolitan area had the highest percentage of its workforce employed in S&E occupations in November 2003 at 13.1%. The Washington, D.C. metropolitan area has the greatest total number of individuals employed in S&E occupations at over one-quarter million. Although the top-20 list for proportion of S&E employment consists mainly of smaller, and perhaps less economically diverse, metropolitan areas, Washington, D.C.; Seattle; Boston; and San Francisco were able to make both top-20 lists.

Employment Sectors

The private for-profit sector is the largest provider of employment for individuals with S&E degrees (figure 3-15), employing 59% of all individuals whose highest degree is in S&E, including 33% of S&E doctoral degree holders. Four-year colleges and universities are an important but not majority employer for S&E doctorate degree holders (44%). This 44% includes a variety of employment types other than the tenured and tenure-track employment that is still sometimes inaccurately referred to as the "traditional" doctorate career path—including many younger doctorate holders in postdoc and other temporary employment situations, as well as individuals with a variety of research and administrative functions.

Figure 3-15
Employment sector for all S&E degree holders and S&E doctoral degree holders: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT, preliminary estimates (2003), http://sestat.nsf.gov. See appendix table 3-9.

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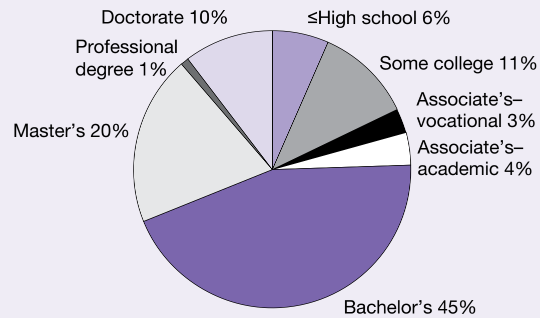
Figure 3-16
Educational distribution, by nonacademic S&E occupations: 2000



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Current Population Survey (2000).

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Educational Distribution of S&E Workers

Discussions of the S&E workforce often focus on individuals who hold doctorate degrees. However, CPS data on the educational achievement of individuals working in S&E occupations outside academia in 2000 indicate that only 10% had doctorates (figure 3-16). In 2000, more than two-thirds of individuals working in nonacademic S&E occupations had bachelor's degrees (45%) or master's degrees (20%).

Almost one-fourth of individuals working in S&E occupations had not earned a bachelor's degree. Although technical issues of occupational classification may inflate the estimate of the size of the nonbaccalaureate S&E workforce, it is also true that many individuals who have not earned a bachelor's degree enter the labor force with marketable technical skills from technical or vocational school training (with or without earned associate's degrees), college courses, and on-the-job training. In information technology (IT), and to some extent in other occupations, employers frequently use certification exams not formal degrees to judge skills (see discussion in chapter 2).

From 1983 to 2004, the proportion of individuals in the S&E workforce without college degrees remained relatively constant, rising only slowly to 73% in 2004. Among individuals working in S&E technician occupations the proportion with college degrees also remained nearly constant, rising to only about 24% in 2004. The occupation of computer programmer, a non-S&E occupation of particular interest in discussions of the S&E labor force, increased its percentage of individuals with college degrees from 50% to 68% (figure 3-20). (See sidebar, "Who Performs Research and Development?")

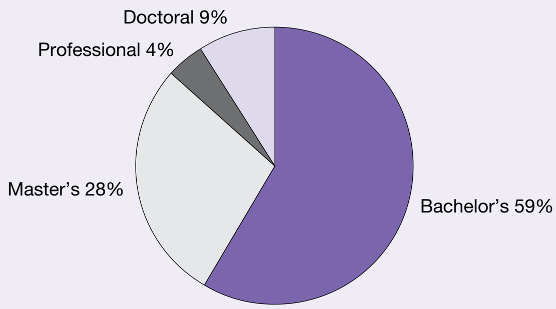
Salaries

Figure 3-21 illustrates the distribution of salaries earned by individuals with S&E degrees. Education produces far more dramatic effects on the "tails" of the distribution (the

Who Performs Research and Development?

Although individuals with S&E degrees use their acquired knowledge in various ways (e.g., teaching, writing, evaluating, and testing), R&D is of particular importance to both the economy and the advancement of knowledge. Figure 3-17 shows the distribution of individuals with S&E degrees by level of degree who report R&D as a major work activity (defined as the activity involving the greatest, or second greatest, number of work hours from a list of 22 possible work activities). Individuals with doctorate degrees constitute only 6% of all individuals with S&E degrees but represent 9% of individuals who report R&D as a major work activity. However, the majority of S&E degree holders who report R&D as a major work activity have only bachelor's degrees (59%). An additional 28% have master's degrees and 4% have professional degrees, mostly in medicine. Figure 3-18 shows the distribution of individuals with S&E degrees, by field of highest degree, who reported R&D as a major work activity. Individuals with engineering degrees constitute more than one-third (37%) of the total.

Figure 3-17
Distribution of S&E-degreed workers with R&D as major work activity, by level of education: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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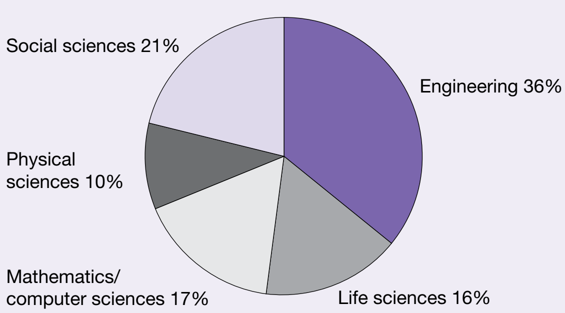
Figure 3-18
Distribution of S&E-degreed workers with R&D as major work activity, by field of highest degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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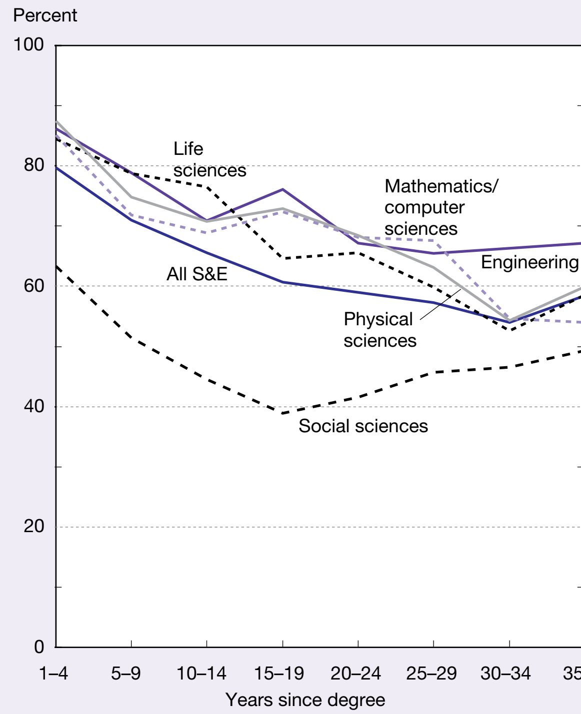
Figure 3-19 shows the percentages of S&E doctorate degree holders reporting R&D as a major work activity by field of degree and by years since receipt of doctorate. Individuals working in physical sciences and engineering report the highest R&D rates over their career cycles, with the lowest R&D rates in social sciences. Although the percentage of doctorate degree holders engaged in R&D activities declines as time since receipt of degree increases, it remains greater than 50% in all fields except social sciences for all years since receipt of degree. The decline may reflect a normal career process of movement into management or other career interests. It may also reflect, even within nonmanagement positions, increased opportunity and the ability of more experienced scientists to perform functions involving the interpretation and use of, as opposed to the creation of, scientific knowledge.

Figure 3-19
S&E doctorate holders engaged in R&D as major work activity: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http//sestat.nsf.gov.

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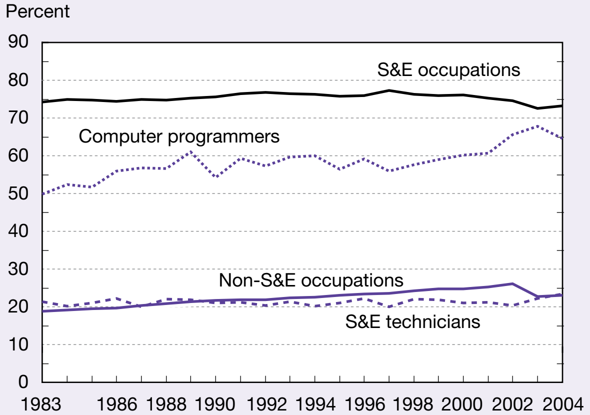
Figure 3-20
Individuals with bachelor's degrees or higher for S&E and selected other occupations: 1983–2004



NOTE: Pre-1992 data based on those who had completed at least 16 years of education.

SOURCES: National Bureau of Economic Research, Monthly Outgoing Rotation files, from the U.S. Department of Labor, Bureau of Labor Statistics, Current Population Survey (1983–2004).

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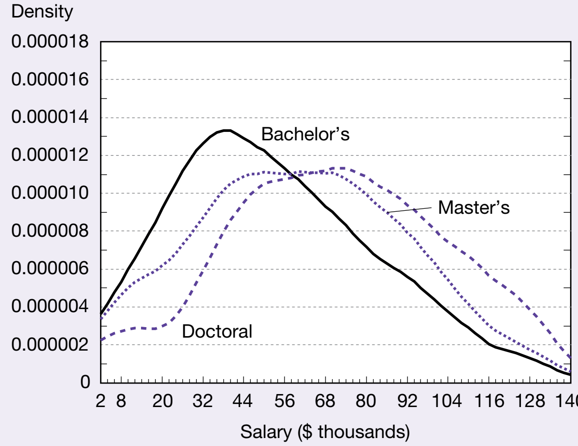
Figure 3-21
Salary distribution of S&E degree holders employed full time, by degree level: 2003



NOTE: Salary distribution smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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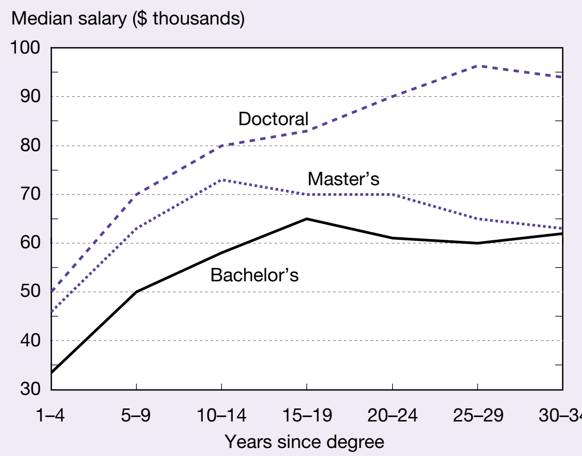
proportion with either very high or very low earnings) than on median earnings. In 2003, 11% of S&E bachelor's degree holders had salaries higher than $100,000, compared with 28% of doctorate degree holders. Similarly, 22% of bachelor's degree holders earned less than $30,000, compared with 8% of doctorate degree holders. The latter figure is inflated because of the inclusion of postdocs. (The Survey of Doctorate Recipients defines postdoc as a temporary position awarded in academia, industry, or government for the primary purpose of receiving additional research training.)

A cross-sectional profile of median 2003 salaries for S&E degree holders over the course of their career is shown in figure 3-22. As is usual in such profiles, median earnings generally increase with time since degree, as workers add on-the-job knowledge to the formal training they received in school. Also usual is to find averages of earnings begin to decline in mid to late career, as is shown here for holders of bachelor's and master's degrees in S&E, which is a common pattern often attributed to "skill depreciation." In contrast, the profile of S&E doctorate degree holder's earnings continues to rise even late in their careers. Median salaries peak at $65,000 for bachelor's holders, $73,000 for master's degree holders, and at $96,000 for doctorate degree holders.

Women and Minorities in S&E

Demographic factors for women and minorities (such as age and years in the workforce, field of S&E employment, and highest degree level achieved) influence employment patterns. Demographically, men differ from women, and minorities differ from nonminorities; thus, their employment patterns also are likely to differ. For example, because larger numbers of women and minorities entered S&E fields only recently, women and minority men generally are younger than non-Hispanic white males and have fewer years of experience. Age and stage in career in turn influence such employment-related factors as salary, position, tenure, and work activity. In addition, employment patterns vary by field (see sidebar, "Growth of Representation of Women, Minorities, and the Foreign Born in S&E Occupations"), and these differences influence S&E employment, unemployment, salaries, and work activities. Highest degree earned, yet another important influence, particularly affects primary work activity and salary.

Figure 3-22
Median salaries of S&E graduates, by degree level and years since degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

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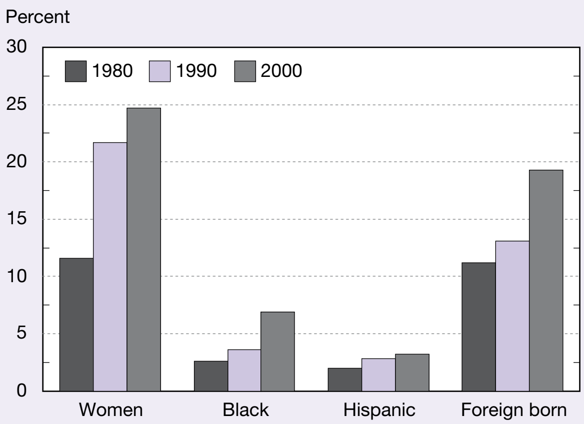
Growth of Representation of Women, Minorities, and the Foreign Born in S&E Occupations

A longer view of changes in the sex and ethnic composition of the S&E workforce can be achieved by examining data on college-educated individuals in nonacademic S&E occupations from the 1980 Census, the 1990 Census, and the 2000 Census Public-Use Microdata Sample (PUMS) (figure 3-23). In 2000, the percentage of historically underrepresented groups in S&E occupations remained lower than the percentage of those groups in the total college-educated workforce:

- Women made up 24.7% of the S&E workforce and 48.6% of the college-degreed workforce.
- Blacks made up 6.9% of the S&E workforce and 7.4% of the college-degreed workforce.
- Hispanics made up 3.2% of the S&E workforce and 4.3% of the college-degreed workforce.

However, since 1980, share of S&E occupations has more than doubled for blacks (2.6% to 6.9%) and women (11.6% to 24.7%). Hispanic representation also increased between 1980 and 2000, albeit at a lower rate (2.0% to 3.2%). The percentage of foreign-born college graduates (including both U.S. and foreign degreed) in S&E jobs increased from 11.2% in 1980 to 19.3% in 2000.

Figure 3-23
College graduates in nonacademic S&E occupations, women, minorities, and foreign-born: 1980, 1990, and 2000



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations of U.S. Decennial Census Public-Use Microdata Sample (PUMS) (1980–2000).

Science and Engineering Indicators 2006

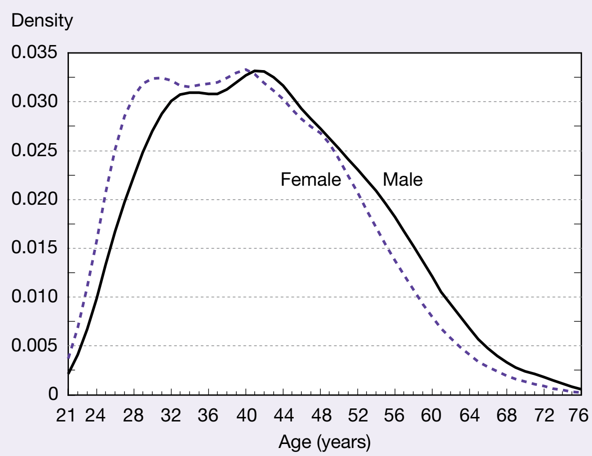
Representation of Women in S&E

Women constituted more than one-fourth (26%) of the college-educated workforce in S&E occupations (and more than one-third, 37%, of those with S&E degrees) but close to half (46%) of the total U.S. workforce in 2003.

Age Distribution and Experience. Differences in age and related time spent in the workforce account for many of the differences in employment characteristics between men and women. On average, women in the S&E workforce are younger than men (figures 3-24 and 3-25): 46% of women and 31% of men employed as scientists and engineers in 2003 received their degrees within the past 10 years. The difference is even more profound at the doctorate level, which has a much greater concentration of female doctorate degree holders in their late 30s. One clear consequence of this age distribution is that a much larger proportion of male scientists and engineers at all degree levels, but particularly at the doctorate level, will reach traditional retirement age during the next decade. This alone will have a significant effect upon sex ratios, and also perhaps on the numbers of female scientists in positions of authority as the large proportion of female doctorate degree holders in their late 30s moves into their 40s.

S&E Occupation. Representation of men and women also differs according to field of occupation. For example, in 2003, women constituted 52% of social scientists, compared with 29% of physical scientists and 11% of engineers (figure 3-26). Since 1993, the percentage of women in most S&E occupations has gradually increased from 23% to 27% across all S&E occupations. However, in mathematics and

Figure 3-24
Age distribution of individuals in S&E occupations, by sex: 2003

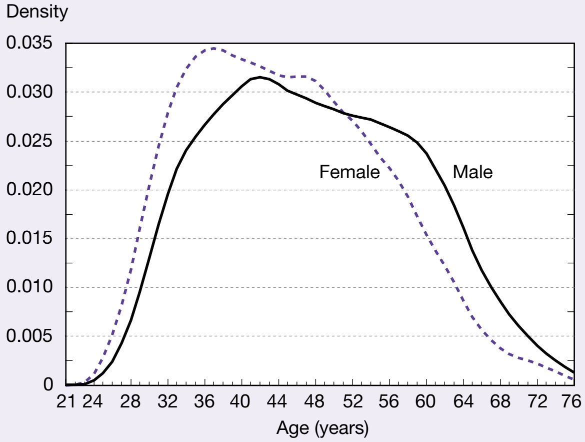


NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Figure 3-25
Age distribution of doctorate holders in S&E occupations: 2003



NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Figure 3-26
Women as proportion of employment in S&E occupations, by broad occupation: 1993 and 2003

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1993) and preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

computer science occupations, the percentage of women declined about 2 percentage points between 1993 and 2003.

Labor Force Participation, Employment, and Unemployment. Unemployment rates were somewhat higher for women in S&E occupations than for men in 2003: 3.7% of men and 4.2% of women were unemployed. By comparison, the unemployment rate in 1993 was 2.7% for men and 2.1% for women (table 3-7).

Table 3-7
Unemployment rate of individuals in S&E occupations, by sex, race/ethnicity, and visa status: 1993 and 2003
(Percent)

Sex/race/ethnicity	1993	2003
All with S&E occupations	2.6	3.9
Male	2.7	3.7
Female	2.1	4.2
White	2.4	3.4
Asian/Pacific Islander	4.0	6.0
Black	2.8	5.3
Hispanic	3.5	2.7
Temporary residents	4.8	2.1

NOTE: 2003 data includes some individuals with multiple races in each category.

SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT (1993) and preliminary estimates (2003), http://sestat.nsf.gov. See appendix table 3-10.

Science and Engineering Indicators 2006

Salaries. In 2003, females in S&E occupations earned a median annual salary of $53,000, about 24% less than the median annual salary earned by male scientists and engineers ($70,000). Several factors may contribute to these salary differentials. Women more often work in educational institutions, in social science occupations, and in nonmanagerial positions. In addition, precisely because of growth in the number of women entering S&E fields, they also tend to have fewer years of experience.

Within NSF's data on individuals with college degrees, increases in representation for women are actually associated with lower wage growth. Between 1993 and 2003, median annual salaries for females in S&E occupations increased by 34%, compared with an increase of 40% for male median salaries (table 3-8). This may also be because of changes in relative years of experience, as more women enter these occupations.

Representation of Racial and Ethnic Minorities in S&E

With the exception of Asians/Pacific Islanders, racial and ethnic minorities represent only a small proportion of those employed in S&E occupations in the United States. Collectively, blacks, Hispanics, and other ethnic groups (the latter includes American Indians/Alaska Natives) constituted 24% of the total U.S. population, 13% of college graduates, and 10% of the college educated in S&E occupations.

Although Asians/Pacific Islanders constitute only 5% of the U.S. population, they accounted for 7% of college graduates and 14% of those employed in S&E occupations in 2003. Although 82% of Asians/Pacific Islanders in S&E occupations were foreign born, native-born Asians/Pacific

Table 3-8
Median annual salary of individuals employed in S&E occupations, by sex, race/ethnicity, and visa status: Selected years, 1993–2003
(Dollars)

Sex/race/ethnicity	1993	1995	1997	1999	2003
S&E employed	48,000	50,000	55,000	60,000	66,000
Male	50,000	52,000	58,000	64,000	70,000
Female	40,000	42,000	47,000	50,000	53,000
White	48,000	50,500	55,000	61,000	67,000
Asian/Pacific Islander	48,000	50,000	55,000	62,000	70,000
Black	40,000	45,000	48,000	53,000	58,000
Hispanic	43,000	47,000	50,000	55,000	60,000
Temporary residents	43,300	49,700	49,000	52,000	60,000

NOTE: 2003 data includes some individuals with multiple races in each category.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1993–1999) and preliminary estimates (2003), http://sestat.nsf.gov.

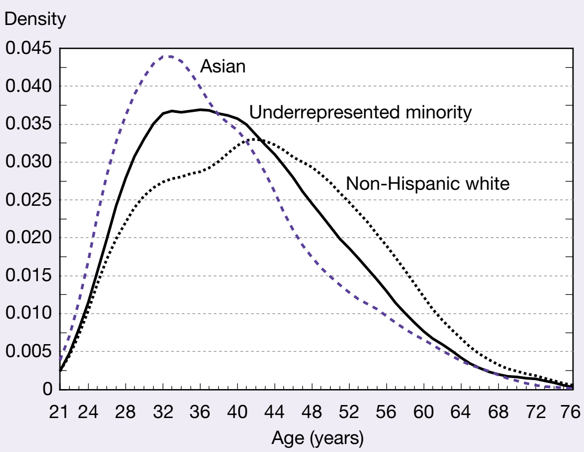
Science and Engineering Indicators 2006

Islanders are also more likely than their numbers to be employed in S&E.

Age Distribution. As in the case of women, underrepresented racial and ethnic minorities are much younger than non-Hispanic whites in the same S&E occupations (figures 3-27 and 3-28), and this is even truer for doctorate degree holders in S&E occupations. In the near future, a much greater proportion of non-Hispanic white doctorate degree holders in S&E occupations will be reaching traditional retirement ages compared with underrepresented racial and ethnic minority doctorate degree holders. Indeed, unlike the distribution of ages of male and female doctorate degree holders, the slope of the right-hand side of the age distribution is far steeper for non-Hispanic whites. This implies a more rapid increase in the numbers retiring or otherwise leaving S&E employment. It should also be noted that Asian/Pacific Islander doctorate degree holders in S&E occupations (measured by race and not by place of birth) are on average the youngest racial/ethnic group.

S&E Occupation. Asian/Pacific Islander, black, and American Indian/Alaska Native scientists and engineers tend to work in different fields than their white and Hispanic counterparts. Fewer Asians/Pacific Islanders work in social sciences than in other fields. In 1999, they constituted 4% of social scientists, but more than 11% of engineers and more than 13% of individuals working in mathematics and computer

Figure 3-27
Age distribution of individuals in S&E occupations, by race/ethnicity: 2003

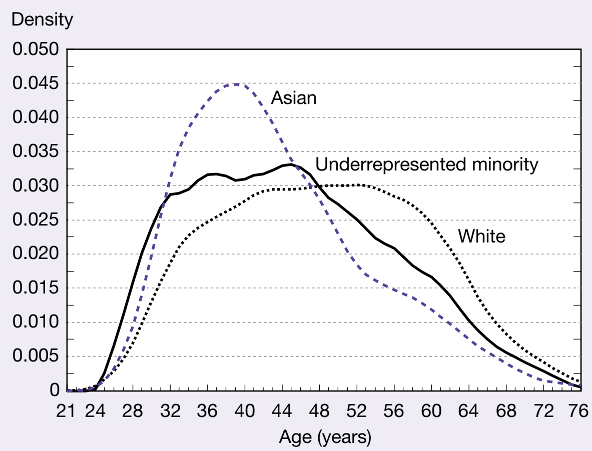


NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Figure 3-28
Age distribution of S&E doctorate holders in S&E occupations, by race/ethnicity: 2003



NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

sciences. More black scientists and engineers work in social sciences and in computer sciences and mathematics than in other fields. In 1999, blacks constituted approximately 5% of social scientists, 4% of computer scientists and mathematicians, 3% of physical scientists and engineers, and 2% of life scientists. Other ethnic groups (which includes American Indians/Alaska Natives) work predominantly in social and life sciences, accounting for 0.4% of social and life scientists and 0.3% or less of scientists in other fields in 1999. Hispanics appear to have a more even representation across all fields, constituting approximately 2.5%–4.5% of scientists and engineers in each field.

Salaries. Salaries for individuals in S&E occupations vary among the different racial and ethnic groups. In 2003 whites and Asians/Pacific Islanders in S&E occupations earned similar median annual salaries of $67,000 and $70,000, respectively, compared with $60,000 for Hispanics and $58,000 for blacks (table 3-8). Some limited sign of convergence appears in data from 1993 to 2003, with the median salary for blacks in S&E occupations rising 45% versus 40% for whites. (See sidebar, “Salary Differentials.”)

Labor Market Conditions for Recent S&E Graduates

The labor market activities of recent S&E graduates often serve as the most sensitive indicators of changes in the S&E labor market. This section looks at a number of standard labor market indicators for bachelor’s and master’s degree recipients, and also examines a number of other indicators that may apply only to recent S&E doctorate recipients.

In general, NSF’s data on recent graduates in 2003 reflects the economic downturn that started in 2001 and its unusually large effect on R&D expenditure, state government budgets, and universities, all areas of importance for scientists and engineers.

Bachelor’s and Master’s Degree Recipients

Recent recipients of S&E bachelor’s and master’s degrees form an important component of the U.S. S&E workforce, accounting for almost half of the annual inflow into S&E occupations. Recent graduates’ career choices and entry into the labor market affect the supply and demand for scientists and engineers throughout the United States. This section offers insight into labor market conditions for recent S&E graduates in the United States. Topics examined include graduate school enrollment rates, employment by level and field of degree, employment sectors, and median annual salaries.

Employment Sectors

The private for-profit sector employs the majority of recent S&E bachelor’s and master’s degree recipients (table 3-9). In 2003, 57% of recent (1–5 years after degree) bachelor’s degree recipients and 49% of recent master’s degree recipients found employment with private for-profit companies. Government was the second most important employer—employing 12% of both recent S&E bachelor’s degree and recent S&E master’s degree graduates.

Employment and Career Paths

Although it is a very subjective measure, one indicator of labor market conditions is whether recent graduates feel that they are in “career-path” jobs. Most recently in 1999, the National Survey of Recent College Graduates asked new S&E bachelor’s and master’s degree recipients whether they had obtained employment in a career track job within 3 months of graduation.

As one might expect, more S&E master’s degree holders reported having a career-path job compared with S&E bachelor’s degree holders. Approximately two-thirds of all S&E master’s degree recipients and one-half of all S&E bachelor’s degree recipients held a career-path job in 1999 (see figure 3-29). Graduates with degrees in computer and information sciences or in engineering were more likely to hold career-path jobs compared with graduates with degrees in other fields: about three-quarters of recent bachelor’s and master’s degree graduates in engineering or computer and mathematical sciences reported that they held career-path jobs.

Salaries

In 1999, recent (1–3 years since degree) bachelor’s degree recipients with degrees in computer and information sciences earned the highest median annual salaries ($44,000) among all recent science graduates. For recent graduates with degrees in engineering, individuals receiving degrees in electrical/electronics, computer, and communications engineering earned the highest median annual salaries ($46,000). The same pattern held true for recent master’s degree recipients: individuals receiving degrees in computer and information sciences earned the highest median annual salaries ($58,000) among science graduates. Among engineering graduates, individuals who received master’s degrees in electrical/electronics, computer, and communications engineering earned the highest median annual salaries ($60,000).

Table 3-9
1998–2002 S&E bachelor’s and master’s degree recipients, by employment sector and degree field: 2003
(Percent)

Employment sector	Bachelor’s	Master’s
For-profit business	57.1	49.1
Nonprofit	8.5	7.7
Government	12.0	12.4
4-year college/university	10.7	17.6
Other education	8.0	10.2
Self-employment	3.7	3.0

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Salary Differentials

Differences in salaries of women and ethnic minorities are often used as indicators of progress that individuals in those groups are making in S&E employment. Indeed, these salary differences are substantial when comparing all individuals with S&E degrees by level of degree: in 1999, women with S&E bachelor's degrees had full-time mean salaries that were 35.1% less than those of men with S&E bachelor's degrees. Blacks, Hispanics, and individuals in other underrepresented ethnic groups with S&E bachelor's degrees had full-time salaries that were 21.9% less than those of non-Hispanic whites and Asians/Pacific Islanders with S&E bachelor's degrees.* These raw differences in salary are lower but still large at the doctorate level (–25.8% for women and –12.7% for underrepresented ethnic groups). In contrast, foreign-born individuals with U.S. S&E degrees have slightly higher salaries than U.S. natives at the bachelor's and master's levels, but their salaries at the doctorate level show no statistically significant differences from those of natives.

However, differences in average age, work experience, fields of degree, and other characteristics make direct comparison of salary and earnings statistics difficult. Generally, engineers earn a higher salary than social scientists, and newer employees earn less than those with more experience. One common statistical method that can be used to look simultaneously at salary and other differences is regression analysis.† Table 3-10 shows estimates of salary differences for different groups after controlling for several individual characteristics.

Although this type of analysis can provide insight, it cannot give definitive answers to questions about the openness of S&E to women and minorities for many reasons. The most basic reason is that no labor force survey ever captures all information on individual skill sets, personal background and attributes, or other characteristics that may affect compensation. In addition, even characteristics that are measurable are not distributed randomly among individuals. An individual's choice of degree field and occupation, for example, will reflect in part the real and perceived opportunities for that individual. The associations of salary differences with individual characteristics, not field choice and occupation choice, are examined here.

Effects of Age and Years Since Degree on Salary Differentials

Salary differences between men and women reflect to some extent the lower average ages of women with degrees in most S&E fields. Controlling for differences in age and years since degree reduces salary differentials for women compared with men by about one-fourth at the

Table 3-10
Estimated salary differentials of individuals with S&E degrees, by individual characteristics: 1999
(Percent)

Variable	Degree		
	Bachelor's	Master's	Doctoral
Female versus male	–35.1	–28.9	–25.8
Controlling for age and years since degree	–27.2	–25.5	–16.7
Plus field of degree	–14.0	–9.6	–10.3
Plus occupation and employer characteristics	–11.0	–8.0	–8.4
Plus family and personal characteristics	–10.2	–7.4	–7.4
Plus sex-specific marriage and child effects	–4.6	NS	–3.1
Black, Hispanic, and other versus white and Asian/Pacific Islander	–21.9	–19.3	–12.7
Controlling for age and years since degree	–13.0	–14.6	–4.7
Plus field of degree	–8.6	–6.7	–2.2
Plus occupation and employer characteristics	–7.3	–4.2	NS
Plus family and personal characteristics	–5.7	–3.3	NS
Foreign born with U.S. degree versus native born	3.7	9.5	NS
Controlling for age and years since degree	6.7	12.4	7.8
Plus field of degree	NS	NS	NS
Plus occupation and employer characteristics	NS	–2.8	–2.8
Plus family and personal characteristics	NS	–3.1	–2.7

NS = not significantly different from zero at $p = .05$

NOTE: Linear regressions on ln (full-time annual salary).

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1999), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

bachelor's degree level (to –27.2%) and by about one-third at the doctorate level (to –16.7%).‡

When controlling for differences in age and years since degree, even larger drops in salary differentials are found for underrepresented ethnic minorities. Such controls reduce salary differentials of underrepresented minorities compared with non-Hispanic whites and Asians/Pacific Islanders by more than two-fifths at the bachelor's degree level (to –13.0%) and by nearly two-thirds at the doctorate level (to –4.7%).

Because foreign-born individuals in the labor force who have S&E degrees are somewhat younger on average than natives, controlling for age and years since degree actually increases the salary differential, making an initial earnings advantage over natives even larger, to 6.7% for foreign-born individuals with S&E bachelor's degrees and to 7.8% for those with S&E doctorates.

Effects of Field of Degree on Salary Differentials

Controlling for field of degree and for age and years since degree reduces the estimated salary differentials for women with S&E degrees to –14.0% at the bachelor's level and to –10.3% at the doctorate level.§ These reductions generally reflect the greater concentration of women in the lower-paying social and life sciences as opposed to engineering and computer sciences. As noted above, this identifies only one factor associated with salary differences and does not speak to why there are differences between males and females in field of degree or whether salaries are affected by the percentage of women studying in each field.

Field of degree is also associated with significant estimated salary differentials for underrepresented ethnic groups. Controlling for field of degree further reduces salary differentials to –8.6% for those individuals with S&E bachelor's degrees and to –2.2% for those individuals with S&E doctorates. Thus, age, years since degree, and field of degree are associated with almost all doctorate-level salary differentials for underrepresented ethnic groups.

Compared with natives at any level of degree, foreign-born individuals with S&E degrees show no statistically significant salary differences when controlling for age, years since degree, and field of degree.

Effects of Occupation and Employer on Salary Differentials

Obviously, occupation and employer characteristics affect compensation.‖ Academic and nonprofit employers typically pay less for the same skills than employers pay in the private sector, and government compensation falls somewhere between the two groups. Other factors affecting salary are relation of work performed to degree earned, whether the person is working in S&E, whether the person is working in R&D, employer size, and U.S. region. However, occupation and employer characteristics may not be determined solely by individual choice, for they may also reflect in part an individual's career success.

When comparing women with men and underrepresented ethnic groups with non-Hispanic whites and Asians/Pacific Islanders, controlling for occupation and employer reduces salary differentials only slightly beyond what is found when controlling for age, years since degree, and field of degree. For foreign-born individuals compared with natives, controls for occupation and employer characteristics also produce only small changes in estimated salary differentials, but in this case, the controls result in small negative salary differentials at the master's (–2.8%) and doctorate (–2.8%) levels.

Effects of Family and Personal Characteristics on Salary Differentials

Marital status, children, parental education, and other personal characteristics are often associated with differences in compensation. Although these differences may indeed involve discrimination, they may also reflect many subtle individual differences that might affect work productivity.# As with occupation and employer characteristics, controlling for these characteristics changes salary differentials only slightly at any degree level. However, most of the remaining salary differentials for women disappear when the regression equations allow for the separate effects of marriage and children for each sex. Marriage is associated with higher salaries for both men and women, but has a larger positive association for men. Children have a positive association with salary for men but a negative association with salary for women.

*"Underrepresented ethnic group" as used here includes individuals who reported their race as black, Native American, or other, or who reported Hispanic ethnicity.

†Specifically presented here are coefficients from linear regressions using the 1999 Scientists and Engineers Statistical Data System (SESTAT) data file of individual characteristics upon the natural log of reported full-time annual salary as of April 1999.

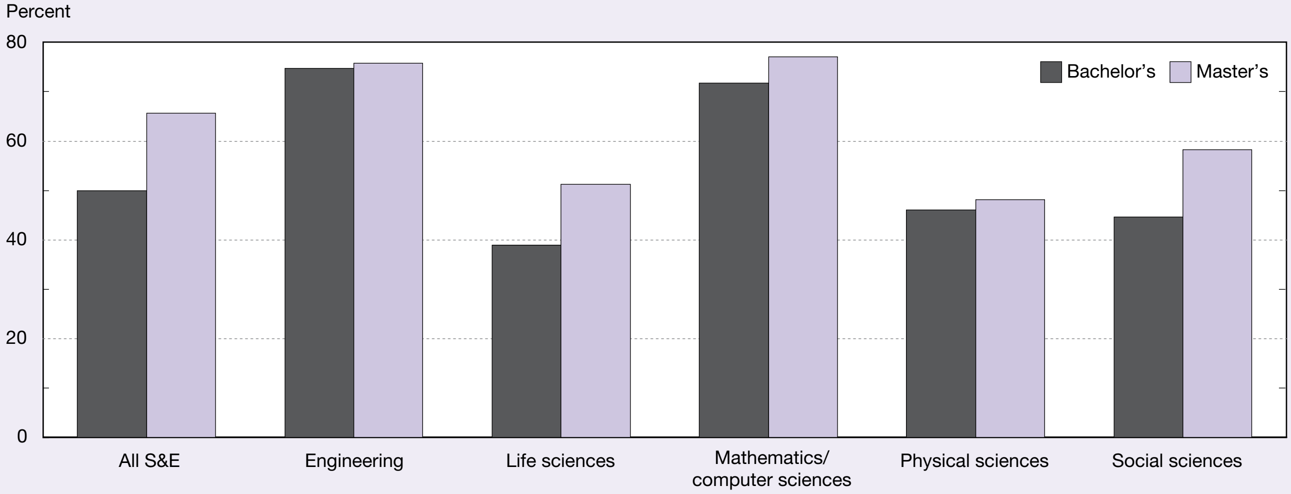
‡In the regression equation, this is the form: age, age^2, age^3, age^4; years since highest degree (YSD), YSD^2, YSD^3, YSD^4.

§Included were 20 dummy variables for NSF/SRS SESTAT field-of-degree categories (out of 21 S&E fields; the excluded category in the regressions was "other social science").

‖Variables added here include 34 SESTAT occupational groups (excluding "other non-S&E"), whether individuals said their jobs were closely related to their degrees, whether individuals worked in R&D, whether their employers had fewer than 100 employees, and their employers' U.S. Census region.

#Variables added here include dummy variables for marriage, number of children in the household younger than 18, whether the father had a bachelor's degree, whether either parent had a graduate degree, and citizenship. Also, sex, nativity, and ethnic minority variables are included in all regression equations.

Figure 3-29
Recent S&E recipients in career-path jobs within 3 months of degree: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of Recent College Graduates (1999).

Science and Engineering Indicators 2006

Doctoral Degree Recipients

Analyses of labor market conditions for scientists and engineers holding doctorate degrees often focus on the ease or difficulty of beginning careers for recent doctoral degree recipients. Although a doctorate degree creates more career opportunities both in terms of salary and type of employment, these opportunities come at the price of many years of foregone labor market earnings. Many doctorate degree holders also face an additional period of low earnings while completing a postdoc. In addition, some doctorate degree holders may not find themselves in the type of employment they desired while in graduate school.

Since the 1950s, the federal government has actively encouraged graduate training in S&E through numerous mechanisms. Doctorate programs have served multiple facets of the national interest by providing a supply of more highly trained and motivated graduate students to aid university-based research. These programs have provided individuals with detailed, highly specialized training in particular areas of research, and paradoxically, through that same specialized training, generated a general ability to perform self-initiated research in more diverse areas.

The career aspirations of highly skilled individuals in general, and doctorate degree holders in particular, often cannot be measured by just salary and employment. Their technical and problem-solving skills make them highly employable, but they often attach great importance to the opportunity to do a type of work they care about and for which they have been trained. For that reason, no single measure can satisfactorily describe the doctoral S&E labor market. Some of the available labor market indicators, such as unemployment rates, working involuntarily out of the field (IOF) outside of their field, satisfaction with field of study, employment in academia versus other sectors, postdocs, and salaries, are discussed below.

As between 1999 and 2001 (see NSB 2004), aggregate measures of labor market conditions changed only moderately between 2001 and 2003 for recent (1–3 years after receipt of degree) S&E doctoral degree recipients. The most notable increase in a measure of labor market distress was unemployment rates: across all fields unemployment for recent S&E doctoral degree holders increased from 1.3% to 2.1% (table 3-11). However, a smaller proportion of recent doctoral degree recipients reported working IOF because jobs were not available, decreasing from 3.4% to 1.9%. However, these aggregate numbers mask numerous changes, both positive and negative, in many individual disciplines.

Unemployment

The 2.1% unemployment rate for recent S&E doctoral degree recipients as of October 2003 was low, compared with the April 2003 unemployment rate for all civilian workers of 6.0%. The highest unemployment rates were for recent doctoral degree recipients in sociology and anthropology (7.7%), mechanical engineering (6.7%), and mathematics (4.0%).

Involuntarily Working Outside Field

Another 1.9% of recent S&E doctoral degree recipients in the labor force reported in 2003 that they could not find (if they were seeking) full-time employment that was "closely related" or "somewhat related" to their degrees, which was a decline from 3.4% in 2001. Although this measure is more subjective than the unemployment rate, the IOF rate often proves to be a more sensitive indicator of labor market difficulties for a highly educated and employable population. However, it is best to use both the IOF rate along with unemployment rates and other measures as different indicators of labor market success or distress.

The highest IOF rates were found for recent doctoral degree recipients in political science (8.7%) and in physics

Table 3-11
Labor market rates for recent S&E doctorate recipients 1–3 years after receiving doctorate, by field: 2001 and 2003
(Percent)

Doctorate field	Unemployment rate 2001	Unemployment rate 2003	Involuntary out-of-field rate 2001	Involuntary out-of-field rate 2003
All S&E	1.3	2.1	3.4	1.9
Engineering	1.8	3.0	1.7	2.1
Chemical	1.6	2.0	2.0	5.8
Civil	3.5	S	3.6	4.5
Electrical	0.9	2.4	1.5	0.0
Mechanical	3.2	6.7	1.7	3.7
Life sciences	1.1	2.5	2.5	1.1
Agriculture	0.3	1.5	4.1	3.0
Biological sciences	1.0	2.7	2.4	0.7
Mathematics/computer sciences	0.3	3.1	2.4	3.1
Computer sciences	0.4	2.1	2.3	2.0
Mathematics	0.3	4.0	2.4	4.2
Physical sciences	1.3	1.3	5.0	4.9
Chemistry	0.8	2.0	3.2	5.6
Geosciences	1.9	2.2	3.0	0.0
Physics/astronomy	1.9	0.0	8.2	6.8
Social sciences	1.3	2.5	5.1	5.7
Economics	2.2	0.5	2.1	2.7
Political science	0.8	0.0	8.7	8.7
Psychology	1.4	2.0	3.8	5.6
Sociology/anthropology	1.2	7.7	6.3	4.7

S = insufficient sample size for estimate

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2001 and 2003).

Science and Engineering Indicators 2006

and astronomy (6.8%). The lowest IOF rates were found in electrical engineering (0.0%), geosciences (0.0%), and the biological sciences (0.7%).

Tenure-Track Positions

Most S&E doctorate degree holders ultimately do not work in academia and this has been true in most S&E fields for several decades (see chapter 5). In 2003, among S&E doctorate degree holders who received their degree 4–6 years previously, 19.8% were in tenure-track or tenured positions at 4-year institutions of higher education, essentially the same as the 19.2% in 2001 (table 3-12). Across fields, rates of tenure program academic employment for individuals who had received their degree 4–6 years previously ranged from 8.4% in chemical engineering to 50.4% in political science. In contrast, among doctorate degree holders who received their degree 1–3 years previously, only 9% were in tenure programs, a drop from 16.2% in 2001. In part this may reflect diminished employment opportunities at the time of graduation for recent doctorate degree recipients. This rate also reflects the continuing employment as postdocs of recent doctoral degree recipients in many fields.

The longer-term trend (1993–2003) for obtaining tenure-track positions is down for both cohorts of recent doctorate degree recipients. For those 1–3 years since degree, tenure-track positions declined from 18.4% to 9.0%. For those 4–6 years after degree, the decline was more modest from 26.6% to 19.8%.

Although S&E doctorate degree holders must consider academia as just one possible sector of employment, the availability of tenure-track positions is an important aspect of the job market for individuals who seek academic careers. Decreases over time in tenure-track employment reflect the availability both of tenure-track job opportunities in academia and of alternative employment opportunities. For example, one of the largest declines in tenure-track employment occurred in computer sciences, from 51.5% in 1993 to 29.4% in 2003, despite many discussions about difficulties that computer science departments were having finding faculty. It is worth noting that computer science also has one of the largest rates of increase in the percentage of recent doctorate degree recipients entering tenure-track positions between 2001 and 2003, which was a period of particular stress for others in computer-related employment.

However, the attractiveness of other alternatives is less likely to explain smaller but steady drops in tenure program employment rates in fields that show other measures of distress, such as physics (with an IOF rate of 6.8%) and biological sciences (which has low unemployment and IOF rates, but shows other indications of labor market distress such as low salaries). Between 1993 and 2003 several fields registered an increase in tenure program rates for individuals who received their doctorate 4–6 years previously, including geosciences (increasing from 26.2% to 34.2%) and agriculture (increasing from 27.0% to 33.0%).

Table 3-12
S&E doctorate recipients holding tenure and tenure-track appointments at academic institutions, by years since receipt of doctorate: 1993, 2001, and 2003
(Percent)

	1993		2001		2003	
Doctorate field	1–3	4–6	1–3	4–6	1–3	4–6
All S&E	18.4	26.6	16.2	19.2	9.0	19.8
Engineering	16.0	24.6	11.4	10.4	10.8	16.3
Chemical	8.1	14.0	5.8	4.3	4.6	8.4
Civil	24.7	27.1	18.8	21.7	29.8	26.0
Electrical	17.6	26.9	9.5	8.2	13.3	14.5
Mechanical	13.5	29.5	9.9	9.3	8.8	27.0
Life sciences	12.6	24.8	12.6	18.2	7.3	18.0
Agriculture	15.6	27.0	23.7	12.8	10.2	33.0
Biological sciences	12.1	24.8	11.3	18.3	5.0	15.1
Mathematics/computer sciences	39.7	54.1	22.5	26.6	32.2	38.5
Computer sciences	37.1	51.5	19.2	23.6	32.0	29.4
Mathematics	41.8	56.0	25.0	29.3	32.4	46.7
Physical sciences	9.7	18.2	10.2	14.9	11.9	16.7
Chemistry	7.7	16.3	10.2	11.5	13.7	14.4
Geosciences	12.7	26.2	17.7	25.4	20.2	34.2
Physics/astronomy	12.0	17.7	7.8	11.4	6.3	12.8
Social sciences	26.4	29.2	25.9	28.3	26.6	30.8
Economics	46.6	48.6	37.1	28.6	45.3	38.0
Political science	53.9	47.1	45.0	40.0	43.8	50.4
Psychology	12.7	15.5	14.8	19.3	11.7	18.8
Sociology/anthropology	37.9	46.9	41.3	44.1	42.7	50.3

NOTE: Two-year institutions not included.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (1993, 2001, and 2003).

Science and Engineering Indicators 2006

Postdocs

The definition of postdocs differs among the academic disciplines, universities, and sectors that employ them, and these differences probably affect self-reporting of postdoc status in the Survey of Doctorate Recipients. Researchers often analyze data on postdoc appointments for recent doctoral degree recipients in relation to recent labor market issues. Although some of these individuals want to receive more training in research, others may accept temporary (and usually lower-paying) postdoc positions because of a lack of permanent jobs in their field.

Science and Engineering Indicators – 1998 (NSB 1998) included an analysis of a one-time postdoc module from the 1995 Survey of Doctorate Recipients. This analysis showed a slow increase in the use of postdocs in many disciplines over time. (This rate was measured cross-sectionally by looking at the percentage of individuals in each graduation cohort who reported ever holding a postdoc position.) In addition, in physics and biological sciences (the fields with the most use of postdocs), median time spent in postdocs extended well beyond the 1–2 years found in most other fields.

Reasons for Taking a Postdoc

In 2003 for all fields of degree 11.6% of postdocs gave “other employment not available” as their primary reason for accepting a postdoc, essentially the same as the 11.5% that gave this reason in 2001. However, in 1999, 32.1% of postdocs said that the primary reason was “other employment not available (NSB 2002, 2004) (table 3-13). Most respondents gave reasons consistent with the defined training and apprenticeship functions of postdocs (e.g., 31% said that postdocs were generally expected for careers in their fields, 18% said they wanted to work with a particular person, 22% said they sought additional training in their fields, and 14% said they sought additional training outside their specialty). In 1999, a high proportion of postdocs in the biological sciences (38%) and physics (38%) had reported “other employment not available” as the primary reason for being in a postdoc, but in 2003, both fields had below-average rates for this particular indicator of labor market distress. In contrast, nearly a third of engineering postdocs in 2003 reported “other employment not available” as the primary reason for their postdoc.

What Were 2001 Postdocs Doing in 2003?

Of individuals in postdocs in April 2001, 32.9% remained in a postdoc in October 2003. This is a small reduction from the 36.5% of 1999 postdocs still in such positions in 2001 (NSB 2004). In addition, 23.2% had moved from a postdoc in 2001 to a tenure-track position at a 4-year educational institution in 2003, up from 12.3% for the previous period; 23.7% had found other employment at an educational institu-

Table 3-13
Primary reason for taking current postdoc, by field: 2003
(Percent)

Doctorate field	Additional training in doctorate field	Training outside doctorate field	Postdoc generally expected in field	Association with particular person or place	Other employment not available	Other
All S&E fields	21.8	14.2	30.7	18.1	11.6	3.5
Biological sciences	19.1	15.1	37.2	17.4	8.2	3.0
Chemistry	21.9	26.9	21.8	16.7	10.9	1.9
Engineering	26.3	12.9	18.4	8.2	31.2	3.0
Geoscience	12.9	15.5	12.5	25.3	29.1	4.7
Physics	22.1	12.1	36.0	21.5	2.0	6.3
Psychology	29.1	8.9	24.0	23.1	10.7	4.2

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2003).

Science and Engineering Indicators 2006

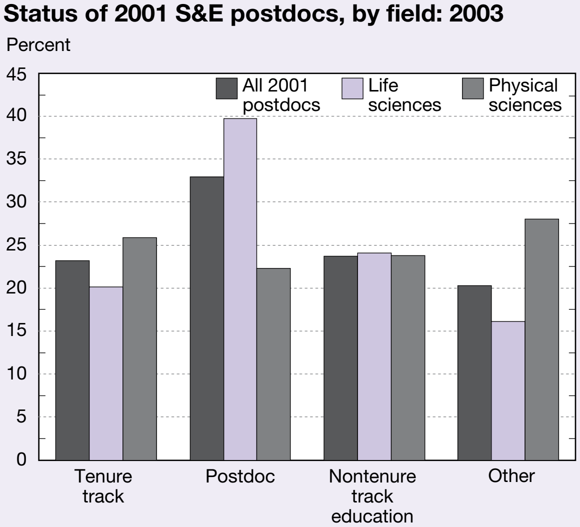
tion; and 20.3% had found some other form of employment (figure 3-30).

No information is available on the career goals of individuals in postdoc positions. It is often assumed that a postdoc is valued most by academic departments at research universities. However, only about one-quarter of postdocs transitioned to a tenure-track position over the 2-year period.

Salaries for Recent S&E Doctoral Degree Recipients

In 2003 for all fields of degree the median annual salary for recent S&E doctoral degree recipients 1–4 years after their degrees was $52,000. Across various S&E fields of degree, median annual salaries ranged from a low of $39,400 in the life sciences to a high of $75,000 in engineering (table 3-14).

Figure 3-30
Status of 2001 S&E postdocs, by field: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2001 and 2003).

Science and Engineering Indicators 2006

Among all doctoral degree recipients, individuals in the top 10% of salary distribution (90th percentile) earned a median annual salary of $100,000. At the 10th percentile, representing the lowest pay for each field, salaries ranged from $20,000 for recent doctoral degree recipients in social sciences to $44,000 for individuals receiving degrees in engineering.

By type of employment, salaries for recent doctoral degree recipients range from $40,000 for postdocs to $80,000 for those employed by private for-profit business (table 3-15).

Age and Retirement

The age distribution and retirement patterns of the S&E labor force greatly affect its size, its productivity, and opportunities for new S&E workers. For many decades, rapid increases in new entries into the workforce led to a relatively young pool of workers, with only a small percentage near traditional retirement age. Now, the general picture is rapidly changing as individuals who earned S&E degrees in the late 1960s and early 1970s move into the latter part of their careers.

Some controversy exists about the possible effects of age distribution on scientific productivity. Increasing average age may mean increased experience and greater productivity among scientific workers. However, others argue that it could reduce opportunities for younger scientists to work independently. In many fields, scientific folklore as well as actual evidence indicate that the most creative research comes from younger people (Stephan and Levin 1992).

This section does not attempt to model and project future S&E labor market trends; however, some general conclusions can be made. Absent changes in degree production, retirement patterns, or immigration, the number of S&E-trained workers in the labor force will continue to grow for some time, but the growth rate may slow significantly as a dramatically greater proportion of the S&E labor force reaches traditional retirement age. As the growth rate slows, the average age of the S&E labor force will increase.

Table 3-14
Salary of recent S&E doctorate recipients 1–4 years after receiving degree: 2003
(Dollars)

Doctorate field	Percentile 10th	25th	50th	75th	90th
All fields	30,000	40,000	52,000	75,000	100,000
Engineering	44,000	63,000	75,000	88,000	102,000
Life sciences	26,000	32,000	39,400	50,000	72,500
Mathematics/computer sciences	40,000	42,500	60,000	92,500	115,000
Physical sciences	34,000	42,000	62,000	92,000	175,000
Social sciences	20,000	41,000	50,000	67,000	82,000

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2003).

Science and Engineering Indicators 2006

Table 3-15
Median annual salary of recent S&E doctorate recipients 1–5 years after receiving degree, by type of employment: 2003
(Dollars)

Doctorate field	All sectors	Private	Tenure track	Postdoc	Other education	Nonprofit/ government
All S&E fields	57,000	80,000	53,000	40,000	48,500	68,000
Computer/mathematical sciences	67,000	89,000	59,000	45,000	60,000	S
Engineering	74,000	83,000	68,000	39,000	51,500	78,700
Life sciences	42,600	70,000	50,000	39,000	44,000	65,000
Physical sciences	60,000	78,800	51,000	40,000	50,000	60,000
Social sciences	52,000	70,000	50,000	37,000	48,000	63,000

S = insufficient sample size for estimate

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2003).

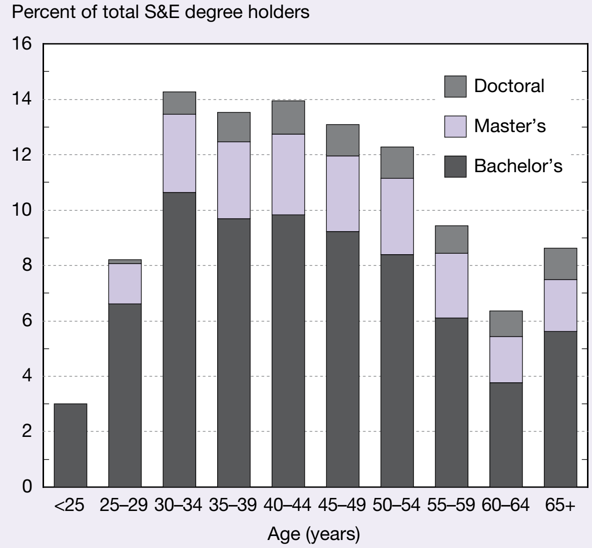
Science and Engineering Indicators 2006

Implications for S&E Workforce

Net immigration, morbidity, mortality, and, most of all, historical S&E degree production patterns affect age distribution among scientists and engineers in the workforce. With the exception of new fields such as computer sciences (in which 56% of degree holders are younger than age 40), the greatest population density of individuals with S&E degrees occurs between the ages of 40 and 49. (Figure 3-31 shows the age distribution of the labor force with S&E degrees broken down by level of degree.) In general, the majority of individuals in the labor force with S&E degrees are in their most productive years (from their late 30s through their early 50s), with the largest group ages 30–34. More than half of workers with S&E degrees are age 40 or older, and the 40–44 age group is more than two times as large as the 60–64 age group.

This general pattern also holds true for those individuals with S&E doctorate degrees. Doctorate degree holders are somewhat older than individuals who have less advanced S&E degrees; this circumstance occurs because fewer doctorate degree holders are in younger age categories, reflecting that time is needed to obtain this degree. The greatest population density of S&E doctorate degree holders occurs between the ages of 40 and 54. This can be most directly seen

Figure 3-31
Age distribution of labor force with S&E highest degrees: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

in figure 3-32, which compares the age distribution of S&E degree holders in the labor force at each level of degree. Even if one takes into account the somewhat older retirement ages of doctorate degree holders, a much larger proportion of them are near traditional retirement ages than are individuals with either S&E bachelor's or master's degrees.

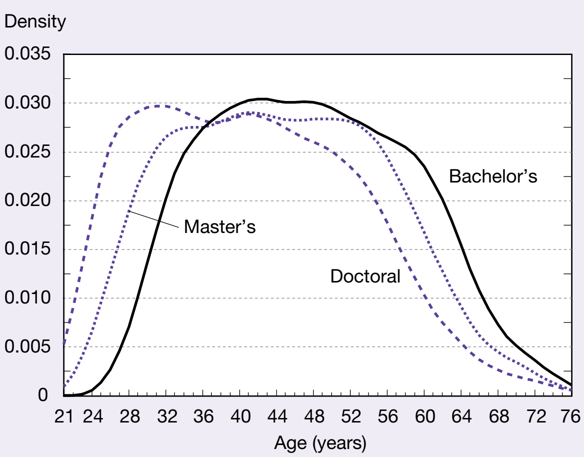
The extent of the recent aging of the S&E labor force is highlighted in figure 3-33, which shows the age distribution of S&E doctorate holders in 1993 and 2003. S&E doctorate holders under age 35 are about the same proportion of the S&E doctorate level labor force in both years. However, over the decade, the 35–54 age group became a much smaller part of the full S&E doctorate-level labor force. What grew was the proportion of S&E doctorate holders age 55 and older.

Across all degree levels and fields, 26.4% of the labor force with S&E degrees is older than age 50. The proportion ranges from 11.1% of individuals with their highest degree in computer sciences to 37.7% of individuals with their highest degree in physics (figure 3-34).

Taken as a whole, the age distribution of S&E-educated individuals suggests several likely important effects on the future S&E labor force:

- Barring large changes in degree production, retirement rates, or immigration, the number of trained scientists and engineers in the labor force will continue to increase, because the number of individuals currently receiving S&E degrees greatly exceeds the number of workers with S&E degrees nearing traditional retirement age.
- However, unless large increases in degree production occur, the average age of workers with S&E degrees will rise.

Figure 3-32
Age distribution of individuals in the labor force whose highest degree is S&E, by degree level: 2003

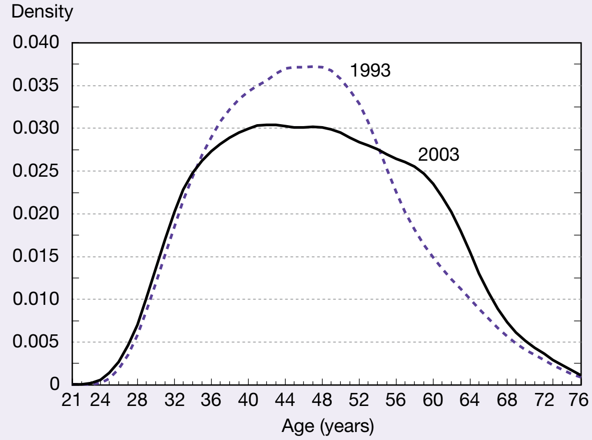


NOTE: Age distribution smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Figure 3-33
Age distribution of S&E doctorate holders in the labor force: 1993 and 2003

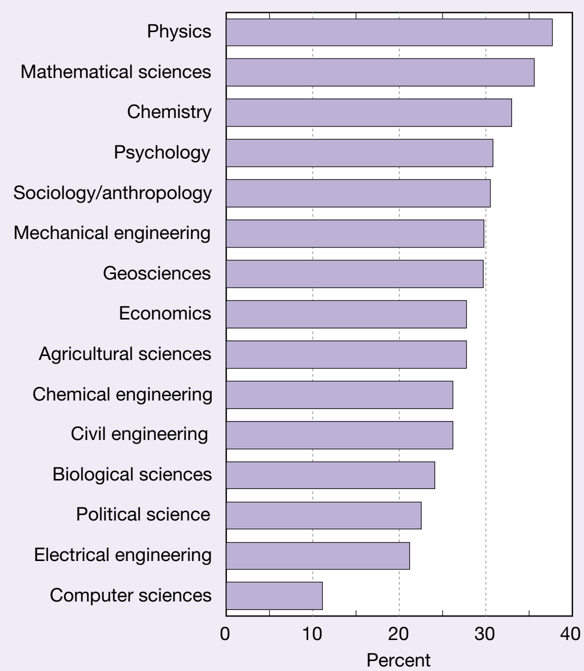


NOTE: Age distribution smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1993) and preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Figure 3-34
Employed S&E degree holders older than 50, by selected field: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

♦ Barring large reductions in retirement rates, the total number of retirements among workers with S&E degrees will dramatically increase over the next 20 years. This may prove particularly true for doctorate degree holders because of the steepness of their age profile. As retirements increase, the difference between the number of new degrees earned and the number of retirements will narrow (and ultimately disappear).

Taken together, these factors suggest a slower-growing and older S&E labor force. Both trends would be accentuated if either new degree production were to drop or immigration to slow, both concerns raised by a recent report of the Committee on Education and Human Resources Task Force on National Workforce Policies for Science and Engineering of the National Science Board (NSB 2003).

S&E Workforce Retirement Patterns

The retirement behavior of individuals can differ in complex ways. Some individuals retire from one job and continue to work part time or even full time at another position, sometimes even for the same employer. Others leave the workforce without a retired designation from a formal pension plan. Table 3-16 summarizes three ways of looking at changes in workforce involvement for S&E degree holders: leaving full-time employment, leaving the workforce, and retiring from a particular job.

By age 62, 50% of S&E bachelor's degree recipients no longer work full time. Similarly, by age 62, 50% of master's degree recipients do not work full time either. However, S&E doctorate degree holders do not reach the 50% not working full time until age 66. Longevity also differs by degree level when measuring the number of individuals who leave the workforce entirely: half of S&E bachelor's degree recipients had left the workforce entirely by age 65, but the same proportion of master's degree and doctorate degree holders did not do so until ages 66 and 70, respectively. Formal retirement also occurs at somewhat higher ages for doctorate degree holders: more than 50% of bachelor's and master's degree recipients have "retired" from jobs by age 62, compared with age 65 for doctorate degree holders.

Figure 3-35 shows data on S&E degree holders working full time at ages 55 through 69. For all degree levels, the portion of S&E degree holders who work full time declines fairly steadily by age, but after age 55 full-time employment for doctorate degree holders becomes significantly greater than for bachelor's and master's degree holders. At age 69, 21% of doctorate degree holders work full time, compared with 16% of bachelor's or master's degree recipients.

Table 3-17 shows rates at which doctorate degree holders left full-time employment, by sector of employment, between 1999 and 2001 and between 2001 and 2003. At nearly every age and sector of employment, a greater proportion of doctoral degree holders left full-time employment in the more recent period than between 1999 and 2001. More examination is needed to understand why this change might have occurred.

Although many S&E degree holders who formally retire from one job continue to work full or part time, this occurs most often among individuals younger than age 63 (table 3-18). However, among "retired" individuals ages 71 to 75, 12% keep working either full time or part time among bachelor's degree holders, 17% among master's degree holders, and 19% among doctoral degree holders.

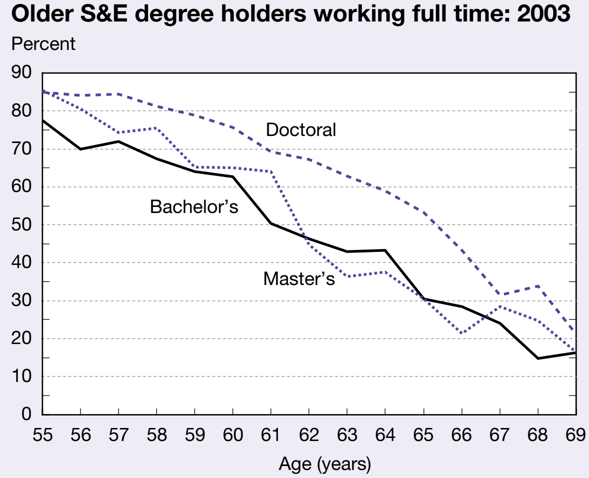
Table 3-16
Retirement age for holders of S&E highest degree: 2003

Highest degree	First age at which >50% were: Not working full time	Not in labor force	Retired from any job
Bachelor's	61	65	62
Master's	62	66	62
Doctoral	66	70	65

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Figure 3-35
Older S&E degree holders working full time: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT, preliminary estimates (2003), http://sestat.nsf.gov. See appendix table 3-14.

Science and Engineering Indicators 2006

Table 3-17
Employed S&E doctorate holders leaving full-time employment, by employment sector and age 2 years previous: 2001 and 2003
(Percent)

	2001 (1999 employment sector)				2003 (2001 employment sector)			
Age (years)	All sectors	Education	Private	Government	All sectors	Education	Private	Government
51–55	9.7	8.0	14.6	6.5	6.3	3.1	10.2	5.1
56–60	16.7	13.2	23.2	17.4	10.3	7.4	14.2	9.7
61–65	34.8	36.8	37.9	22.9	25.6	22.7	32.3	19.9
66–70	54.4	59.3	47.7	52.5	33.6	37.9	29.7	15.0
71–73	51.6	50.7	S	S	36.9	34.9	38.6	41.1

S = insufficient sample size for estimate

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (1999, 2001, and 2003).

Science and Engineering Indicators 2006

Table 3-18
S&E highest-degree individuals who have retired but continue to work: 2003
(Percent)

	Bachelor's		Master's		Doctoral	
Age (years)	Part time	Full time	Part time	Full time	Part time	Full time
50–55	8.2	51.1	14.0	62.3	22.6	50.6
56–62	13.8	28.9	15.8	35.3	24.1	33.1
63–70	10.7	9.0	18.3	11.8	21.2	12.9
71–75	9.0	2.6	9.3	8.0	14.7	4.7

NOTE: Retired are individuals who said they had ever retired from any job.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

Global S&E Labor Force and the United States

"There is no national science just as there is no national multiplication table" (*Anton Chekhov* 1860–1904).

Science is a global enterprise. The common laws of nature cross political boundaries, and the international movement of people and knowledge made science global long before "globalization" became a label for the increasing interconnections among the world's economies. The United States (and other countries as well) gains from new knowledge discovered abroad and from increases in foreign economic development. U.S. industry also increasingly relies on R&D performed abroad. The nation's international economic competitiveness, however, depends on the U.S. labor force's innovation and productivity.

Other chapters in *Science and Engineering Indicators 2006* provide indirect indicators on the global labor force. Production of new scientists and engineers through university degree programs is reported in chapter 2. Indicators of R&D performed by the global S&E labor force are provided in chapter 4 (R&D expenditures and alliances), chapter 5 (publications output and international collaborations), and chapter 6 (patenting activity).

Section Overview

Although the number of researchers employed in the United States has continued to grow faster than the growth of the general workforce, this is still a third less than the growth rate for researchers across all Organisation for Economic Co-operation and Development (OECD) countries. Foreign-born scientists in the United States are more than a quarter, and possibly more than a third, of the S&E doctorate degree labor force, and are even more important in many physical science, engineering, and computer fields. Along with the increases in graduate education for domestic and foreign students elsewhere in the world (as discussed in chapter 2), national governments and private industry have increased their efforts to recruit the best talent from wherever it comes. As a result, the United States is becoming less dominant as a destination for migrating scientists and engineers.

Counts of the Global S&E Labor Force

Few direct measures of the global S&E labor force exist. Reports on the number of researchers in OECD member countries constitute one source of data. From 1993 to 1999, the number of researchers reported in OECD countries increased by 33.9% (a 5.0% average annual rate of increase) from approximately 2.46 million to 3.30 million (figure 3-36). During this same period, comparable U.S. estimates increased 30.7% (a 4.6% average annual rate of increase) from approximately 965,000 to 1.26 million. Of course, non-OECD countries also have scientists and engineers. Figure 3-37, based on estimates by Robert Barro and Jong-Wha Lee, shows the global distribution of tertiary education graduates (roughly equivalent in U.S. terms to individuals who have earned at least technical school or associate's degrees and also including all degrees up to doctorate) in 2000, or the most recently available data. About one-fourth of the tertiary graduates in the labor force were in the United States. However, the next three largest countries in terms of tertiary education are China, India, and Russia, which are all non-OECD members.

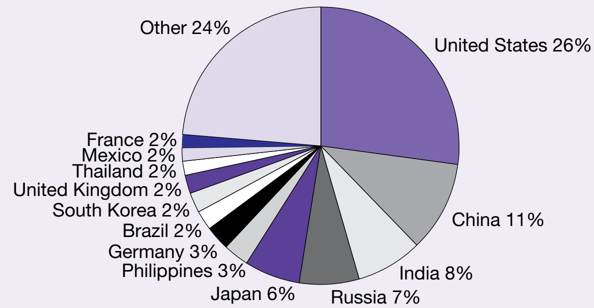
Migration to the United States

Migration of skilled S&E workers across borders is increasingly seen as a major determinant of the quality and flexibility of the labor force in most industrial countries. The knowledge of scientists and engineers can be transferred across national borders more easily than many other skills. Additionally, cutting-edge research and technology inevitably create unique sets of skills and knowledge that can be transferred through the physical movement of people. The United States has benefited, and continues to benefit, from this international flow of knowledge and personnel (see Regets 2001 for a general discussion of high-skilled migration). However, competition for skilled labor continues to increase. Many countries have both increased their research investments and also made high-skilled migration an important part of national economic strategies. An NSB taskforce noted "[g]lobal competition for S&E talent is intensifying, such that the United States may not be able to rely on the international S&E labor market to fill unmet skill needs" (NSB 2003). (See sidebar, "High-Skill Migration to Japan.")

The nature of high-skilled migration makes it difficult to count foreign-born scientists and engineers working in the United States. Individuals may come for just a few years to pursue training or to work in a particular job. In addition to making their measure dependent on the timing of surveys, many of these short- to medium-term migrants will have all foreign degrees and not be included at all in some surveys.

An indication of the scope of the problems with undercounting of foreign-born scientists and engineers comes from a comparison of SESTAT occupational data with approximately comparable data from the 2000 Census. Using the 5% Public-Use Microdata Sample (PUMS), it is possible to compare the proportion of foreign-born individuals among those with S&E occupations other than postsecondary teacher (table 3-19). According to the 1999 SESTAT, 15.0% of college graduates in S&E occupations are foreign born, compared with the 22.4% recorded by the 2000 Census. A particularly noteworthy difference appears in the proportion of foreign-born individuals among those with doctorate degrees; this proportion increases from 28.7% in the 1999 SESTAT to 37.6% in the 2000 Census. The large increases shown by 2000 Census data may in part reflect recent arrivals to the United States, because 42.5% of all college-educated foreign born in these S&E occupations reported arriving in the United States after 1990. Among foreign-born doctorate

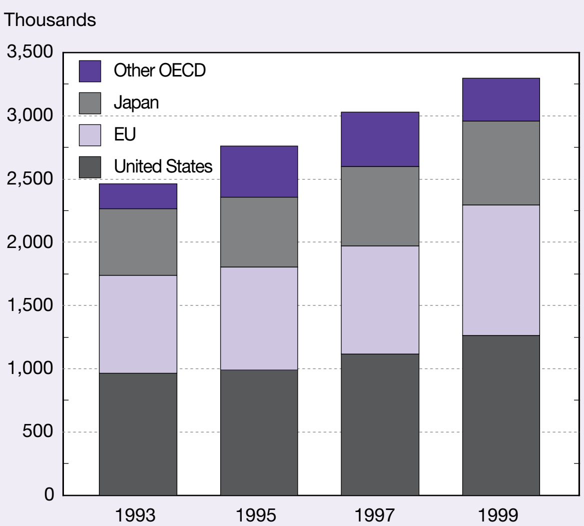
Figure 3-37
Tertiary-educated population more than 15 years old: 2000



SOURCE: Adapted from R.J. Barro and J. Lee, *International Data on Educational Attainment: Updates and Implication,* Center for International Development (2000). See appendix table 3-15.

Science and Engineering Indicators 2006

Figure 3-36
Researchers in OECD countries: 1993, 1995, 1997, and 1999



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTE: 1999 numbers reflect EU-25 membership.

SOURCE: OECD, *Main Science and Engineering Indicators* (2004).

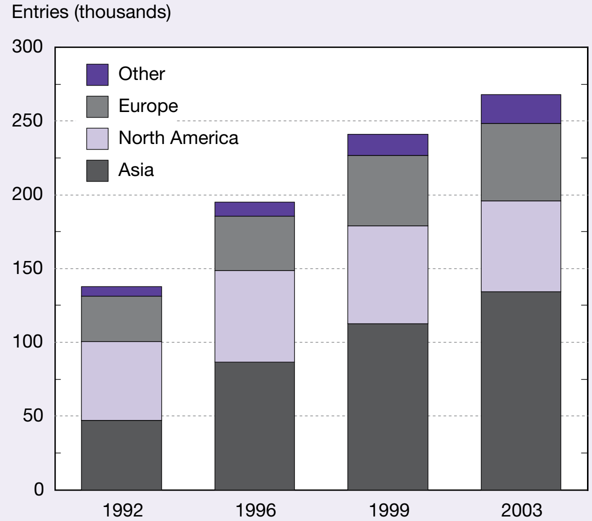
Science and Engineering Indicators 2006

High-Skill Migration to Japan

Recent political debate and legislative change in the United States, Germany, Canada, and many other developed countries have focused on visa programs for temporary high-skilled workers. A 1989 revision of Japanese immigration laws made it easier for high-skilled workers to enter Japan with temporary visas, which allow employment and residence for an indefinite period (even though the same visa classes also apply to work visits that may last for only a few months).

Scott Fuess of the University of Nebraska (Lincoln) and the Institute for the Study of Labor (Bonn) analyzed 12 Japanese temporary visa occupation categories associated with high-skilled workers. Updating Fuess' data, in 2003, 268,045 workers entered Japan in high-skilled visa categories, a 93% increase compared with 1992 (figure 3-38). For comparison purposes, this equals half of the number of Japanese university graduates entering the labor force each year and is more than the number entering the United States in roughly similar categories (H-1B, L-1, TN, O-1, O-2) (Fuess 2001).

Figure 3-38
High-skilled worker visas in Japan: Selected years, 1992–2003



SOURCES: S. Fuess, Jr., *Highly Skilled Workers and Japan: Is There International Mobility?* University of Nebraska and Institute for the Study of Labor (2001); and *Japan Statistical Yearbook,* Ministry of Internal Affairs and Communications, Japan (2004). See appendix table 3-17.

Science and Engineering Indicators 2006

degree holders in S&E occupations, 62.4% reported arriving in the United States after 1990. The 1999 NSF/SRS estimates in table 3-19 include these post-1990 arrivals only if their degrees are from a U.S. institution.

New NSF estimates of the foreign born in S&E occupations are also shown in table 3-19 (table 3-20 shows NSF estimates of foreign born by field of degree, regardless of occupation). The 2003 SESTAT estimates provide an important update over 1999 SESTAT estimates because it includes those with degrees from foreign educational institutions if they were present in the United States in April 2000, at the time of the Decennial Census (new migrants with only foreign degrees who have entered the United States since April 2000 are not included). The estimate of 35.6% of doctorate holders in S&E occupations being foreign born is consistent with an increased coverage of foreign degrees. An unresolved mystery is why the SESTAT proportion of foreign-born doctorate degree holders in S&E occupations is less than either the 2000 Census or the 39.5% found on the 2003 American Community Survey. One possibility is that NSF's data, through a series of detailed questions, may more accurately screen out foreign degrees that are not really doctorate equivalents. However, it is also possible that the 2003 SESTAT, which is based in part on a sample of individuals on the 2000 Census, does not detect foreign doctorate degree holders staying in the United States for just a few years to pursue postdocs and other research opportunities while on temporary visas.

By field of degree, in the 2003 SESTAT data, the foreign born are over half of all holders of doctorates in engineering (including 57% of doctorate holders in electrical engineering) and in computer science. Only in the geosciences and the social sciences are the foreign born significantly less than a third of doctorate holders in S&E fields. At the bachelor's degree level, 15% of S&E degree holders were foreign born—ranging from 7% of bachelor's degree holders in sociology/anthropology to 27% of bachelor's degree holders in physics/astronomy and 28% in electrical engineering.

Origins of S&E Immigrants

Immigrant scientists and engineers come from a broad range of countries. Figure 3-39 shows country of birth for the 3.1 million foreign-born S&E degree holders in the United States, 300,000 of whom have doctorates. Although no one source country dominates, 14% came from India and 9% came from China. Source countries for foreign-born holders of S&E doctorates are somewhat more concentrated, with China providing 21% and India 14%.

Temporary Work Visas

In recent years, policy discussion has focused on the use of various forms of temporary work visas by foreign-born scientists. Many newspaper and magazine stories have been written about the H-1B visa program, which provides visas for up to 6 years for individuals to work in occupations requiring at least a bachelor's degree (or to work as fashion models). Although a common misperception exists that only

Table 3-19
NSF versus Census Bureau estimates of foreign-born individuals in S&E occupations, by education level: 1999, 2000, and 2003
(Percent)

			2003	
Education	1999 NSF/SRS SESTAT	2000 Census 5% PUMS	NSF/SRS SESTAT	Census Bureau American Community Survey
All college educated	15.0	22.4	22.5	25.0
Bachelor's	11.3	16.5	16.3	18.8
Master's	19.4	29.0	29.0	32.0
Doctoral	28.7	37.6	35.6	39.5

NSF/SRS = National Science Foundation, Division of Science Resources Statistics; SESTAT = Scientists and Engineers Statistical Data System; PUMS = Public-Use Microdata Sample

NOTES: Includes all S&E occupations other than postsecondary teachers because field of instruction not included in occupation coding for 2000 Census or American Community Survey. All college educated includes those with professional degrees.

SOURCES: NSF/SRS, SESTAT (1999) and preliminary estimates (2003), http://sestat.nsf.gov; U.S. Census Bureau, PUMS (2000); and American Community Survey (2003).

Science and Engineering Indicators 2006

Table 3-20
Foreign-born proportion of total with S&E highest degrees, by field and level of highest degree: 2003
(Percent)

		Highest degree		
Field	All degree levels	Bachelor's	Master's	Doctoral
All S&E	18.9	15.2	27.2	34.6
Engineering	26.7	21.5	38.3	50.6
Chemical	25.7	17.5	49.2	47.0
Civil	24.9	19.7	39.5	54.2
Electrical	34.0	28.1	45.9	57.0
Mechanical	22.9	19.5	34.2	52.2
Life sciences	16.7	12.6	21.2	36.2
Agriculture	11.7	8.8	15.6	32.7
Biological sciences	19.1	14.7	23.9	37.4
Mathematics/computer sciences	25.8	19.3	40.4	47.5
Computer sciences	29.9	22.3	46.5	57.4
Mathematics	18.5	14.4	25.2	43.1
Physical sciences	23.0	16.9	28.9	36.9
Chemistry	25.5	18.2	42.0	37.0
Geosciences	11.4	8.3	13.0	26.2
Physics/astronomy	32.2	26.6	34.4	40.1
Social sciences	11.5	10.8	13.3	16.9
Economics	21.6	19.7	30.5	31.5
Political science	11.0	9.5	17.1	24.2
Psychology	9.7	10.1	8.5	9.8
Sociology/anthropology	7.2	6.7	10.2	13.6

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), preliminary estimates (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2006

IT workers may use these visas, a wide variety of skilled workers actually use H-1B visas.

Exact occupational information on H-1B visas issued is not available. Some occupational data on H-1B admissions in 2001, which count individuals who reenter the United States multiple times, does exist. This information can provide an approximate guide to the occupational distribution of individuals on H-1B visas. Individuals working in computer-related positions accounted for more than half (57.8%) of H-1B admissions, and those working in architecture and engineering constituted another 12.2%. Another 4.6% indicated other scientific and technical occupations, and the 8.7% of those in categories such as education and medicine also may include many with S&E backgrounds (table 3-21). It is possible that the occupational distribution of H-1B visas may now be less computer related—both because of the downturn in the computer industry and changes made in the visa program since 2001.

An important change to the H-1B visa program took effect on October 1, 2003: the annual ceiling on admissions fell from 195,000 to 65,000 because of the expiration of legislation that had allowed the additional visas. In FY 2005, this ceiling was reached in the first day of the fiscal year. Although universities and academic research institutions are exempt from this ceiling, this change is likely to constrain the use of foreign scientists and engineers by private industry for any R&D located in the United States. In 2005, an additional 20,000 exemptions from the H-1B quotas were added for students receiving master's degrees or doctorates from U.S. schools.

Table 3-21
H-1B visa admissions, by occupation: FY 2001

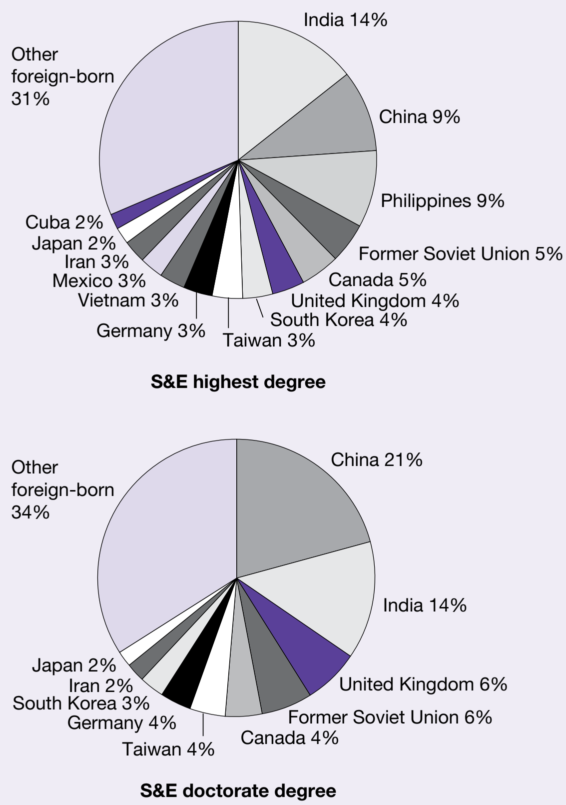
Occupation	Admissions Number	Admissions Percent
All occupations	331,206	100.0
Computer related	191,397	57.8
Architecture, engineering, surveying	40,388	12.2
Education	17,431	5.3
Medicine	11,334	3.4
Life sciences	6,492	2.0
Social sciences	6,145	1.9
Mathematical/physical sciences	5,772	1.7
Other professional/ technical	5,662	1.7
Other (non-S&E related)	46,585	14.1

NOTE: Total admissions includes each entry to United States and thus is much greater than number of visas issued.

SOURCE: U.S. Department of Homeland Security, Bureau of Citizenship and Immigration Services, administrative data.

Science and Engineering Indicators 2006

Figure 3-39
Foreign-born individuals with S&E highest degree living in United States, by place of birth: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT, preliminary estimates (2003), http://sestat.nsf.gov. See appendix table 3-18.

Science and Engineering Indicators 2006

Scientists and engineers may also receive temporary work visas through intracompany transfer visas (L-1 visas), high-skilled worker visas under the North American Free Trade Agreement (TN-1 visas, a program previously primarily for Canadians, granted full access for Mexican professionals in 2004), work visas for individuals with outstanding abilities (O-1 visas), and several smaller programs. In addition, temporary visas are used by researchers who may also be students (F-1 and J-1 visas) or postdocs, and by visiting scientists (mostly J-1 visas but often H-1B visas or other categories). Counts of visas issued for each of these categories are shown in table 3-22. The annual quota of H-1B visas is controlled through issuance of visas to workers rather than through applications from companies. (See sidebar, "Visas for Scientists and Engineers.")

Stay Rates for U. S. Doctoral Degree Recipients With Temporary Visas

How many foreign students who receive S&E doctorates from U.S. schools remain in the United States? According to a report by Michael Finn (2003 and unpublished 2005 data) of the Oak Ridge Institute for Science and Education, 61% of 1998 U.S. S&E doctoral degree recipients with temporary visas remained in the United States in 2003. This is up from a 56% 5-year stay rate found in 2001. The number of foreign students staying after obtaining their doctorates implies that between 4,500 and 5,000 foreign students remain from each

Table 3-22
Temporary visas issued in categories likely to include scientists and engineers: FY 2004

Visa type	Category	Number
Work		
H-1B	Specialty occupations requiring bachelor's equivalent	138,958
L-1	Intracompany transfers	62,700
O-1	People of extraordinary ability	6,437
O-2	Workers assisting O-1	2,611
Student/exchange		
F-1	Students	218,898
J-1	Exchange visitors	254,504

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, administrative data.

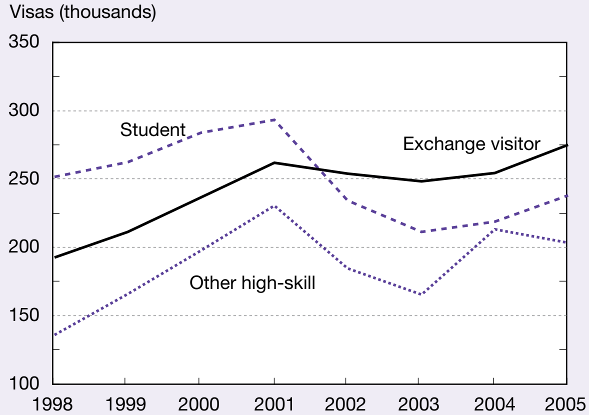
Science and Engineering Indicators 2006

Visas for Scientists and Engineers

The ability and willingness of people to cross national borders crucially affects the science and technology enterprise in the United States. Foreign students help to fill graduate classrooms and laboratories. Visiting scientists facilitate the exchange of knowledge in ways that the telephone and the Internet cannot. Most importantly, foreign-born scientists constitute more than one-fourth of the S&E degree holders doing research in both academia and in industry (and a much higher proportion of doctorate degree-level researchers). For this reason, a great deal of concerned speculation has focused on the effects of the tragic events of September 11, 2001, on the mobility of scientists to the United States.

The visas issued in the categories most used by students and high-skilled workers peaked in FY 2001 (a fiscal year that ended on September 30, 2001). Between FY 2001 and FY 2004, the number of F-1 student visas issued dropped by 25.4%, a drop partly ameliorated by a 3.6% increase between FY 2003 and FY 2004 (see figure 3-40). The increase in F-1 student visas issued occurred despite a continued drop in applications: the adjusted rate at which the State Department refused student visa applicants fell from 25.3% to 22.6% (see table 3-23). Relatively few potential students were formally rejected because of security issues, but U.S. law also requires student visa applicants to prove that they are unlikely to want to stay in the United States after the completion of their studies.

Figure 3-40
Student, exchange, and other high-skill-related temporary visas issued: FY 1998–2005



NOTE: Student visa = F-1; exchange visitor visa = J-1; and high-skill-related visas = L-1, H-1B, H-3, O-1, O-2, and TN.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division (1998–2005).

Science and Engineering Indicators 2006

Table 3-23
Initial visa applications by major high-skilled categories: FY 2001–2005

	Student (F-1)		Exchange visitor (J-1)	
Year	Applications	Refused (%)	Applications	Refused (%)
2001	380,385	22.9	275,959	5.1
2002	322,644	27.4	270,702	6.2
2003	288,731	25.3	275,335	7.8
2004	282,662	22.6	274,789	7.4
2005	333,161	19.8	311,728	5.8

NOTE: Application counts and refusal rates are adjusted for reapplications and appeals by same individual.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, administrative data.

Science and Engineering Indicators 2006

annual cohort of new S&E doctorates in all fields. Stay rates differ by field of degree, ranging from only 36% in economics to 70% in computer and electrical engineering in 2003 (table 3-24).

The small increase in 5-year stay rates between 2001 and 2003 may reflect improvements in labor market conditions at the time each cohort entered the U.S. labor force. This increase occurred despite a small decline in the 5-year stay rate for Chinese students receiving U.S. S&E doctorates—from 96% to 90%.

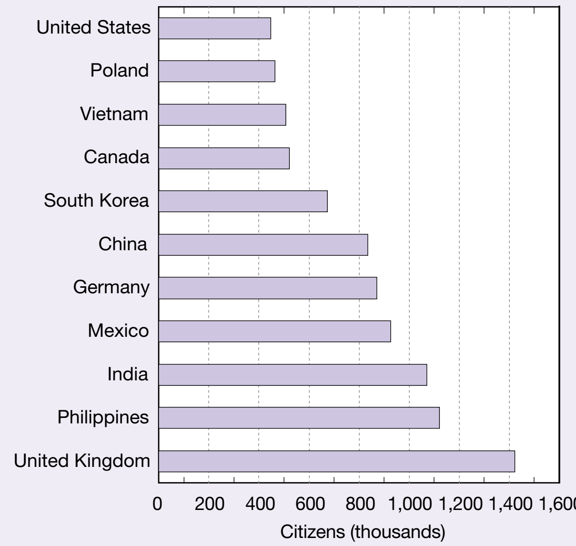
Within each discipline, the stay rate remained mostly stable for the 1998 graduation cohort between 1999 and 2003. Quite possibly, however, some of this stability came from individuals in this cohort who reentered the United States and thus replaced others in the same graduation cohort who left.

Highly Skilled Migrants in OECD Countries

Estimates of international migrants residing in OECD countries were made by Docquier and Marfouk (2004) using estimates from the various national censuses. Based on their data, figure 3-41 shows the 11 countries with the largest number of citizens found residing in OECD countries in 2000. With 1.4 million tertiary-educated citizens in other OECD countries, the United Kingdom has the largest "high-skilled diaspora." Although originally used to describe much less voluntary dispersals of population in history, high-skilled diaspora is increasingly used to describe networks of contact and information flow that form among the internationally mobile portion of a country's nationals. These networks can provide advantages for a country that help to mitigate any loss of human capital through migration.

The United States, ranking number 11 with 448,000 tertiary-educated citizens in other OECD countries, has a fairly small high-skilled diaspora compared with its population, and particularly compared with its number of educated workers.

Figure 3-41
Citizens having at least tertiary-level education residing in OECD countries, by top 11 countries: 2000



OECD = Organisation for Economic Co-operation and Development

SOURCE: F. Docquier and A. Marfouk, International Migration by Educational Attainment (1990–2000), Institute for the Study of Labor (2004).

Science and Engineering Indicators 2006

Table 3-24
Temporary residents receiving U.S. S&E doctorates in 1998 who were in the United States, by degree field: 1999–2003
(Percent)

Degree field	Foreign doctorate recipients	In United States				
		1999	2000	2001	2002	2003
All S&E fields	7,958	66	64	63	62	61
Agricultural sciences	463	48	47	47	47	46
Computer sciences	328	71	71	72	72	70
Computer/electrical engineering	688	78	76	75	74	70
Economics	516	40	39	37	37	36
Life sciences	1,620	72	68	67	68	67
Mathematics	447	67	63	62	60	59
Other engineering	1,894	68	67	67	65	64
Other social sciences	583	39	38	37	37	37
Physical sciences	1,419	75	74	72	71	69

SOURCE: M. Finn, Oak Ridge Institute for Science and Education, unpublished tabulations.

Science and Engineering Indicators 2006

Conclusion

The U.S. S&E labor market continues to grow, both in absolute numbers and as a percentage of the total labor market. Although the most dramatic growth has occurred in the IT sector, other areas of S&E employment also have recorded strong growth over the past two decades.

In general, labor market conditions for individuals with S&E degrees improved during the 1990s. (These conditions have always been better than the conditions for college graduates as a whole.) However, engineering and computer science occupations have been unusually affected by the recent recession, causing the unemployment rate for individuals in all S&E occupations to reach a 20-year high of 4.6% in 2003 before dropping to 3.0% in 2004. Labor market conditions for new doctoral degree recipients have been good according to most conventional measures; for example, the vast majority of S&E doctorate degree holders are employed and doing work relevant to their training. However, these gains have come in the nonacademic sectors. In nearly all fields, the proportion of doctoral recipients that obtain tenure-track academic positions, long a minority, has continued to decline. The globalization of the S&E labor force continues to increase as the location of S&E employment becomes more internationally diverse and S&E workers become more internationally mobile. These trends reinforce each other as R&D spending and business investment cross national borders in search of available talent, as talented people cross borders in search of interesting and lucrative work, and as employers recruit and move employees internationally. Although these trends appear most strong in the high-profile international competition for IT workers, they affect every science and technology area.

The rate of growth of the S&E labor force may decline rapidly over the next decade because of the aging of individuals with S&E educations, as the number of individuals with S&E degrees reaching traditional retirement ages is expected to triple. If this slowdown occurs, the rapid growth in R&D employment and spending that the United States has experienced since World War II may not be sustainable.

The growth rate of the S&E labor force would also be significantly reduced if the United States becomes less successful in the increasing international competition for immigrant and temporary nonimmigrant scientists and engineers. Many countries are actively reducing barriers to high-skilled immigrants entering their labor markets at the same time that entry into the United States is becoming somewhat more difficult.

Slowing of the S&E labor force growth would be a fundamental change for the U.S. economy, possibly affecting both technological change and economic growth. Some researchers have raised concerns that other factors may even accentuate the trend (NSB 2003). Any sustained drop in S&E degree production would produce not only a slowing of labor-force growth, but also a long-term decline in the S&E labor force.

Note

1. Not all analyses of changes in earnings are able to control for level of skill. For example, data on average earnings within occupation overtime may not be a good indicator of labor market conditions if the average experience level were to fall for workers in a rapidly growing occupation.

Glossary

Career path job: A job that helps a graduate fulfill his or her future career plans.

High-skilled diaspora: Increasingly used to describe networks of contact and information flow that form among the internationally mobile portion of a country's nationals.

Involuntary employment outside of field: A person either employed outside his or her field because a job in that field was not available or employed part time in that field because a full-time job was not available.

Stay rate: In this chapter, the proportion of students on temporary visas who have stayed in the United States 1–5 years after doctorate degree conferral.

Tertiary educated: Roughly equivalent in U.S. terms to individuals who have earned at least technical school or associate's degrees, including all degrees up to doctorate.

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Chapter 4
Research and Development: Funds and Technology Linkages

List of Sidebars

List of Tables

List of Figures

Highlights

National R&D Trends

U.S. R&D declined for the first time in almost 50 years in 2002 as a result of cutbacks in business R&D, but it has since recovered due to growth in all sectors of the economy.

- U.S. R&D grew to $291.9 billion in 2003 after declining in 2002 for the first time since 1953. U.S. R&D is projected to increase further to $312.1 billion in 2004.
- The business sector's share of U.S. R&D peaked in 2000 at 75%, but following the stock market decline and subsequent economic slowdown of 2001 and 2002, the business activities of many R&D-performing firms were curtailed. The business sector is projected to have performed 70% of U.S. R&D in 2004.

The decades-long trend of federal R&D funding shrinking as a share of the nation's total R&D reversed after 2000.

- The federal share of R&D funding first fell below 50% in 1979 and dropped to a low of 24.9% in 2000.
- The federal share of R&D funding grew to a projected 29.9% in 2004 as private investment slowed and federal spending on R&D expanded, particularly in the areas of defense, health, and counterterrorism.

U.S. R&D is dominated by development, largely performed by the business sector, with most basic research conducted at universities and colleges.

- In 2004 the United States performed an estimated $58.4 billion of basic research, $66.4 billion of applied research, and $187.3 billion of development.
- Universities and colleges have historically been the largest performers of basic research in the United States, and in recent years they have accounted for over half (55% in 2004) of the nation's basic research. Most basic research is federally funded.
- The development of new and improved goods, services, and processes is dominated by industry, which performed 90.2% of all U.S. development in 2004.

Location of R&D Performance

R&D is geographically concentrated, and states vary significantly in terms of the types of research performed within their borders.

- In 2003, the top 10 states in terms of R&D accounted for almost two-thirds of U.S. R&D. California alone accounted for more than one-fifth of the $278 billion of R&D that could be attributed to one of the 50 states or the District of Columbia.
- Federal R&D accounts for 86% of all R&D in New Mexico, the location of the two largest federally funded research and development centers (FFRDCs) in terms of R&D performance, Los Alamos National Laboratory and Sandia National Laboratories.
- Over half of all R&D performed in the United States by computer and electronic products manufacturers is located in California, Massachusetts, and Texas.
- The R&D of chemicals manufacturing companies is particularly prominent in two states, accounting for 61% of New Jersey's and 49% of Pennsylvania's business R&D. Together these two states represent almost one-third of the nation's R&D in this sector.

Business R&D

Business sector R&D is projected to have rebounded from its 2002 decline to a new high in 2004.

- R&D performed by the business sector is estimated to have reached $219.2 billion in 2004.
- The average R&D intensity of companies performing R&D in the United States peaked in 2001 at 3.8%, as R&D budgets remained steady despite a decline in sales of R&D-performing companies. R&D intensity declined to 3.2% in 2003 as a result of the 2002 decline in company R&D and stronger sales growth in 2003.
- Computer and electronic products manufacturers and computer-related services companies, combined, performed over one-third of all company-funded research and development in 2003.

Federal R&D

The current level of federal investment in R&D, both in absolute terms and as a share of the budget, is over an order of magnitude greater than what it was prior to World War II.

- In the president's 2006 budget submission, the federal government is slated to set aside $132.3 billion for R&D, amounting to 13.6% of its discretionary budget.
- Federal agencies are expected to obligate $106.5 billion for R&D support in FY 2005. The five largest R&D-funding agencies account for 94% of total federal R&D.

Defense-related R&D dominates the federal R&D portfolio.

- The largest R&D budget function in the FY 2006 budget is defense, with a proposed budget authority of $74.8 billion, or 59% of the entire federal R&D budget.
- In FY 2006, the Department of Defense (DOD) requested research, development, testing, and evaluation budgets in excess of $1 billion for four weapon systems.

Federal R&E Tax Credit

From 1990 to 2001, research and experimentation (R&E) tax credit claims by companies in the United States grew twice as fast as industry-funded R&D, after adjusting for inflation, but growth in credit claims varied throughout the decade.

- R&E tax credit claims reached an estimated $6.4 billion in 2001.
- From 1990 to 1996, companies claimed between $1.5 billion and $2.5 billion in R&E credits annually; since then, annual R&E credits have exceeded $4 billion. However, in 2001 R&E tax credit claims still accounted for less than 4% of industry-funded R&D expenditures.

Technology Linkages: Contract R&D, Public-Private Partnerships, and Industrial Alliances

Since 1993 R&D expenses paid to other domestic R&D performers outside their companies have increased as a proportion of company-funded R&D performed within firms.

- In 2003, companies in the United States reported $10.2 billion in R&D expenses paid to other domestic R&D performers outside their companies, compared with $183.3 billion in company-funded R&D performed within firms. The ratio of contracted-out R&D to in-house R&D was 5.6% for the aggregate of all industries in 2003, compared with 3.7% in 1993.

Participation by federal laboratories in cooperative research and development agreements (CRADAs) increased in FY 2003 but was still below the mid-1990s peak.

- Federal laboratories participated in a total of 2,936 CRADAs with industrial companies and other organizations in FY 2003, up 4.3% from a year earlier, but still below the 3,500 peak in FY 1996.

U.S. companies continue to partner with other American and international companies worldwide to develop and exploit new technologies.

- New industrial technology alliances worldwide reached an all-time peak in 2003 with 695 alliances, according to the Cooperative Agreements and Technology Indicators database. Alliances involving only U.S.-owned companies have represented the largest share of alliances in most years since 1980, followed by alliances between U.S. and European companies.

International R&D

R&D is performed and funded primarily by a small number of developed nations.

- In 2000, global R&D expenditures totaled at least $729 billion, half of which was accounted for by the two largest countries in terms of R&D performance, the United States and Japan.
- The R&D performance of Organisation for Economic Co-operation and Development (OECD) countries grew to $652 billion in 2002. The G-7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) performed over 83% of OECD R&D in 2002.
- More money was spent on R&D activities in the United States in 2002 than in the rest of the G-7 countries combined.

R&D intensity indicators, such as R&D/gross domestic product (GDP) ratios, also show the developed, wealthy economies well ahead of lesser-developed economies.

- Overall, the United States ranked fifth among OECD countries in terms of reported R&D/GDP ratios. Israel (not an OECD member country), devoting 4.9% of its GDP to R&D, led all countries, followed by Sweden (4.3%), Finland (3.5%), Japan (3.1%), and Iceland (3.1%).
- In the United States, the slowdown in GDP growth in 2001 preceded the decline of U.S. R&D in 2002. This resulted in U.S. R&D to GDP ratios of 2.7% in 2001 (a recent high) and 2.6% in 2002. Following the 2002 decline, R&D grew more rapidly than GDP in the United States, resulting in an R&D to GDP ratio of 2.7% in 2003.[1] The U.S. economy expanded at a faster pace in 2004, and R&D as a proportion of GDP remained at 2.7%.
- Although China and Germany reported similar R&D expenditures in 2000, on a per capita basis, Germany's R&D was over 16 times that of China.

R&D Investments by Multinational Corporations

U.S. multinational corporations (MNCs) continued to expand R&D activity overseas. However, the level of R&D expenditures by foreign MNCs in the United States has been even larger in recent years.

- In 2002, R&D expenditures by affiliates of foreign companies in the United States reached $27.5 billion, up 2.3% from 2001 after adjusting for inflation. By comparison, total U.S. industrial R&D performance declined by 5.6%, after adjusting for inflation, over the same period. On the other hand, foreign affiliates of U.S. MNCs performed $21.2 billion in R&D expenditures abroad in 2002, up 5.6% from 2001, after adjusting for inflation.

Cross-country R&D investments through MNCs continue to be strong between U.S. and European companies. At the same time, certain developing or newly industrialized economies are emerging as significant hosts of U.S.-owned R&D, including China, Israel, and Singapore.

- In 1994, major developed economies or regions accounted for 90% of overseas R&D expenditures by U.S. MNCs. This share decreased to 80% by 2001. The change reflects modest expenditures growth in European locations, compared with larger increases in Asia (outside Japan) and Israel.

Introduction

Chapter Overview

In 2006 the United States commemorates the bicentennial of Meriwether Lewis and William Clark's completed expedition of discovery across a then-uncharted North American continent. This expedition, championed by President Thomas Jefferson and funded by a federal appropriation of $2,500 in 1803, foreshadowed future voyages of discovery in the realms of science and technology (S&T) unimaginable two centuries ago. The commemoration of this expedition is recognition of the importance of scientific discovery to the nation and to the world.

The research and development activities undertaken today possess many of the same characteristics demonstrated by the Lewis and Clark expedition. Commerce, Jefferson's primary justification for the expedition, remains a driving force in discovery, and today profit-seeking firms perform most of the nation's R&D. At the same time, just as Congress did in 1803, governments still recognize that, for a variety of reasons, the private sector cannot or will not fund all of the R&D that might benefit society, and, therefore, public financing maintains an important role in the global R&D enterprise. And in our own time, modern R&D projects still require the teamwork and collaboration exhibited by Lewis and Clark's Corps of Discovery to advance the frontier of S&T.

Observing the trends in R&D and innovation, economist Jacob Schmookler (1962) concluded that, "The historical shifts in inventive attention appear to reflect the interplay of advancing knowledge, which opens up new inventive opportunities for exploitation, and the unfolding economic needs and opportunities arising out of a changing social order." These two forces—advancing scientific and technological knowledge and economic demand—can be characterized, respectively, as the supply and the demand sides of invention. Under this framework, advances in S&T may occur when the cost of invention (a function of current scientific knowledge) drops below the profit potential of invention (a function of demand). Similarly, shifts in demand for technological advances can raise the profit potential of invention above the cost of invention.

Technology developments resulting in part from national defense and other government investments in the first half of the 20th century, coupled with the growth of research universities and specialized industrial laboratories in advanced countries, cemented the role of S&T as a key contributor to national economic growth, productivity, security, and social welfare. In the second half of the 20th century, industrial innovation became increasingly globalized following international investments by multinational corporations (MNCs). Global R&D and related international investments are still concentrated in a few developed countries or regions. However, certain developing economies have increased their national R&D expenditures and have become hosts of R&D by U.S. MNCs within the past decade. Concurrent with these developments, industrial R&D is often performed in collaboration with external partners and contractors, assisted by an increasing international pool of scientific discoveries and talent.

Policymakers in both the public and private sectors constantly seek to evaluate their organizations' performance as a benchmark against both historical trends and current and future competitors. But because it is difficult to measure these advances directly, policymakers often use data on R&D expenditures as a proxy measure for the effort expended to make these advances possible. R&D expenditures indicate both the relative importance of advancing S&T compared with other goals as well as the perceived value of future S&T innovations. For example, R&D must compete for funding with other activities supported by discretionary government spending—from education to national defense. The resulting share of a government's budget that is devoted to R&D activities thus indicates governmental and societal commitment to R&D relative to other government programs. Likewise, profit-seeking firms invest in product R&D to the extent that they foresee a potential market demand for new and improved goods and services. Other indicators discussed in this chapter include industrial technology alliances and federal technology transfer activities.

Chapter Organization

This chapter is organized into seven sections that examine trends in R&D expenditures and collaborative technology activities. The first section provides an overview of national trends in R&D performance and R&D funding. The second analyzes data on the location of R&D performance in the United States. The third and fourth sections focus on the respective roles of business enterprises and the federal government in the R&D enterprise.

The fifth section summarizes available information on external technology sourcing and collaborative R&D activities across R&D-performing sectors, including industrial contract R&D expenditures, federal technology transfer, and domestic and international technology alliances.

The sixth section compares R&D trends across nations. It contains sections on total and nondefense R&D spending; ratios of R&D to gross domestic product (GDP) in various nations; international R&D funding by performer and source (including information on industrial subsectors and academic science and engineering fields); the allocation of R&D efforts among components (basic research, applied research, and development); and international comparisons of government R&D priorities and tax policies.

The seventh section presents data on R&D by U.S. MNCs and their overseas affiliates and by affiliates of foreign companies in the United States. Data include R&D expenditures by investing or host countries and their industrial focus, and R&D employment.

National R&D Trends

U.S. R&D grew to $291.9 billion in 2003 after declining in 2002 for the first time since 1953, when these data were first collected (see sidebar "Definitions of R&D").[2] The National Science Foundation (NSF) projects that U.S. R&D will continue to increase to $312.1 billion in 2004.

Definitions of R&D

R&D. According to international guidelines for conducting research and development surveys, R&D, also called research and experimental development, comprises creative work "undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and the use of this stock of knowledge to devise new applications" (OECD 2002b, p. 30).

Basic research. The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be performed in fields of present or potential commercial interest.

Applied research. The objective of applied research is to gain the knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Development. Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

R&D plant. R&D plant includes the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Budget authority. Budget authority is the authority provided by federal law to incur financial obligations that will result in outlays.

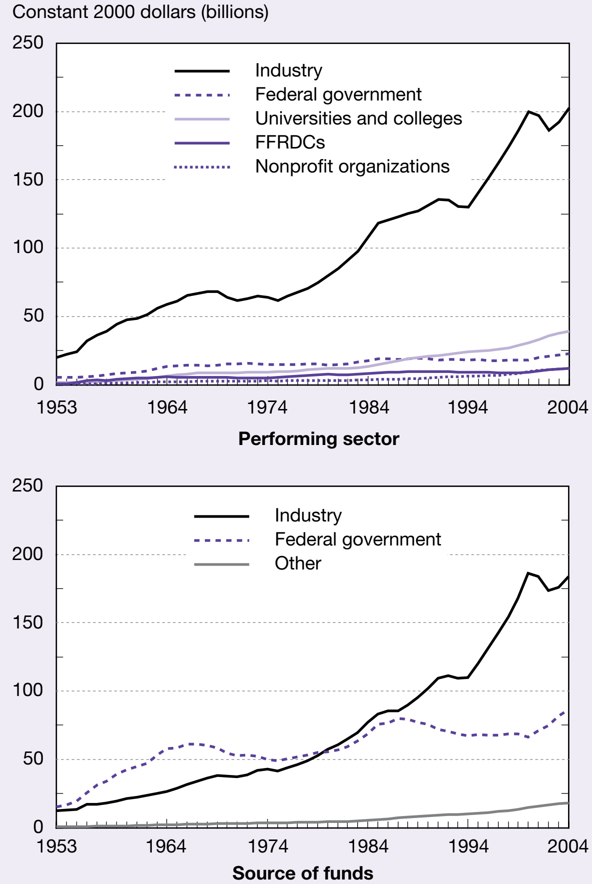
Obligations. Federal obligations represent the dollar amounts for orders placed, contracts and grants awarded, services received, and similar transactions during a given period, regardless of when funds were appropriated or payment was required.

Outlays. Federal outlays represent the dollar amounts for checks issued and cash payments made during a given period, regardless of when funds were appropriated or obligated.

As a point of reference, in 1990 total U.S. R&D was $152.0 billion—less than half the projected figure for 2004. After adjusting for inflation, total R&D declined 2.2% between 2001 and 2002, then increased 3.9% in 2003 and increased a projected 4.7% in 2004.[3] These recent growth rates in R&D exceed the average annual growth rate over the prior two decades, but they do not match the 6% per year inflation-adjusted growth of the late 1990s that resulted from substantial increases in company R&D, most notably in information and communications technology (ICT) industries and in small R&D-performing firms (figure 4-1).[4] These official U.S. R&D data are derived by adding up the R&D performance for all sectors of the economy for which it can be reasonably estimated. For a description of the R&D activity not captured in these data, see sidebar "Unmeasured R&D."

Figure 4-1
National R&D, by performing sector and source of funds, 1953–2004

Constant 2000 dollars (billions)



FFRDC = federally funded research and development center

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-3 and 4-4.

Science and Engineering Indicators 2006

Unmeasured R&D

The estimates of U.S. R&D presented in this volume are derived from surveys of establishments that have historically performed the vast majority of R&D in the United States. However, to evaluate U.S. R&D performance over time and in comparison with other countries, it is necessary to gauge how much R&D is going unmeasured in the United States. The following are indicators of unmeasured R&D performance in the United States:

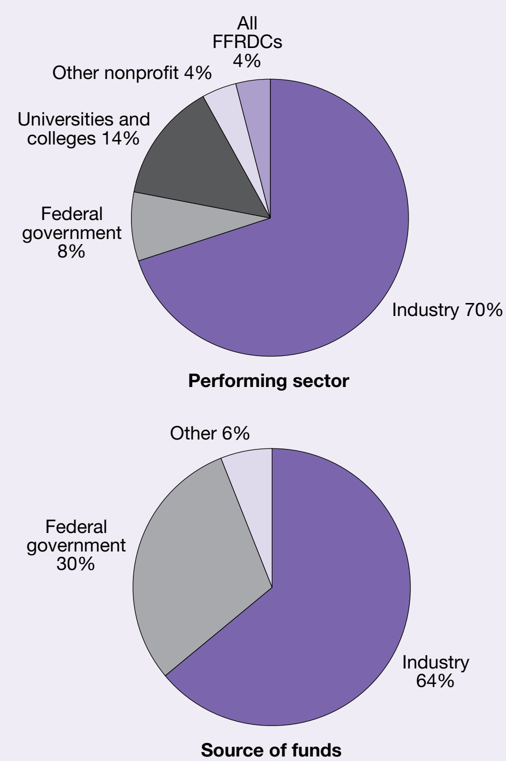
- To reduce cost and respondent burden, U.S. industrial R&D estimates are derived from a survey of R&D-performing companies with five or more employees. There are no estimates of R&D performance for companies with fewer than five employees; however, the 2004 census business registry classifies over 6,000 such companies in the scientific R&D services industry and almost 4,000 in the software industry.
- The activity of individuals performing R&D on their own time (and not under the auspices of a corporation, university, or other organization) is similarly not included in official U.S. R&D statistics. However, the U.S. Patent and Trademark Office reports that historically over 13% of U.S. patents for invention have been granted to U.S. individuals (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/all_tech.htm#parta1_2b).
- The National Science Foundation (NSF) Survey of Research and Development Expenditures at Universities and Colleges collects data on "organized research," which includes sponsored projects as well as any separately budgeted research activity. However, no official estimates exist for the amount of academic departmental research, small projects, and general scholarly work performed without external funding. Scientists and engineers who do not receive a research grant often continue their research on a smaller scale as departmental research. Due to lack of resources, approximately 2,000 highly rated grant proposals were declined by NSF in FY 2004.
- Non-science and engineering R&D is excluded from U.S. industrial R&D statistics, and R&D in the humanities is excluded from U.S. academic R&D statistics. Other countries include both in their national statistics, making their national R&D expenditures relatively larger when compared with those of the United States.
- R&D performed by state and local governments in the United States is not currently surveyed or estimated for national statistics. A survey conducted in 1998 estimates that state agencies performed over $400 million of R&D in FY 1995 (http://www.nsf.gov/statistics/nsf99348/).
- Although NSF estimates the R&D performance of nonprofit organizations, a nonprofit R&D survey has not been fielded since 1998.

R&D Performance

The decline in 2002 and subsequent recovery of U.S. R&D can largely be attributed to the business sector, which performed 70% of U.S. R&D in 2004 (figure 4-2). The next largest sector in terms of R&D performance—universities and colleges—performs one-fifth the R&D of businesses. However, universities and colleges perform over half of the nation's basic research (table 4-1) (see the discussion of R&D by character of work that appears later in this chapter). Federal agencies and all federally funded research and development centers (FFRDCs) combined performed 12% of U.S. total R&D in 2004.[5] Federal R&D is discussed in more detail later in this chapter.

From 2000 to 2004, U.S. R&D increased by 2% per year in real terms. The business sector's share of U.S. R&D peaked in 2000 at 75%, but following the stock market decline and subsequent economic slowdown of 2001 and 2002, the business activities of many R&D-performing firms were curtailed. As a result, business R&D grew by only 0.3% per year in real terms between 2000 and 2004. During this period more robust growth was evident at federal agencies and FFRDCS, where R&D performance increased by 6.5% per year in real terms,

Figure 4-2
Shares of national R&D expenditures, by performing sector and source of funds: 2004



FFRDC = federally funded research and development center

NOTES: Values rounded to nearest whole number. National R&D expenditures estimated at $312 billion in 2004.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-3 and 4-5.

Science and Engineering Indicators 2006

and at universities and colleges, where R&D performance increased by 6.3% per year in real terms.[6]

R&D Funding

Besides performing the majority of U.S. R&D, the business sector is also the largest source of R&D funding in the United States and provided 64% ($199 billion) of total R&D funding in 2004 (figure 4-2). Most businesses spend their R&D budgets on either internal R&D projects or for contract R&D performed by other businesses (see section on contract R&D). Only 1.7% of business R&D funding flows to other sectors. The federal government provided the second largest share of R&D funding, 30% ($93.4 billion). Unlike in the business sector, the majority of federal R&D dollars finance R&D in other sectors, with only 40.3% of these funds financing federal agencies and FFRDCs. The other sectors of the economy (e.g., state governments, universities and colleges, and nonprofit institutions) contributed the remaining 6% ($20 billion) (table 4-1; see also sidebar "Alternative Methods for Stimulating R&D: Prizes as R&D Incentives").

Table 4-1
U.S. R&D expenditures, by character of work, performing sector, and source of funds: 2004

	Source of funds ($ millions)					
Performing sector	Total	Industry	Federal government	U&C	Other nonprofit institutions	Total expenditures (% distribution)
R&D	312,068	199,025	93,384	11,095	8,565	100.0
Industry	219,226	195,691	23,535	NA	NA	70.2
Industry-administered FFRDCs	2,584	NA	2,584	NA	NA	0.8
Federal government	24,742	NA	24,742	NA	NA	7.9
U&C	42,431	2,135	26,115	11,095	3,087	13.6
U&C-administered FFRDCs	7,500	NA	7,500	NA	NA	2.4
Other nonprofit institutions	12,750	1,199	6,072	NA	5,478	4.1
Nonprofit-administered FFRDCs	2,834	NA	2,834	NA	NA	0.9
Percent distribution by source	100.0	63.8	29.9	3.6	2.7	NA
Basic research	58,356	9,551	36,075	7,579	5,150	100.0
Industry	9,278	7,427	1,851	NA	NA	15.9
Industry-administered FFRDCs	706	NA	706	NA	NA	1.2
Federal government	4,887	NA	4,887	NA	NA	8.4
U&C	31,735	1,458	20,589	7,579	2,109	54.4
U&C-administered FFRDCs	3,917	NA	3,917	NA	NA	6.7
Other nonprofit institutions	6,651	666	2,944	NA	3,042	11.4
Nonprofit-administered FFRDCs	1,181	NA	1,181	NA	NA	2.0
Percent distribution by source	100.0	16.4	61.8	13.0	8.8	NA
Applied research	66,364	35,975	25,315	2,883	2,190	100.0
Industry	41,009	35,117	5,892	NA	NA	61.8
Industry-administered FFRDCs	1,268	NA	1,268	NA	NA	1.9
Federal government	8,407	NA	8,407	NA	NA	12.7
U&C	9,223	555	4,983	2,883	802	13.9
U&C-administered FFRDCs	1,806	NA	1,806	NA	NA	2.7
Other nonprofit institutions	4,287	304	2,595	NA	1,388	6.5
Nonprofit-administered FFRDCs	365	NA	365	NA	NA	0.5
Percent distribution by source	100.0	54.2	38.1	4.3	3.3	NA
Development	187,349	153,498	31,993	633	1,224	100.0
Industry	168,939	153,147	15,792	NA	NA	90.2
Industry-administered FFRDCs	610	NA	610	NA	NA	0.3
Federal government	11,447	NA	11,447	NA	NA	6.1
U&C	1,474	122	543	633	176	0.8
U&C-administered FFRDCs	1,778	NA	1,778	NA	NA	0.9
Other nonprofit institutions	1,812	229	534	NA	1,048	1.0
Nonprofit-administered FFRDCs	1,288	NA	1,288	NA	NA	0.7
Percent distribution by source	100.0	81.9	17.1	0.3	0.7	NA

NA = not available

FFRDC = federally funded research and development center; U&C = universities and colleges

NOTES: State and local government support to industry included in industry support for industry performance. State and local government support to U&C ($2,890 million in total R&D) included in U&C support for U&C performance.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-3, 4-7, 4-11, and 4-15.

Science and Engineering Indicators 2006

Federal R&D Funding

The federal government was once the foremost sponsor of the nation's R&D, funding as much as 66.8% of all U.S. R&D in 1964 (figure 4-3). The federal share first fell below 50% in 1979 and dropped to a low of 24.9% in 2000. The declining share of federal R&D funding is most evident in the business sector. In the late 1950s and early 1960s over half of the nation's business R&D was funded by the federal government, but by 2000 less than 10% of business R&D was federally funded.[7] The decades-long trend of federal R&D funding shrinking as a share of the nation's total R&D reversed after 2000. As private investment slowed, federal spending on R&D expanded, particularly in the areas of defense, health, and counterterrorism. These changing conditions resulted in a growing federal share of R&D funding, projected at 29.9% in 2004.

Nonfederal R&D Funding

R&D funding from nonfederal sources is projected to have reached $218.7 billion in 2004. After adjusting for inflation, nonfederal R&D funding was only 0.7% higher in 2004 than in 2000. Business sector funding dominates nonfederal R&D support. Of the total 2004 nonfederal R&D support, 91% ($199 billion) was company funded. The business sector's share of national R&D funding first surpassed the federal government's share in 1980. From 1980 to 1985, industrial support for R&D, in real dollars, grew at an average annual rate of 7.8%. This growth was maintained

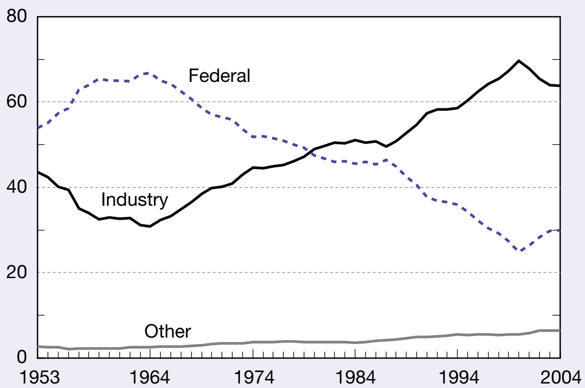
Alternative Methods for Stimulating R&D: Prizes as R&D Incentives

Uncertainty is a defining characteristic of research and development. At the outset of an R&D project, there is no guarantee of technical success. Given this uncertainty, investments of time and money into R&D "are not likely to be forthcoming in volume without commensurate prospective rewards in income or prestige" (Schmookler 1962). In some cases, even when technical success is virtually guaranteed, the lack of a perceived profitable market or of well-defined property rights for an invention stymies investment in R&D. In many cases where market incentives are insufficient to motivate private sector R&D investment, governments and other nonprofit organizations directly fund R&D through grants, contracts, and cooperative agreements.

A less common approach to stimulate R&D is to create a market for the results of R&D where none existed. This can be achieved by either offering a prize for achieving some technical goal or by making credible promises to purchase products resulting from the R&D. These methods have been used for centuries to foster innovation. Prominent examples of prizes and market-based incentives for R&D include:

- The series of prizes offered in 1714 by the British government to the person who could develop an accurate technique for measuring longitude. John Harrison, after 40 years of work, won the top prize of 20,000 pounds for his chronometer, H4.
- A prize of 12,000 francs offered in 1795 by Napolean's Society for the Encouragement of Industry for a method of food preservation usable by the French military. The prize was awarded in 1810 for a process that sterilized food sealed in champagne bottles.
- The $10 million Ansari X PRIZE for the first private manned spacecraft to exceed an altitude of 100 km twice in as many weeks. Mojave Aerospace led by Burt Rutan and Paul Allen won the prize on 4 October 2004 with its spacecraft, SpaceShipOne. The resulting media publicity likely outweighed the prize money, as the X PRIZE became the number two news story of 2004. (http://www.xprizefoundation.com/news/default.asp)
- The Methuselah Mouse Prize (MPrize) for the scientific research team that develops the longest living *Mus musculus,* the breed of mouse most commonly used in scientific research. The goal of this prize is to encourage research into the potential for near-term science-based aging interventions. (http://www.methuselahmouse.org/)
- InnoCentive, founded in 2001 by Eli Lilly and Company, an online incentive-based initiative for R&D. Using the website, a firm can anonymously post a research problem along with a bounty and a deadline for responses. As of 2005, there were 75,000 registered scientists from more than 165 countries registered with InnoCentive. If a scientist can provide a solution that meets the firm's specified criteria, that person will collect the bounty. (www.innocentive.com)
- Project BioShield, signed into law by President Bush on 21 July 2004, creates a guaranteed market for next-generation vaccines and drugs to protect Americans from the threat of bioterrorism. The law provides the Department of Homeland Security with $5.6 billion over 10 years for the purchase of next generation countermeasures against anthrax and smallpox as well as other biological or chemical agents. (http://www.whitehouse.gov/bioshield/)
- The National Aeronautics and Space Administration's (NASA's) Centennial Challenges Program offers a number of monetary prizes to stimulate innovation and competition in solar system exploration and other NASA mission areas. (http://exploration.nasa.gov/centennialchallenge/cc_index.html)

Figure 4-3
National R&D expenditures, by source of funds: 1953–2004



SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix table 4-5.

Science and Engineering Indicators 2006

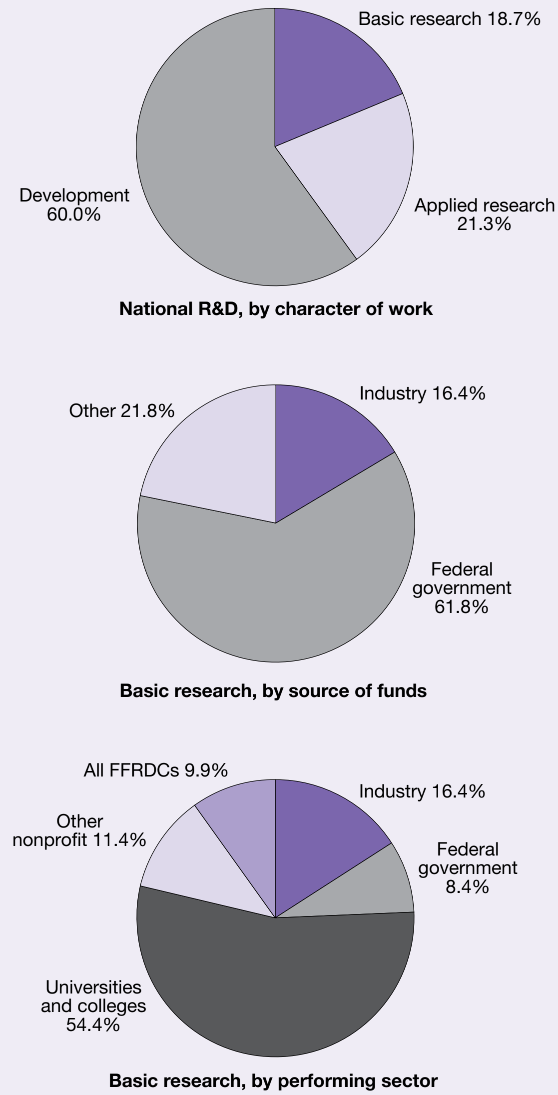
through both the mild 1980 recession and the more severe 1982 recession (figure 4-1). Between 1985 and 1994, growth in R&D funding from industry was slower, averaging only 3.1% per year in real terms, but from 1994 to 2000, industrial R&D support grew in real terms by 9.2% per year. This rapid growth rate came to a halt following the downturn in both the market valuation and economic demand for new technology in the first years of the 21st century. Between 2000 and 2002, industrial R&D support declined by 3.4% per year in real terms, but it subsequently grew at inflation-adjusted rates of 1.4% in 2003 and 4.5% in 2004.

Although R&D funding from other nonfederal sectors (namely, academic and other nonprofit institutions and state and local governments) is small in comparison to federal and business R&D spending, it has grown rapidly. In the 20 years between 1984 and 2004, funding from these sectors grew at an average annual rate of 6.4%, twice as fast as R&D funding from the federal and business sectors combined. Most of these funds went to research performed within the academic sector.

R&D by Character of Work

Because R&D encompasses a broad range of activities, it is helpful to disaggregate R&D expenditures into the categories of basic research, applied research, and development. Despite the difficulties in classifying specific R&D projects, these categories are useful for characterizing the expected time horizons, outputs, and types of investments associated with R&D expenditures. In 2004 the United States performed an estimated $58.4 billion of basic research, $66.4 billion of applied research, and $187.3 billion of development (table 4-1). As a share of all 2004 R&D expenditures, basic research represented 18.7%, applied research represented 21.3%, and development represented 60.0% (figure 4-4).

Figure 4-4
National R&D by character of work, basic research by source of funds, and basic research by performing sector: 2004



FFRDC = federally funded research and development center

NOTES: Figures rounded to nearest whole number. National R&D expenditures estimated at $313 billion in 2004.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-3, 4-7, 4-11, and 4-15.

Science and Engineering Indicators 2006

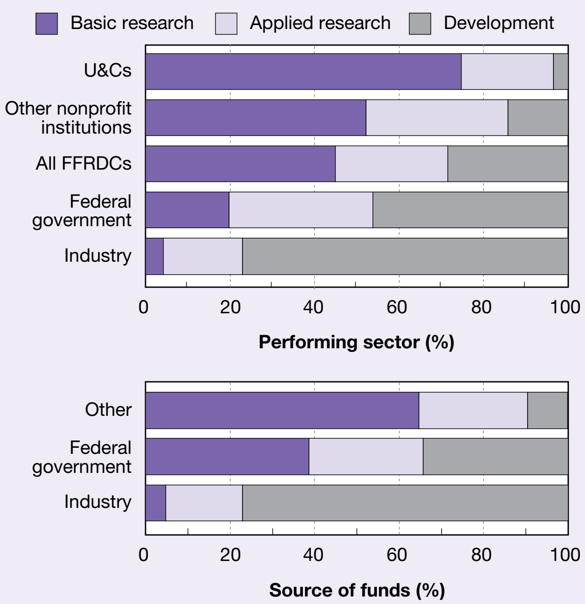
Basic Research

Universities and colleges have historically been the largest performer of basic research in the United States, and in recent years they have accounted for more than half (55% in 2004) of the nation's basic research (table 4-1). Organizations influence the type of R&D conducted by their scientists and engineers both directly and indirectly. The most direct influence is the decision to fund specific R&D projects. This influence tends to be weaker in academia than in industry or government

agencies because academic researchers generally have more freedom to seek outside R&D funding. This reliance on external sources of funding, along with the tenure system, makes universities and colleges well suited to carrying out basic research (particularly undirected basic research).

The federal government, estimated to have funded 61.8% of U.S. basic research in 2004, has historically been the primary source of support for basic research (figure 4-4). Moreover, the federal government funded 64.9% of the basic research performed by universities and colleges in 2004. Industry devoted only an estimated 4.8% of its total R&D support to basic research in that year (figure 4-5), representing 16% of the national total. The reasons for industry's relatively small contribution to basic research are that this activity generally involves a high degree of risk in terms of technical success and the potential commercial value of any discovery, as well as concern about the ability of the firm to enforce property rights over the discovery. However, firms may have other reasons for performing basic research in addition to immediate commercial demands. For example, a company that supports basic research could boost its human capital (by attracting and retaining academically motivated scientists and engineers) and strengthen its innovative capacity (i.e., its ability to absorb external scientific and technological knowledge). The industries that invest the most in basic research are those whose new products are most directly tied to recent advances in S&E, such as the pharmaceuticals industry and the scientific R&D services industry.

Figure 4-5
R&D performing sectors and source of funds, by character of work: 2004



FFRDC = federally funded research and development center; U&C = universities and colleges

NOTES: State and local government support to industry is included in industry support for industry performance. State and local government support to U&C ($2,890 million in total R&D) is included in U&C support for U&C performance.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-3, 4-7, 4-11, and 4-15.

Science and Engineering Indicators 2006

Applied Research

The business sector spends over three times as much on applied research than on basic research and accounts for about half of U.S. applied research funding. In 2004 the federal government invested $25.3 billion in applied research funding, 38.1% of the U.S. total. Whereas most of the federal investment in basic research supports work done at universities and colleges, the majority of federally funded applied research is performed by federal agencies and FFRDCs. Historically, the federal government's investment has emphasized basic research over applied research, reflecting the belief that the private sector is less likely to invest in basic research. In 2004, the federal government spent 43% more on basic research funding than on applied research funding (figure 4-5).

Within industry, applied research refines and adapts existing scientific knowledge and technology into knowledge and techniques useful for creating or improving products, processes, and services. The level of applied research in an industry reflects both the market demand for substantially (as opposed to cosmetically) new and improved goods and services, as well as the level of effort required to transition from basic research to technically and economically feasible concepts. Examples of industries that perform a relatively large amount of applied research are the chemicals industry, the aerospace industry (largely financed by the Department of Defense [DOD]), and the R&D services industry (encompassing many biotechnology companies).

Development

Development expenditures totaled an estimated $187.3 billion in 2004, representing the majority of U.S. R&D expenditures. The development of new and improved goods, services, and processes is dominated by industry, which performed 90.2% of all U.S. development in 2004. Universities, colleges, and other nonprofit institutions account for less than 2% of U.S. development performance. The balance of development is performed by federal agencies and FFRDCs, representing 8% of the U.S. total in 2004.

Industry and the federal government together funded 99% of all development in 2004, with industry providing 82% and the federal government providing 17%. Most federal development spending is defense related. The federal government generally invests in the development of such products as military aircraft and space exploration vehicles, for which it is the only consumer. Other typologies can be used to analyze R&D. One alternative is used in the federal budget as discussed in the section entitled "Federal S&T Budget" within "Federal R&D Funding by National Objective" appearing later in this chapter.

Location of R&D Performance

R&D performance is geographically concentrated in the United States. Over 50% of U.S. R&D is performed in only seven states.[8] Although R&D expenditures are concentrated in relatively few states, patterns of R&D activity vary considerably among the top R&D-performing locations (appendix tables 4-23 and 4-24). (For a broader range of indicators of state-level S&E activities, see chapter 8.)

Distribution of R&D Expenditures Among States

In 2003 the 20 highest-ranking states in R&D expenditures accounted for 84% of U.S. R&D expenditures, whereas the 20 lowest-ranking states accounted for 6%. The top 10 states accounted for almost two-thirds of U.S. R&D expenditures in 2003 (table 4-2). California alone accounted for more than one-fifth of the $278 billion U.S. R&D total, exceeding the next highest state by a factor of three.[9] Figure 4-6, a cartogram of the United States with states sized in proportion to the amount of R&D performed within them, illustrates the geographic concentration of U.S. R&D along both coasts and in the Great Lakes region.

States vary significantly in the size of their economies because of differences in population, land area, infrastructure, natural resources, and history. Consequently, state variations in R&D expenditure levels may simply reflect differences in economic size or the nature of R&D efforts. One way to control for the size of each state's economy is to measure each state's R&D level as a percentage of its gross state product (GSP).[10] Like the ratio of national R&D to GDP discussed later in this chapter, the proportion of a state's GSP devoted to R&D is an indicator of R&D intensity. Some of the states with the highest R&D to GSP ratios include Michigan, home to the major auto manufacturers; Massachusetts, home to a number of large research universities and a thriving high-technology industry; and Maryland, home to the National Institutes of Health (NIH). A list of states and corresponding R&D intensities can be found in appendix table 4-24.

Sector Distribution of R&D Performance by State

Although leading states in total R&D tend to be well represented in each of the major R&D-performing sectors, the proportion of R&D performed in each of these sectors varies across states. Because business sector R&D accounts for 71% of the distributed U.S. total, it is not surprising that 9 of the top 10 states in terms of total R&D performance are also in the top 10 in terms of industry R&D (table 4-2). University-performed R&D accounts for only 14% of the U.S. total, but it is also highly correlated with the total R&D performance in a state.

There is less of a relationship between federal R&D performance (both intramural and FFRDC) and total R&D, as federal R&D is more geographically concentrated than the R&D performed by other sectors.[11] Figure 4-7, a cartogram of the United States with states sized in proportion to federal R&D performance in the state, illustrates that the top four states in terms of federal R&D (California, New Mexico, Maryland, and Virginia), along with the District of Columbia, account for over half (56%) of all federal R&D performance. Federal R&D accounts for 86% of all R&D in New Mexico, the location of the two largest FFRDCs in terms of R&D performance, Los Alamos National Laboratory and Sandia National Laboratories. Federal R&D accounts for 41% of all R&D performed in Maryland, Virginia, and the District of Columbia, reflecting the concentration of federal facilities and administrative offices within the national capital area.

Table 4-2
Top 10 states in R&D performance, by sector and intensity: 2003

Rank	State	Total R&D[a] (current $ millions)	Sector ranking: Industry	U&C	Federal intramural and FFRDC[b]	R&D intensity (R&D/GSP ratio): State	R&D/GSP (%)	GSP (current $ billions)
1	California	59,664	California	California	California	New Mexico	8.72	57.1
2	Michigan	16,884	Michigan	New York	New Mexico	Massachusetts	5.26	297.1
3	Massachusetts	15,638	New Jersey	Texas	Maryland	Maryland	4.77	213.1
4	Texas	14,785	Massachusetts	Maryland	Virginia	Michigan	4.70	359.4
5	New York	13,031	Texas	Pennsylvania	District of Columbia	Washington	4.68	245.1
6	New Jersey	12,795	Washington	Massachusetts	Massachusetts	Rhode Island	4.46	39.4
7	Washington	11,469	New York	Illinois	Washington	California	4.15	1,438.1
8	Illinois	11,045	Illinois	North Carolina	Illinois	District of Columbia	3.80	70.7
9	Maryland	10,162	Pennsylvania	Michigan	New York	Connecticut	3.76	174.1
10	Pennsylvania	9,944	Ohio	Ohio	Alabama	New Hampshire	3.45	48.2

FFRDC = federally funded research and development center; GSP = gross state product; U&C = universities and colleges

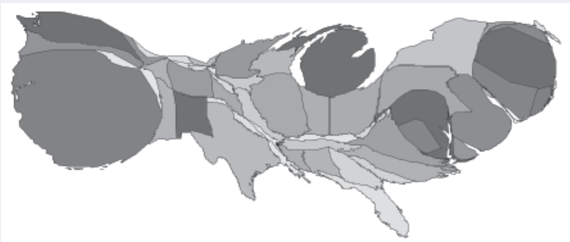
[a]Includes in-state total R&D performance of industry, universities, federal agencies, FFRDCs, and federally financed nonprofit R&D.
[b]Includes costs associated with administration of intramural and extramural programs by federal personnel and actual intramural R&D performance.

NOTES: Rankings do not account for margin of error of estimates from sample surveys.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series); and U.S. Bureau of Economic Analysis, U.S. Department of Commerce (2005), http://www.bea.gov/bea/newsrel/gspnewsrelease.htm.

Science and Engineering Indicators 2006

Figure 4-6
R&D expenditures and R&D/gross state product ratios, by state: 2003

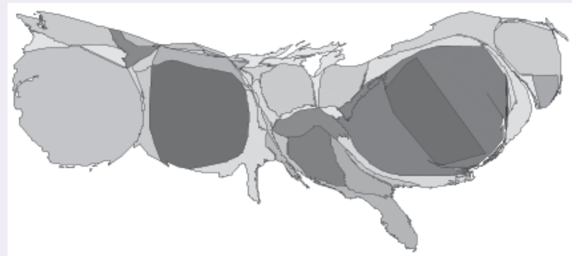


NOTES: States sized relative to their R&D in 2003. Darker shading indicates higher R&D/GSP ratio (R&D intensity).

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-23 and 4-24.

Science and Engineering Indicators 2006

Figure 4-7
Federal intramural and FFRDC R&D expenditures, by state: 2003



FFRDC = federally funded research and development center

NOTES: States sized relative to their federal intramural and FFRDC R&D in 2003. Darker shading indicates federal R&D represents larger share of state's total R&D.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-23.

Science and Engineering Indicators 2006

Federal R&D also represents 37% of the R&D performed in Alabama, due largely to DOD's Redstone Arsenal laboratories and the National Aeronautics and Space Administration's (NASA's) George C. Marshall Space Flight Center, both in Huntsville. Looking across all states, federal R&D represents only 12% of the distributed U.S. total.

Industrial R&D in Top States

The types of companies that carry out R&D vary considerably among the 10 leading states in industry-performed R&D (table 4-3). This reflects regional specialization or clusters of industrial activity. For example, in Michigan the motor vehicles industry accounted for 70% of industrial R&D in 2003, whereas it accounted for only 8% of the nation's total industrial R&D. In Washington, companies performing computer-related services (such as software development) dominate, accounting for over 50% of the state's business-sector R&D. These companies accounted for 13% of the nation's business R&D in 2003.

The computer and electronic products manufacturing industries account for 24% of the nation's total industrial R&D, but they account for a larger share of the industrial R&D in California (33%), Massachusetts (47%), and Texas (46%). These three states have clearly defined regional centers of high-technology research and manufacturing: Silicon Valley in California, Route 128 in Massachusetts, and the Silicon Hills of Austin, Texas. Over half of all R&D performed in the United States by computer and electronic products companies is located in these three states.

The R&D of chemicals manufacturing companies is particularly prominent in New Jersey and Pennsylvania, both of which host robust pharmaceutical and chemical industries. These companies account for 61% of New Jersey's and 49% of Pennsylvania's business R&D. Together these two states represent almost one-third of the nation's R&D in this sector.

The R&D services sector is even more concentrated geographically, with California, Massachusetts, and Ohio accounting for nearly half of the nation's R&D in this sector. Companies in this sector, consisting largely of biotechnology companies, contract research organizations, and early-stage technology firms, maintain strong ties to the academic sector and often are located near large research universities. (See the section entitled "Technology Linkages: Contract R&D, Public-Private Partnerships, and Industrial Alliances" appearing later in this chapter.) The state of Ohio has been particularly aggressive in pursuing policies that support this sector. Ohio's $1.1 billion Third Frontier Project, initiated in 2002, commits $500 million over 10 years to fund new technology, biomedical research, and technology transfer, and more than $500 million to enhance research facilities.[12]

The R&D performance of small companies (defined as having from 5 to 499 employees) is also concentrated geographically.[13] Nationally, small companies perform 18% of the nation's total business R&D, but in California, Massachusetts, and New York these companies perform between 21% and 23% of the states' business R&D. About 40% of the R&D performed in the United States by companies in this category is performed in these three states.

Business R&D

Businesses perform R&D with a variety of objectives in mind, but most business R&D is aimed at developing new and improved goods, services, and processes. For most firms, R&D is a discretionary expense similar to advertising. R&D does not directly generate revenue in the same way that production expenses do, so it can be trimmed with little impact on revenue in the short term. Firms attempt to invest in R&D at a level that maximizes future profits while maintaining current market share and increasing operating efficiency. R&D expenditures therefore indicate the level of effort dedicated to producing future products and process

Table 4-3
Top 10 states in industry R&D performance and share of R&D, by selected industry: 2003
(Percent)

State	Industry-performed R&D (current $ millions)	Share of industry-performed R&D					
		Chemicals[a]	Computer and electronic products[b]	Computer-related services	R&D services	Motor vehicles	Companies with 5–499 employees
All states	204,004	15.9 L	23.9 L	13.4 L	8.6	8.3	17.6
California	47,142	7.0	33.1	18.7	13.7	5.0	21.4
Michigan	15,241	D	1.7	D	3.0	70.4	7.0
New Jersey	11,401	61.0	2.9	D	D	0.2	11.6
Massachusetts	11,094	8.3	47.3	11.8	13.4	0.2	23.4
Texas	11,057	4.5	45.7	9.7	6.5	0.6	17.4
Washington	9,222	D	D	D[c]	5.5	0.3	10.9
New York	8,556	30.0	23.6	7.0	7.9	3.2	22.2
Illinois	8,319	21.4	34.4	10.3	2.6	3.8	13.6
Pennsylvania	7,091	48.6	9.1	5.2	7.5	1.4	19.0
Ohio	6,260	10.6	4.6	5.4	9.7	D	16.4

D = data withheld to avoid disclosing operations of individual companies; L = lower bound estimate

[a]Includes R&D of drugs and druggists' sundries wholesale trade industry.
[b]Includes R&D of professional and commercial equipment and supplies, including computers wholesale trade industry.
[c]In 2002, computer-related services accounted for more than 50% of Washington's industry-performed R&D.

NOTES: Rankings do not account for margin of error of estimates from sample surveys. Detail does not add to total because not all industries are shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (2003).

Science and Engineering Indicators 2006

improvements in the business sector; by extension, they may reflect firms' perceptions of the market's demand for new and improved technology.

As previously mentioned, R&D performed by private industry is estimated to have reached $219.2 billion in 2004. The federal government funded 10.7% ($23.5 billion) of this total, and company funds and other private sources financed the remainder. These estimates are derived from the NSF and the U.S. Census Bureau's annual Survey of Industrial Research and Development, which collects financial data related to R&D activities from companies performing R&D in the United States. These data provide a basis for analyzing the technological dynamism of the business sector and are the official source for U.S. business R&D estimates (see sidebar "Industry Classification Complicates Analysis").

In addition to absolute levels of R&D expenditures, another key S&T indicator in the business sector is R&D intensity, a measure of R&D relative to production in a company, industry, or sector. Many ways exist to measure R&D intensity; the one used most frequently is the ratio of company-funded R&D to net sales.[14] This statistic provides a way to gauge the relative importance of R&D across industries and among firms in the same industry. The average R&D intensity of companies performing R&D in the United States peaked in 2001 at 3.8% as R&D budgets remained steady despite a decline in sales of R&D-performing companies. R&D intensity declined to 3.2% in 2003 as a result of the 2002 decline in company R&D and strong sales growth in 2003.

Largest R&D Industries

Although all industries benefit from advances in S&T, industries perform different amounts of R&D.[15] Some industries have relatively low R&D intensities (0.5% or less), such as the utilities industry and the finance, insurance, and real estate industries (appendix table 4-22). Six groups of industries account for three-quarters of company funded business R&D and 95% of federally funded business R&D (table 4-4).

Computer and Electronic Products

The computer and electronic products manufacturing sector accounts for the largest amount of business R&D performed in the United States (table 4-4). Industries in this sector include companies that manufacture computers, computer peripherals, communications equipment, and similar electronic products, and companies that manufacture components for such products. The design and use of integrated circuits and the application of highly specialized miniaturization technologies are common elements in the production processes of the computer and electronic products sector.

In 2003, these industries performed at least $42.5 billion of R&D, or 21% of all business R&D.[17] Companies and other nonfederal sources funded almost all of this R&D. The focus of the R&D in this sector is on development, with less than 16% of company-funded R&D devoted to basic and applied research. Two of the more R&D-intensive industries—communications equipment and semiconductor manufacturing—are included in this group. Both devoted more than 11% of sales to R&D in 2003.

Industry Classification Complicates Analysis

Each company sampled in the Survey of Industrial Research and Development is assigned to a single industry based on payroll data for the company,[16] and each is requested to report its R&D expenditures for the entire company. These expenditures are assigned to the previously established single industry. This classification scheme reasonably categorizes most companies into industries closely aligned with their primary business activities. However, for diversified companies that perform R&D in support of a variety of industries, any single assigned industry is only partly correct. And in some cases, the industry assigned based on payroll data is not directly related to a company's R&D activities.

Given this classification scheme, interpretation of industry-level R&D data is not always straightforward. It is important to assess the relationships between industries as well as the business structure within industries when analyzing R&D data. For example, most of the federally funded R&D reported in the navigational, measuring, electromedical, and control instruments industry is performed by large defense contractors that also produce aerospace products. And investigations of survey microdata revealed that most of the R&D classified into the trade industry represents the activities of manufacturing firms that have integrated their supply chains and brought their warehousing, sales, and marketing efforts in house. For example, a large pharmaceutical firm could be classified in the trade industry if the payroll associated with its sales and marketing efforts outweighed that of its manufacturing activities. Therefore any analysis of the pharmaceutical industry's R&D should involve a concurrent analysis of the R&D reported in the drugs and druggists' sundries wholesalers industry. The same holds true for the computer and electronic products industries and their representative trade industry, professional and commercial equipment and supplies wholesalers. Wherever possible, this report aggregates industry-level data in a way that accounts for these classification issues.

Table 4-4
R&D and domestic net sales, by selected business sector: 2002 and 2003
(Current $ millions)

Sector	Total R&D		Federal R&D		Company R&D		Domestic net sales	
	2002	2003	2002	2003	2002	2003	2002	2003
All industries	190,809	203,853	16,401	22,108	174,408	181,745	4,903,345	5,809,394
Highlighted sectors	145,887 L	159,560 L	15,686 L	20,829 L	130,201	138,731	2,073,655	2,224,473
Automotive manufacturing	15,199 L	16,874 L	NA	NA	15,199	16,874	487,740	703,834
Chemicals	27,452 L	32,474 L	246 L	103 L	27,206	32,370	415,873	489,604
Computer/electronic products	42,367 L	39,871 L	289 L	61 L	42,078	39,810	526,577	450,528
Computer-related services	27,549 L	27,436 L	1,643 L	1,148 L	25,907	26,288	262,774	201,567
Aerospace/defense manufacturing	16,126 L	23,410 L	9,872	14,179	6,254 L	9,231 L	265,994 L	270,054 L
R&D services	17,193	19,497	3,636	5,338	13,557	14,158	114,697	108,886
All other industries	D	D	D	D	44,207	43,014	2,829,690	3,584,921

L = lower bound estimate; D = data withheld to avoid disclosing operations of individual companies; NA = not available; all federal R&D for transportation industries (including that of automotive manufacturing) included in aerospace/defense manufacturing sector.

NOTES: All federal R&D for navigational, measuring, electromedical, and control instruments industry included in aersospace/defense manufacting sector. All nonfederal R&D and domestic net sales for the navigational, measuring, electromedical, and control instruments industry included in computer/electronic products sector. Potential disclosure of individual company operations only allows lower bound estimates for federal R&D in the chemicals, computer/electronic products, and computer-related services sectors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (2003).

Science and Engineering Indicators 2006

Chemicals

The chemicals industry performed an estimated $32.5 billion of R&D in 2003. Like the computer and electronic products industries, very little of the R&D in the chemicals industry is federally funded. In terms of R&D performance, the largest industry within the chemicals subsector is pharmaceuticals and medicines. In 2003, pharmaceutical companies performed $25.4 billion of company-funded R&D, representing 79% of nonfederal R&D funding of the chemicals sector.

The Pharmaceutical Research and Manufacturers of America (PhRMA), an industry association that represents

the country's leading research-based pharmaceutical and biotechnology companies, annually surveys its members for information on their R&D investments. In 2003, PhRMA members reported investing $27.1 billion domestically in R&D, of which 38% was for basic and applied research (PhRMA 2005).[18] Most of PhRMA members' domestic R&D investment supports continuing R&D on projects that originated in their own laboratories (73% in 2003), but 20% supports R&D on products licensed from other companies (notably biotechnology companies), universities, or the government. In NSF's Survey of Industrial Research and Development, companies that predominantly license their technology rather than manufacture finished products are often classified in the scientific R&D services industry. Therefore, a sizeable amount of biotechnology R&D that serves the pharmaceutical industry is reported in the R&D services sector (see section "R&D Services").

Computer-Related Services

Industries associated with software and computer-related services (such as data processing and systems design) performed approximately $26.1 billion of company-funded R&D in 2003.[19] The R&D of these industries combined with that of the computer and electronic products manufacturers discussed earlier account for over one-third of all company-funded R&D in 2003. As computing and information technology became more integrated with every sector of the economy, the demand for services associated with these technologies boomed. The R&D of companies providing these services also grew dramatically during this period. In 1987, when an upper bound estimate of software and other computer-related services R&D first became available, companies classified in the industry group "computer programming, data processing, other computer-related, engineering, architectural, and surveying services" performed $2.4 billion of company-funded R&D, or 3.8% of all company-funded industrial R&D. In 2003 the company-funded R&D of a comparable group of industries (excluding engineering and architectural services) accounted for 14.3% of all company-funded industrial R&D (table 4-5).[20] Although the R&D activities of computer-related services companies have grown dramatically, this group is not the sole performer of software development R&D in the United States. In fact, companies in almost every industry report expenditures for software development R&D.

Aerospace and Defense Manufacturing

Although it is common to refer to the "defense industry," there is no such category in the industry classification system used by the federal government. Companies performing the majority of DOD's extramural R&D are classified in the aerospace products and parts industry; other transportation equipment industries; and the navigational, measuring, electromedical, and control instruments manufacturing industry. In 2003 these industries reported performing $14.3 billion of federal R&D, accounting for 69% of all federal R&D expenditures reported by companies (table 4-4). Almost half of the $15.7 billion of R&D performed by companies classified in the aerospace industry in 2003 came from federal sources. (See the section on federal R&D later in this chapter for further discussion of defense R&D.)

R&D Services

Companies in the business of selling scientific and engineering R&D services to other companies or licensing the results of their R&D are generally classified in the architectural, engineering, and related services industry or the scientific R&D services industry. Companies in this sector perform the majority of the federal R&D that is not performed by aerospace and defense manufacturing firms, $3.8 billion in 2003. Despite the significant amount of government-sponsored R&D performed by this sector, R&D services companies increasingly rely on nonfederal sources of R&D financing. The R&D performed by companies in the R&D services sector and funded by company and other nonfederal sources has grown from $5.8 billion in 1997 to $13.8 billion in 2003, an increase of 138%.[21] By comparison,

Table 4-5
Estimated share of computer-related services in company-funded R&D and domestic net sales of R&D-performing companies: 1987–2003
(Percent)

Year	Company-funded R&D	Domestic net sales
1987	3.8	1.4
1988	3.6	1.5
1989	3.4	1.4
1990	3.7	1.5
1991	3.6	1.6
1992	4.0	1.6
1993	8.2	1.5
1994	6.6	2.2
1995	8.8	3.3
1996	8.8	2.6
1997	9.1	2.5
1998	9.5	2.2
1999	10.6	2.2
2000	10.9	2.8
2001	13.0	3.5
2002	14.6	5.4
2003	14.3	3.5

NOTES: Data before 1998 are for companies classified in Standard Industrial Classification (SIC) industries 737 (computer and data processing services) and 871 (engineering, architectural, and surveying services). For 1998 on, data are for companies classified in North American Industry Classification System (NAICS) industries 5112 (software), 51 minus (511, 513; other information), and 5415 (computer systems design and related services). With SIC classification, information technology services share of company-funded R&D is 10.4% for 1998, indicating that SIC-based data may overestimate information technology services R&D and net sales relative to NAICS-based data.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, special tabulations (2005).

Science and Engineering Indicators 2006

the company-funded R&D of all other industries increased by 33% over the same period. Because much of the R&D reported by these companies also appears in their reported sales figures, the R&D intensity of the R&D services sector is particularly high (13% in 2003).

Although the companies in this sector and their R&D activities are classified as nonmanufacturing, many of the industries they serve are manufacturing industries. For example, many biotechnology companies in the R&D services sector license their technology to companies in the pharmaceutical manufacturing industry. If a research firm was a subsidiary of a manufacturing company rather than an independent contractor, its R&D would be classified as R&D in a manufacturing industry. Consequently, growth in R&D services may, in part, "reflect a more general pattern of industry's increasing reliance on outsourcing and contract R&D" (Jankowski 2001). (For more information, see the section entitled "Contract R&D Expenses.")

Automotive Manufacturing

The sixth largest business sector in terms of R&D is automotive manufacturing. Companies in this industry reported performing $16.9 billion of company-funded R&D in 2003, accounting for 9% of all such R&D performed by businesses in the United States. At one time, this industry played a larger role in U.S. business R&D, accounting for as much as 16.2% of all company-funded and -performed R&D in 1959.

In 2003, 13 companies in the automotive manufacturing industry reported R&D expenditures over $100 million, representing approximately 85% of the industry's R&D. In most industries large companies perform more R&D than small companies, but in the automotive manufacturing industry the distribution of R&D is even more skewed towards large companies, with the R&D activities of the "Big Three" auto manufacturers (General Motors, Ford, and DaimlerChrysler) dominating the sector. In their annual reports to shareholders, these companies reported combined total engineering, research, and development expenses of $15.8 billion in FY 2003 (see sidebars "R&D Expenses of Public Corporations" and "Trends in R&D for Industrial Research Institute Members").[22]

Federal R&D

In the president's 2006 budget submission, the federal government is slated to invest $132.3 billion in R&D, amounting to 13.6% of its discretionary budget (i.e., that part of the annual federal budget that the president proposes and Congress debates and sets). The current level of federal investment in R&D, both in absolute terms and as a share of the budget, is over an order of magnitude greater than what it was prior to World War II, when the government had no unified national agenda for supporting science. In its early days, the U.S. government fostered innovation primarily through intellectual property protection and relatively small investments in R&D, but World War II changed how the federal government viewed its role in the national R&D enterprise. During the war, penicillin, a new drug at the time, greatly reduced the number of deaths caused by infection among Allied forces. And advances in military research, such as radar, were critical contributors to the Allied victory. Recognizing these achievements, President Franklin D. Roosevelt wrote to Vannevar Bush, the wartime director of the Office of Scientific Research and Development, requesting recommendations for how science could be mobilized in times of peace as it was in times of war, specifically "for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living" (Roosevelt 1944). Vannevar Bush's response in 1945, a report entitled "Science—The Endless Frontier," provided a framework for a more active federal role in support of science. He argued that:

> There are areas of science in which the public interest is acute but which are likely to be cultivated inadequately if left without more support than will come from private sources. These areas—such as research on military problems, agriculture, housing, public health, certain medical research, and research involving expensive capital facilities beyond the capacity of private institutions—should be advanced by active Government support…[W]e are entering a period when science needs and deserves increased support from public funds. (Bush 1945)

Bush's report was enormously influential, and many of its principles, including the importance of government support for R&D and of maintaining freedom of scientific inquiry, are evident in today's federal science policy and institutions.

Richard Nelson (1959) and Kenneth Arrow (1962) formalized the economic argument that the private sector generally invests less than the socially optimal amount in R&D. Briefly, the argument is that knowledge, the primary output of R&D, is nonrival and partially nonexcludable. That is, knowledge can be used by any number of actors at one time, and it is difficult or impossible to exclude others from using it. This being the case, firms will only invest in those R&D projects from which, through secrecy, patents, or some other means, they are able to recoup their investment plus an acceptable profit. The government endeavors to correct this market failure through a number of policy measures, the most direct of which is the funding and performance of R&D that would not, or could not, be financed or performed in the private sector. This section presents data on such R&D funding and performance as well as on the federal R&D tax credit, an indirect means of stimulating R&D in the private sector.

R&D by Federal Agency

Federal agencies are expected to obligate $106.5 billion for R&D support in FY 2005. Although more than 25 agencies report R&D obligations, the 5 largest R&D-funding agencies account for 94% of total federal R&D. These agencies vary considerably in terms of their R&D funding

R&D Expenses of Public Corporations

Most firms that make significant investments in R&D track their R&D expenses separately in their accounting records and financial statements. The annual reports of public corporations often include data on these R&D expenses. In 2003 the 20 public corporations with the largest reported worldwide R&D expenses spent $103.8 billion on R&D. Microsoft topped the list with $7.8 billion in R&D expenses, followed by Ford Motor Company with $7.5 billion (table 4-6). Companies in the information and communications technologies (ICT) sector dominate this list, with nine representatives accounting for 44% of the total R&D expenses. The remaining 11 companies include 6 automobile manufacturers and 5 pharmaceutical manufacturers. The top 20 companies are headquartered in six different countries, with nine headquartered in the United States. However, the location of a company's headquarters is not necessarily the location of all its R&D activities. Most of the companies on this list have manufacturing and research facilities in multiple countries around the world. (For more information, see the section entitled "R&D Investments by Multinational Corporations.")

A recent change in accounting standards by the Financial Accounting Standards Board (FASB) will result in discontinuities in companies' reported R&D expenses, making it more difficult to evaluate R&D spending trends from publicly available financial data. By 2006 most large companies are expected to follow the guidelines of FASB's Statement of Financial Accounting Standards (SFAS) 123, *Accounting for Stock-Based Compensation,* which requires companies to expense the fair value of all stock-based compensation.[23] Many high-technology companies have historically compensated their R&D employees with stock options and stock awards. This stock-based compensation may not have been reported as company expenses prior to these new guidelines. The dramatic increase in Microsoft's R&D expenses from 2002 to 2003, resulting in its move from number 10 to number 1 on the list of global R&D companies, was the result of Microsoft's early implementation of SFAS 123 in July 2003.[24] Prior to that date, the value of stock options awarded to employees was not included in the reported expenses of the company. Accounting for the value of this compensation resulted in Microsoft restating its 2002 R&D expenses up by $1.9 billion. The company does not detail how much stock-based compensation contributes to its 2003 R&D expenses. Microsoft's R&D in table 4-6 is likely exaggerated relative to other companies because it was an early adopter of SFAS 123. (See sidebar "Trends in R&D for Industrial Research Institute Members" for information on how some U.S.-based corporations intended to adjust their R&D strategies in 2005.)

Table 4-6
Top 20 R&D-spending corporations: 2003

	R&D rank		R&D expense ($ millions)			Sales ($ millions)		R&D intensity (%)	
Company (country)	2003	2002	2003	2002	Change (%)	2003	2002	2003	2002
Microsoft[a] (United States)	1	10	7,779	6,595	17.0	36,835	32,187	21.1	20.5
Ford Motor (United States)	2	1	7,500	7,700	–2.6	164,196	162,586	4.6	4.7
Pfizer (United States)	3	6	7,131	5,176	37.8	45,188	32,373	15.8	16.0
DaimlerChrysler (Germany)	4	2	6,689	7,289	–8.2	163,811	179,595	4.1	4.1
Toyota Motor (Japan)	5	5	6,210	6,113	1.6	157,411	146,121	3.9	4.2
Siemens (Germany)	6	3	6,084	6,987	–12.9	89,127	100,873	6.8	6.9
General Motors (United States)	7	4	5,700	5,800	–1.7	183,244	184,214	3.1	3.1
Matsushita Electric Industrial (Japan)	8	9	5,272	5,015	5.1	68,078	67,368	7.7	7.4
International Business Machines (United States)	9	7	5,068	4,750	6.7	89,131	81,186	5.7	5.9
GlaxoSmithKline (United Kingdom)	10	8	4,910	5,101	–3.8	37,717	37,314	13.0	13.7
Johnson & Johnson (United States)	11	12	4,684	3,957	18.4	41,862	36,298	11.2	10.9
Sony (Japan)	12	14	4,683	4,033	16.1	68,230	68,023	6.9	5.9
Nokia (Finland)	13	22	4,514	3,664	23.2	35,365	36,038	12.8	10.2
Intel (United States)	14	11	4,360	4,034	8.1	30,141	26,764	14.5	15.1
Volkswagen (Germany)	15	25	4,233	3,471	22.0	104,639	104,393	4.0	3.3
Honda Motor (Japan)	16	15	4,086	3,976	2.8	74,293	72,554	5.5	5.5
Motorola (United States)	17	13	3,771	3,754	0.5	27,058	26,679	13.9	14.1
Novartis (Switzerland)	18	24	3,756	3,362	11.7	24,864	25,111	15.1	13.4
Roche Holding (Switzerland)	19	27	3,694	3,298	12.0	24,188	23,030	15.3	14.3
Hewlett-Packard (United States)	20	19	3,652	3,312	10.3	73,061	56,588	5.0	5.9

[a]Fiscal year ended June 2004.

SOURCE: Institute of Electronics and Electronics Engineers (IEEE), IEEE Spectrum Top 100 R&D Spenders, Standard & Poor's data (2004), http://www.spectrum.ieee.org/WEBONLY/publicfeature/nov04/1104rdt1.pdf.

Science and Engineering Indicators 2006

Trends in R&D for Industrial Research Institute Members

For over 20 years the Industrial Research Institute (IRI), a nonprofit association of more than 200 leading R&D-performing industrial companies, has surveyed its U.S.-based members on their intentions for the coming year with respect to R&D expenditures, focus of R&D, R&D personnel, and other items. Because IRI member companies carry out a large amount of industrial R&D in the United States, the results from these surveys help identify broad trends in corporate R&D strategies. The most recent survey, administered in late 2004, suggests that many companies are shifting the focus of their R&D spending from directed basic research and support of existing business to new business projects (IRI 2005). This reported shift in R&D priorities also is reflected in how responding companies intend to spend their R&D budgets. IRI survey respondents reported the following plans for 2005:

- Increase total company expenditures on R&D
- Increase hiring of new graduates
- Increase outsourcing of R&D to other companies
- Increase outsourcing for university R&D and federal laboratories
- Increase participation in alliances and joint R&D ventures

Overall, these strategic moves are consistent with responses suggesting increased R&D budgets following a period of relative austerity. Responding companies are increasing R&D spending to support existing lines of business as well as new business projects and are leveraging their R&D spending through joint R&D ventures and grants/contracts for university R&D. (For more information, see "Technology Linkages: Contract R&D, Public-Private Partnerships, and Industrial Alliances.")

strategies, processes, and procedures, reflecting the unique mission, history, and culture of each.

Department of Defense

According to preliminary data, DOD will obligate $51.4 billion for R&D support in FY 2005. DOD funds more R&D than any other federal agency, representing 48% of all federal R&D obligations. More than 88% of these funds ($45.7 billion) will be spent on development, with $39.6 billion slated for major systems development (figure 4-8).[25] Industrial firms are expected to perform 70.4% of DOD-funded R&D in FY 2005. DOD accounts for more than 84% of all federal R&D obligations to industry in FY 2005. Federal intramural R&D and R&D performed by FFRDCs account for most of DOD's remaining R&D activity and represent 25.7% of its fiscal year total. According to the Office of Management and Budget (OMB), 72% of DOD's basic and applied research funding was allocated using competitive merit review processes with internal (program) evaluations in 2005.[26]

Department of Health and Human Services

HHS, the primary source of federal health-related R&D funding (largely through the National Institutes of Health), will obligate the second largest amount for R&D in FY 2005 at $28.9 billion, representing 27% of all federal R&D obligations. In contrast to DOD, HHS will allocate most of its R&D funding ($15.2 billion) for basic research. In FY 2005, HHS is expected to provide universities and colleges, the primary recipients of HHS funding, with $16.0 billion, which represents 67% of all federal R&D funds obligated to universities and colleges (table 4-7). HHS will provide 74% ($4.4 billion) of all federal R&D funds obligated to nonprofit institutions. Most of these institutions are large research hospitals such as Massachusetts General Hospital and the Dana-Farber Cancer Institute (NSF/SRS 2002). In 2005, competitive merit review processes with external (peer) evaluations were used to allocate 86% of HHS's basic and applied research funding.

National Aeronautics and Space Administration

The third largest agency in terms of R&D support is NASA, with R&D obligations expected to total $8.1 billion in FY 2005. Over one-third ($2.9 billion) of NASA's R&D activity is in development, much of which relies on industrial performers similar to those funded by DOD. However, unlike the industrial R&D funded by DOD, the majority (69%) of that funded by NASA supports research projects (basic and applied) as opposed to development. NASA is also the primary sponsor of R&D projects at nine federal facilities (including the Ames Research Center in California's Silicon Valley and the Marshall Space Flight Center in Huntsville, Alabama) and one FFRDC, the Jet Propulsion Laboratory, administered by the California Institute of Technology.

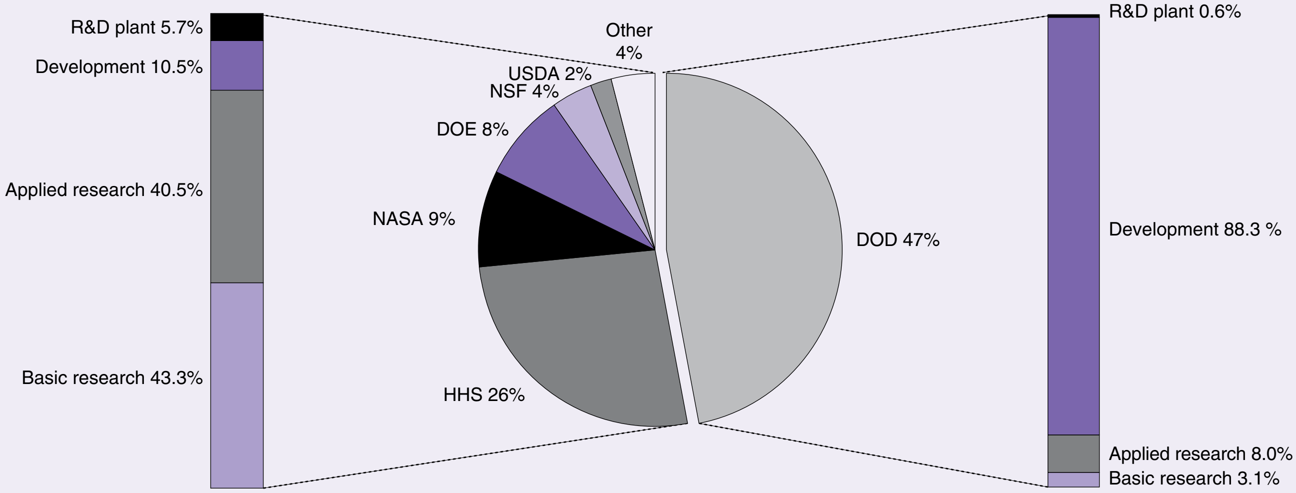
Department of Energy

Of the large R&D-funding agencies, the Department of Energy (DOE) relies the most on the R&D capabilities of FFRDCs. In FY 2005, DOE obligated 60% of its estimated $8 billion in R&D funding to FFRDCs. Of the 37 FFRDCs, DOE sponsored 16 and accounted for 59% of all federal R&D obligations to FFRDCs in FY 2005. Due to the scale and complexity of its research projects, most of DOE's research can only be performed in its intramural laboratories and FFRDCs. (See sidebar "Rationales for Federal Laboratories and FFRDCs.")

National Science Foundation

NSF is the federal government's primary source of funding for general S&E R&D and is expected to fund $3.8 billion of R&D in FY 2005. Of these funds, 94% are for basic research. NSF is the second largest federal source of R&D

Figure 4-8
Projected federal obligations for R&D and R&D plant, by agency and character of work: FY 2005



DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

NOTE: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming). See appendix table 4-30.

Science and Engineering Indicators 2006

Rationales for Federal Laboratories and FFRDCs

- **Scale.** Some R&D efforts require capital expenditures, facilities, and staffing that exceed the capabilities or resources of private sector research organizations. Termed “big science,” this R&D is often compared to the Manhattan Project of World War II and today spans the spectrum of scientific exploration from high-energy physics (e.g., DOE’s Fermi National Accelerator Laboratory) to medicine (e.g., the National Cancer Institute at Frederick, located within Fort Detrick, a U.S. Army base in Frederick, Maryland) to astronomy (e.g., NSF’s National Astronomy and Ionosphere Center in Arecibo, Puerto Rico).
- **Security.** The sensitive nature of some R&D necessitates direct government supervision. Security has historically been a concern of defense-related R&D performed at Department of Defense (DOD) and Department of Energy (DOE) laboratories and federally funded research and development centers (FFRDCs). However, the growing focus on the threat of bioterrorism highlights that some nondefense R&D, such as that carried out by the Centers for Disease Control and Prevention, is also influenced by national security.
- **Mission and Regulatory Requirements.** Some federal agencies, such as the Department of Transportation and the Food and Drug Administration, must perform a certain amount of R&D to fulfill their missions. To ensure impartiality and fairness, this R&D is performed in federal laboratories.
- **Knowledge Management.** For logistical reasons, federal laboratories and FFRDCs are often tasked with performing long-term or mission-critical R&D. These organizations possess the institutional memory and close connection to the sponsoring agency required by these types of projects. An additional benefit of in-house expertise in R&D sponsoring agencies is the complementary role it plays in the management of extramural R&D programs.

Table 4-7
Estimated federal R&D obligations, by performing sector and agency funding source: FY 2005

Character of work and performer	Total obligations ($ millions)	Primary funding agency		Secondary funding agency	
		Agency	Percent	Agency	Percent
All federal government	106,487.8	DOD	48	HHS	27
Federal intramural	24,813.0	DOD	49	HHS	23
Industrial firms	42,938.0	DOD	84	NASA	7
Industry-administered FFRDCs	1,639.3	DOE	60	HHS	30
Universities and colleges FFRDCs	4,955.4	DOE	59	NASA	28
Other nonprofit organizations	5,971.5	HHS	74	NASA	10
Nonprofit-administered FFRDCs	1,463.9	DOE	58	DOD	38
Basic research	26,860.3	HHS	57	NSF	13
Federal intramural	5,106.5	HHS	50	DOD	16
Industrial firms	1,674.8	HHS	51	NASA	27
Industry-administered FFRDCs	342.2	HHS	79	DOE	19
Universities and colleges	13,924.5	HHS	64	NSF	22
Universities and colleges FFRDCs	1,985.0	DOE	61	NASA	25
Other nonprofit organizations	2,920.6	HHS	83	NSF	8
Nonprofit-administered FFRDCs	655.1	DOE	93	DOD	4
Applied research	27,837.7	HHS	49	DOD	15
Federal intramural	8,175.9	HHS	39	DOD	17
Industrial firms	5,012.0	DOD	40	NASA	32
Industry-administered FFRDCs	890.6	DOE	72	HHS	24
Universities and colleges	9,070.0	HHS	79	DOD	5
Universities and colleges FFRDCs	1,533.3	DOE	90	NASA	4
Other nonprofit organizations	2,599.4	HHS	75	NASA	8
Nonprofit-administered FFRDCs	190.7	DOE	58	DOD	23
Development	51,788.7	DOD	88	NASA	6
Federal intramural	11,529.7	DOD	87	NASA	6
Industrial firms	36,251.0	DOD	94	DOE	3
Industry-administered FFRDCs	406.5	DOE	71	DOD	29
Universities and colleges	905.8	DOD	58	NASA	18
Universities and colleges FFRDCs	1,437.1	NASA	59	DOE	22
Other nonprofit organizations	451.5	NASA	47	DOD	25
Nonprofit-administered FFRDCs	618.0	DOD	78	DOE	21

DOD = Department of Defense; DOE = Department of Energy; FFRDC = federally funded research and development center; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation

NOTE: Subtotal by performer may not add to total because state and local governments and foreign performers of R&D not detailed.

SOURCE: NSF, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming).

Science and Engineering Indicators 2006

funds to universities and colleges; $3.2 billion is slated for academic researchers in FY 2005. In 2005, 73% of NSF's basic and applied research funding was allocated using competitive merit review processes with external (peer) evaluations. Most of its remaining research funding was allocated using competitive merit review processes with internal (program) evaluations.

Other Agencies

DOD, HHS, NASA, DOE, and NSF are expected to account for 94.1% of all federal R&D obligations in FY 2005 and slightly higher shares of federal obligations for basic research (94.5%) and development (98.8%). The remaining federal R&D obligations come from a variety of mission-oriented agencies such as the Department of Agriculture (USDA), the Department of Commerce (DOC), and the Department of the Interior (DOI). Unlike the larger R&D-funding agencies, USDA, DOC, and DOI direct most of their R&D funds to their own laboratories, which are run by the Agricultural Research Service, the National Institute for Standards and Technology (NIST), and the U.S. Geological Survey, respectively.

Federally Funded R&D by Performer

Federal Funding to Academia

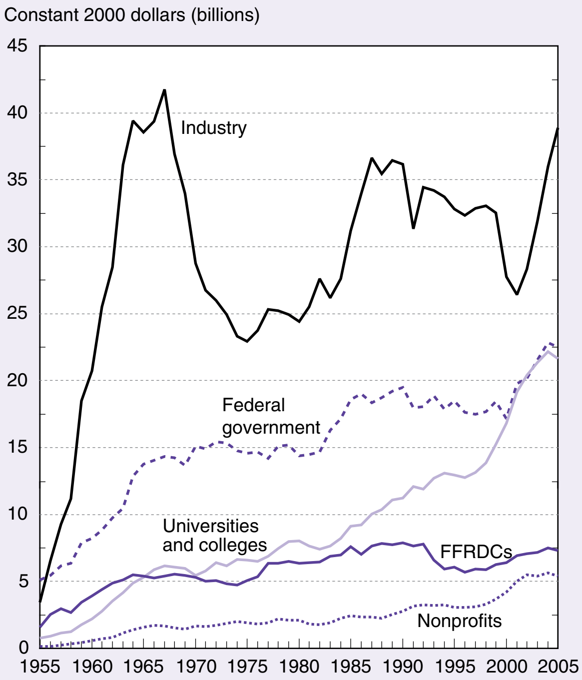
The federal government has historically been the primary source of R&D funding to universities and colleges, accounting for as much as two-thirds of all academic R&D funding in the early 1980s. (For more detailed information on academic R&D, see chapter 5). In 1955, obligations for academic R&D accounted for 7% of all federal R&D funding, or $0.75 billion in constant 2000 dollars. Fifty years later, R&D funding to academia represents 22% of all federal

R&D obligations, or $21.65 billion in constant 2000 dollars. As figure 4-9 illustrates, funding to academia grew rapidly after 1998, the result of a successful bipartisan effort to double the budget of NIH from its 1998 level over 5 years.

Federal Funding to Industry

Since 1956, the federal government has obligated the largest share of its R&D funding to industry. Federal funding for this sector, largely for development projects, has experienced more variability over the past 50 years than for any other sector (figure 4-9). R&D obligations to industry grew rapidly in the 1960s and peaked at $42 billion in constant 2000 dollars as the government invested heavily in its space program. Following the successful Apollo 11 mission to the moon, R&D obligations to industry declined and did not experience another surge until over a decade later, when Cold War investments in military technology resulted in another period of growth. Similarly, military investments following the events of September 11, 2001, resulted in an influx of federal R&D funding to industry. After adjusting for inflation, federal R&D obligations to industry increased by more than 47% from 2001 to 2005. Beginning in 1989, the amount of federally funded R&D reported by industry began to diverge from the amount reported by the federal government. For details on this discrepancy, see sidebar "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures."

Figure 4-9
Federal obligations for R&D, by performing sector: FY 1955–2005



FFRDC = federally funded research and development center

NOTE: Preliminary 2005 data.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming).

Science and Engineering Indicators 2006

Federal Intramural R&D

In FY 2005, obligations for federal intramural R&D totaled $24.8 billion. These funds supported R&D performed at federal laboratories as well as costs associated with the planning and administration of both intramural and extramural R&D projects. Among individual agencies, DOD continued to fund the most intramural R&D and is expected to account for almost half of all federal obligations for intramural R&D in FY 2005 (table 4-8). DOD's intramural R&D obligations are more than twice that of the second largest R&D-performing agency, HHS, which performs most of its intramural R&D at NIH in Maryland. Only two other agencies report intramural R&D obligations in excess of $1 billion in FY 2005, NASA and USDA.

Federally Funded Research and Development Centers

FFRDCs are unique organizations that help the U.S. government meet special long-term research or development goals that cannot be met as effectively by in-house or contractor resources. (See sidebar, "Rationales for Federal Laboratories and FFRDCs.") According to the *Federal Register,* an FFRDC is required "to operate in the public interest with objectivity and independence, to be free from organizational conflicts of interest, and to have full disclosure of its affairs to the sponsoring agency" (National Archives and Records Administration [NARA] 1990). First established during World War II to assist DOD and DOE with R&D on nuclear weapons, FFRDCs today perform R&D with both defense and civilian applications.

Of the 36 FFRDCs active in 2003, DOE sponsors 16, or more than any other agency.[27] These 16 FFRDCs performed a total of $9.2 billion of R&D in 2003, or more than three-quarters of that performed by all FFRDCs combined (appendix table 4-25). Four FFRDCs reported R&D expenditures of more than $1 billion in 2003—Los Alamos National Laboratory, Sandia National Laboratories, Jet Propulsion Laboratory, and Lawrence Livermore National Laboratory—accounting for over half of all FFRDC R&D expenditures.

Federal Research Funding by Field

Federal agencies fund research in a wide range of S&E fields, from aeronautical engineering to sociology. The relative amount of research funding differs by field, as do trends in funding over time. According to preliminary estimates, federal obligations for research (excluding development) totaled $54.7 billion in FY 2005. Life sciences received the largest portion of this funding (54%, or $29.7 billion), followed by engineering (17%), physical sciences (10%), environmental sciences (7%), and mathematics and computer sciences (5%) (figure 4-11). Social sciences, psychology, and all other sciences accounted for the remainder.

HHS, primarily through NIH, provided the largest share (53%) of all federal research obligations in FY 2005, with

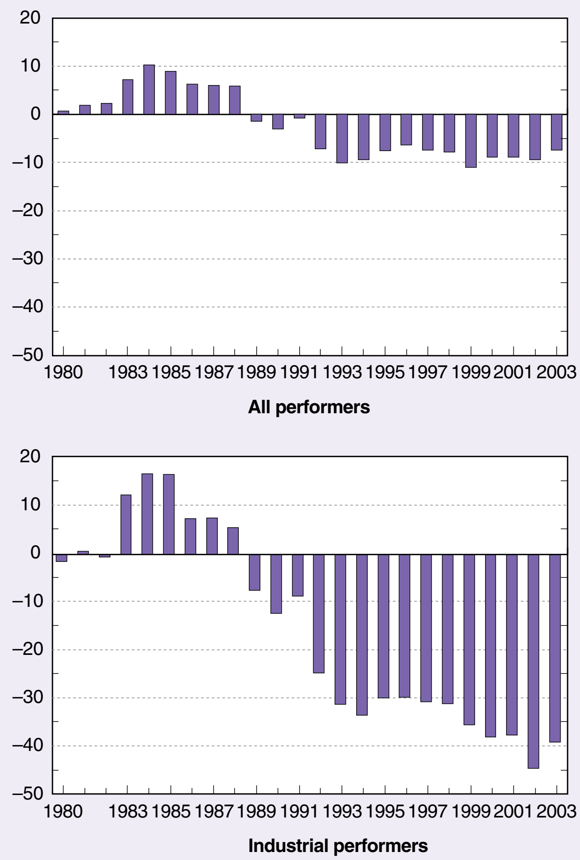
Tracking R&D: Gap Between Performer- and Source-Reported Expenditures

In many Organisation for Economic Co-operation and Development (OECD) countries, including the United States, total government R&D support figures reported by government agencies differ substantially from those reported by performers of R&D work. Consistent with international guidance and standards, most countries' national R&D expenditure totals and time series are based primarily on data reported by performers (OECD 2002b). This convention is preferred because performers are in the best position to indicate how much they spent conducting R&D in a given year and to identify the source of their funds. Although funding and performing series may be expected to differ for many reasons, such as different bases used for reporting government obligations (fiscal year) and performance expenditures (calendar year), the gap between the two R&D series has widened during the past several years.

For the United States, the reporting gap has become particularly acute over the past several years. In the mid-1980s, performer-reported federal R&D exceeded federal reports of funding by $3–$4 billion annually (5%–10% of the government total). This pattern reversed itself toward the end of the decade; in 1989 the government-reported R&D total exceeded performer reports by $1 billion. The gap subsequently grew to about $8 billion by 2002. In other words, almost 10% of the government total in 2002 was unaccounted for in performer surveys (figure 4-10). The difference in federal R&D totals was primarily in DOD development funding of industry. For 2002 federal agencies reported $29.5 billion in total R&D obligations to industrial performers, compared with $16.4 billion in federal funding reported by industrial performers. Overall, industrywide estimates equal a 44% paper "loss" of federally reported 2001 R&D support (figure 4-6). This discrepancy shrank in 2003 to 39%.

Several investigations into the possible causes for the data gap produced insights into the issue, but a conclusive explanation has been elusive. According to a recent investigation (U.S. General Accounting Office 2001b, p. 2), "Because the gap is the result of comparing two dissimilar types of financial data (federal obligations and performer expenditures), it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the federal R&D funds obligated to them. Thus, even if the data collection and reporting issues were addressed, a gap would still exist." Echoing this assessment, the National Research Council (2005) notes that comparing federal outlays for R&D (as opposed to obligations) to performer expenditures results in a smaller discrepancy.

Figure 4-10
Difference in U.S. performer-reported and agency-reported federal R&D: 1980–2003



NOTE: Difference is defined as percentage of federally reported R&D, with a positive difference indicating that performer-reported R&D exceeds agency-reported R&D.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series); and, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming). See appendix table 4-29.

Science and Engineering Indicators 2006

most of its obligations funding medical and other related life sciences. The next four largest federal agencies in terms of research funding in FY 2005 were DOE (11%), DOD (10%), NASA (10%), and NSF (7%). DOE provides substantial funding for research in the physical sciences ($2.3 billion) and engineering ($2.0 billion). DOD's research funding is focused on engineering ($3.0 billion) and on mathematics and computer sciences ($0.8 billion). NASA's research funding also emphasizes engineering ($2.4 billion), followed by environmental sciences ($1.2 billion) and physical sciences ($1.1 billion). NSF, whose mission is to "promote the progress of science," has a more balanced research portfolio, contributing between $0.6 and $0.8 billion to researchers in each of the following groups of fields:

Table 4-8
Estimated federal total, intramural, and FFRDC R&D obligations, by agency: FY 2005
(Millions of dollars)

Agency	Total obligations	Intramural	FFRDC	Intramural plus FFRDC (%)
All federal government	106,487.8	24,813.0	8,058.6	30.9
Department of Defense	51,402.1	12,199.7	1,009.2	25.7
Department of Health and Human Services	28,865.6	5,810.1	602.9	22.2
National Aeronautics and Space Administration	8,114.0	2,028.5	1,411.8	42.4
Department of Energy	7,957.8	844.0	4,761.3	70.4
National Science Foundation	3,844.2	35.3	216.3	6.5
Department of Agriculture	1,969.3	1,333.7	0.0	67.7
Department of Commerce	979.3	800.5	0.6	81.8
Department of Transportation	736.8	228.2	10.7	32.4
Environmental Protection Agency	572.2	271.2	0.0	47.4
Department of the Interior	548.7	489.1	0.0	89.1
Department of Veterans Affairs	359.3	359.3	0.0	100.0
Department of Education	288.1	15.7	0.0	5.4
Agency for International Development	267.1	31.8	0.0	11.9
Smithsonian Institution	114.0	114.0	0.0	100.0
Department of Labor	107.6	92.0	0.0	85.5
Department of Justice	94.5	42.2	0.0	44.7
Nuclear Regulatory Commission	75.4	15.2	45.8	80.9
Social Security Administration	70.0	3.9	0.0	5.6
Department of the Treasury	68.7	62.5	0.0	91.0
Department of Housing and Urban Development	42.6	27.7	0.0	65.0
Federal Communications Commission	3.6	3.6	0.0	100.0
Library of Congress	2.6	2.6	0.0	100.0
Department of State	2.2	0.7	0.0	31.8
Federal Trade Commission	1.6	1.6	0.0	100.0
Appalachian Regional Commission	0.7	0.1	0.0	14.3
National Archives and Records Administration	0.1	0.1	0.0	100.0

FFRDC = federally funded research and development center

NOTE: Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by federal personnel.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming).

Science and Engineering Indicators 2006

mathematics and computer sciences, physical sciences, environmental sciences, engineering, and life sciences.

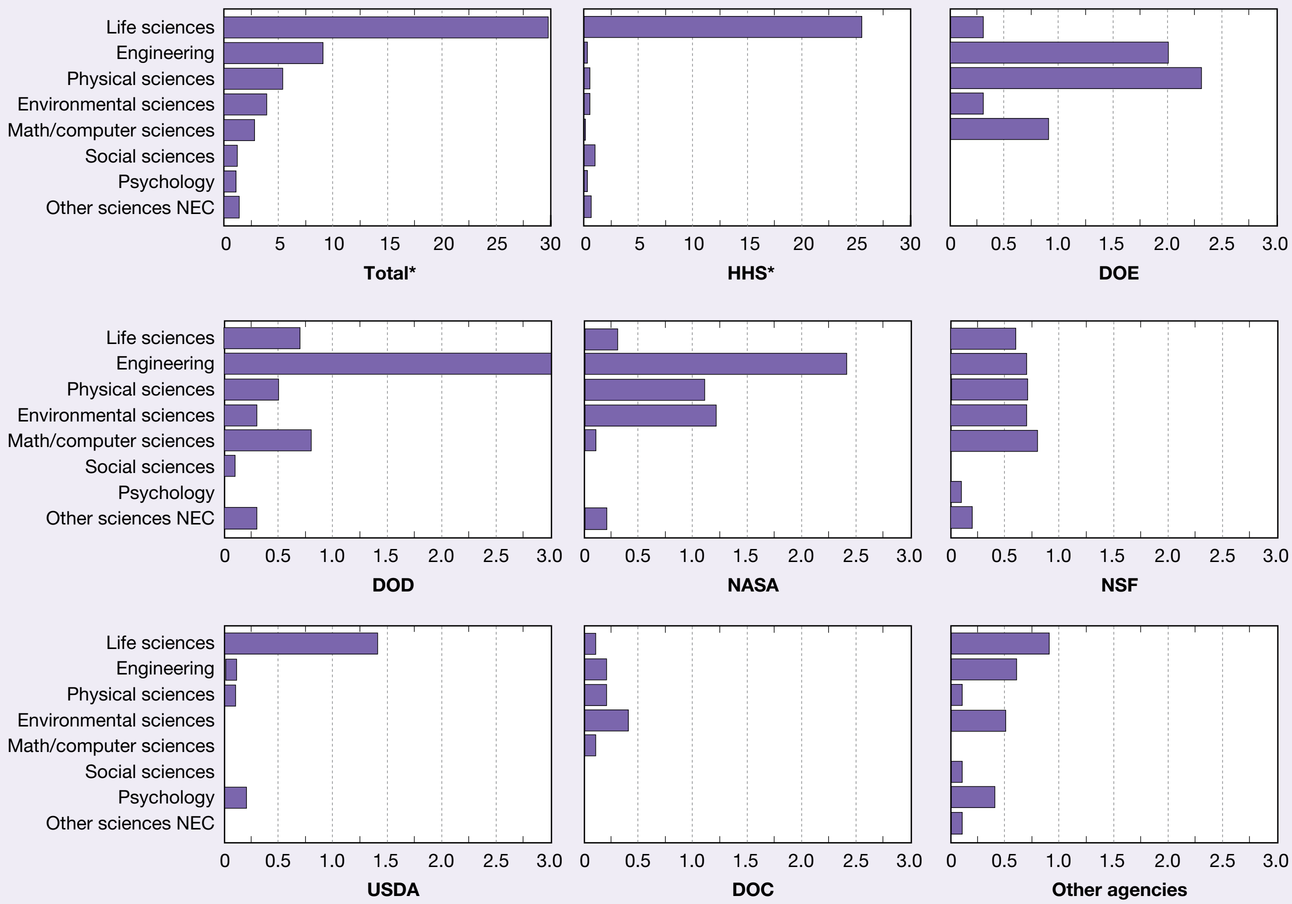
Federal obligations for research have grown at different rates for different S&E fields, reflecting changes in perceived public needs in those fields, changes in the national resources (e.g., scientists, equipment, and facilities) that have been built up in those fields over time, as well as differences in scientific opportunities across fields. Over the period 1984–2005, total federal research obligations grew, on average, 3.9% per year in real terms, from $22.2 billion in 2000 dollars to $49.5 billion in 2000 dollars. The groups of fields that experienced higher-than-average growth over this period were mathematics and computer sciences (6.7% per year in real terms), life sciences (5.7%), and psychology (6.7%) (appendix table 4-32). Funding for the remaining groups of fields also grew at a faster rate than inflation over this period: environmental sciences (3.0%), engineering (2.1%), social sciences (2.0%), and physical sciences (0.5%).

Caution should be employed when examining trends in federal support for more detailed S&E fields than those presented above because federal agencies classify a significant amount of R&D only by major S&E field, such as life sciences, physical sciences, or social sciences. In FY 2003, for example, 15% of the federal research obligations classified by major S&E field were not subdivided into detailed fields. This was less pronounced in physical sciences and in mathematics and computer sciences, in which all but 9% of the research dollars were subdivided. It was most pronounced in engineering and social sciences, in which, respectively, 35% and 62% of federal research obligations were not subdivided into detailed fields (appendix table 4-32).

Federal R&D Budget by National Objective

Before any agency can obligate funds for R&D, it must first have budget authority from Congress for such activity. In the president's FY 2006 budget submission to Congress, the proposed total federal budget authority for R&D is $127.5 billion. Adjusting for inflation, this amount is a 2% decline from the prior year's budget. This decline follows a 5-year period of increasing inflation-adjusted federal R&D budgets. Although

Figure 4-11
Estimated federal obligations for research, by agency and major S&E field: FY 2005
Current dollars (billions)



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NEC = not elsewhere classified; NSF = National Science Foundation; USDA = Department of Agriculture

*Scale differs for total and HHS from all other agencies.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming). See appendix table 4-31.

Science and Engineering Indicators 2006

R&D tends to be a popular budgetary item, the growing federal budget deficit may hamper future growth in federal R&D.

To assist Congress and the president in evaluating and adjusting the federal budget, OMB requests agencies to allocate their budget requests into specific categories called budget functions. These budget functions represent a wide range of national objectives the government aims to advance, from national defense to health to transportation. Changing trends in federal R&D budget authority by budget function tend to reflect shifts in presidential and congressional priorities (see sidebar "Federal R&D Initiatives").

Defense-Related R&D

The largest R&D budget function in the FY 2006 budget is defense, with a proposed budget authority of $74.8 billion, or 59% of the entire federal R&D budget. In 1980 the federal budget authority for defense-related R&D was roughly equal to that for nondefense R&D, but by 1985 defense R&D had grown to more than double nondefense R&D (figure 4-12). The gap between the defense and nondefense R&D budgets shrank almost every year after 1986 until 2001, when the defense budget function represented 53% of the federal R&D budget. The terrorist attacks of September 11, 2001, reversed this trend, and the annual federal defense R&D budget grew by $29 billion over the next 5 years.

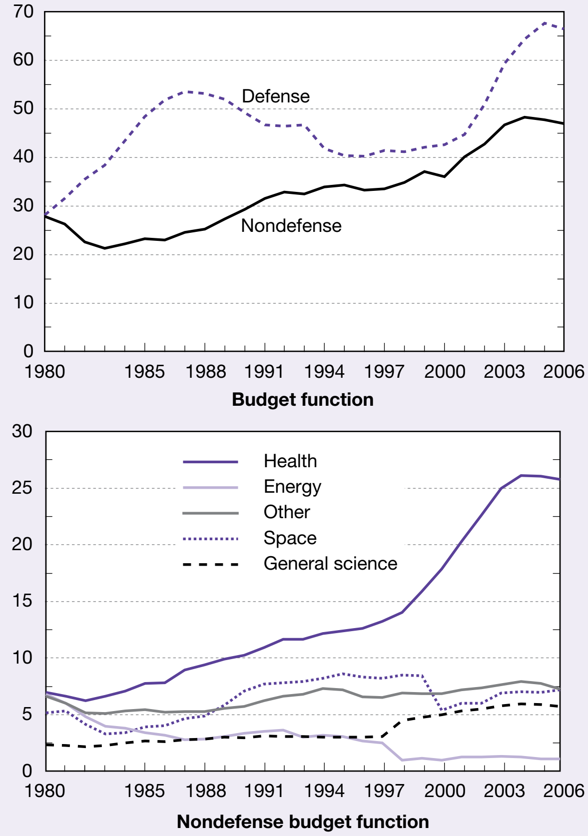
As described earlier, the majority of defense-related R&D goes toward the development of new and improved military technology, from weapons systems to communication technology. In FY 2006, DOD requested research, development, testing, and evaluation budgets in excess of $1 billion for four systems (US DOD 2005):

Federal R&D Initiatives

The Bush administration has identified a number of R&D priority areas that often involve the expertise of multiple federal agencies, from combating terrorism to developing hydrogen fuel cell technology. To improve the efficiency and effectiveness of federal R&D investments in these areas, the administration has encouraged strategic coordination among stakeholder agencies. The multiagency R&D priorities detailed in the administration's FY 2006 budget include:

- **Climate Change.** The Climate Change Science Program is focused on improving decisionmaking on climate change science issues. This program involves 13 departments and agencies and has an FY 2006 R&D budget of $1.9 billion, with the National Aeronautics and Space Administration (NASA) providing over 60% of the funding.
- **Combating Terrorism.** Following September 11, 2001, efforts were made to harness federal R&D programs that could help to deter, prevent, or mitigate terrorist acts. In the FY 2006 budget, over $4 billion is slated for homeland security-related R&D. Although the Department of Homeland Security has an important coordinating role in these R&D efforts, it is not the largest agency in terms of homeland-security R&D spending. The National Institutes of Health (NIH), with almost $1.8 billion targeted toward biodefense R&D, has the largest homeland security R&D budget.
- **Hydrogen Fuel.** The Hydrogen Fuel Initiative (HFI) seeks to support R&D aimed at developing and improving technologies for producing, distributing, and using hydrogen to power automobiles. The Department of Energy is the lead agency in this effort, with $258 million budgeted for HFI R&D in FY 2006.
- **Nanotechnology.** The National Nanotechnology Initiative (NNI) supports basic and applied research on the unique phenomena and processes that occur at the nanometer scale. NNI involves 11 R&D-funding agencies and an additional 11 coordinating agencies (such as the U.S. Patent and Trademark Office). The FY 2006 budget provides $1.1 billion in R&D support to NNI, with the largest investment ($344 million) to be made by the National Science Foundation (NSF).
- **Networking and Information Technology.** The multiagency Networking and Information Technology Research and Development (NITRD) program aims to leverage agency research efforts in advanced networking and information technologies. The FY 2006 budget provides $2.1 billion for NITRD R&D. Seven agencies participate in the program, with NSF providing the largest share of NITRD funding ($803 million).

Figure 4-12
Federal R&D budget authority, by budget function: FY 1980–2006



NOTES: Other includes all nondefense functions not separately graphed, such as agriculture and transportation. 1998 increase in general science and decrease in energy and 2000 decrease in space were results of reclassification.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal R&D Funding by Budget Function: Fiscal Years 2004–06* (forthcoming). See appendix table 4-26.

Science and Engineering Indicators 2006

- **Missile Defense ($8.1 billion):** "A multilayer, multifaceted program designed to protect the United States, our Allies and deployed forces from missile attack."
- **Joint Strike Fighter ($4.9 billion)**: "The Joint Strike Fighter (JSF) is the next-generation strike fighter for the Air Force, Marine Corps, Navy, and U.S. allies."
- **Future Combat System ($3.4 billion):** "The FCS [Future Combat System] R&D program will develop network centric concepts for a multi-mission combat system that will be overwhelmingly lethal, strategically deployable, self-sustaining and highly survivable in combat through the use of an ensemble of manned and unmanned ground and air platforms."
- **DD(X) Destroyer ($1.1 billion):** "DD(X) will be an optimally crewed, multi-mission surface combatant designed to fulfill volume firepower and precision strike requirements."

Civilian-Related R&D

R&D accounts for 13.3% of the FY 2006 federal nondefense discretionary budget authority of $398.5 billion.[28] Although this is less than that reserved for defense activities (16.9% of the $441.8 billion discretionary budget authority in FY 2006), over 90% of federal basic research funding is for nondefense budget functions, accounting for a large part of the budgets of agencies with nondefense missions such as general science (NSF), health (NIH), and space research and technology (NASA) (table 4-9; appendix table 4-27).

The most dramatic change in national R&D priorities over the past 25 years has been the growing importance of health-related R&D. As illustrated in figure 4-12, health-related R&D rose from representing 25% of the federal nondefense R&D budget allocation in FY 1980 to 55% in FY 2006. Most of this growth occurred after 1998, when NIH's budget was set on a pace to double by 2003 (Meeks 2002).

The budget allocation for space-related R&D peaked in the 1960s, during the height of the nation's efforts to surpass the Soviet Union in space exploration. Since the loss of the Space Shuttle Columbia and its crew of seven on 1 February 2003, manned space missions have been curtailed. Nonetheless, the proportion of the federal R&D budget for space research is slightly higher in 2006 (15.3%) than in 2003 (14.9%). In the president's FY 2006 budget, 54% of NASA's $16.5 billion discretionary budget was allocated for R&D.

Compared with that of health-related R&D, the budget allocation for general science R&D has grown relatively little in the past 25 years. In fact, the growth in general science R&D is more the result of a reclassification of several DOE programs from energy to general science in FY 1998 than the result of increased budget allocations (figure 4-12). The formation of the Department of Homeland Security (DHS) and the coincident reclassification of much of its formerly civilian R&D activities as defense R&D is a more recent example of how R&D budget function classifications can change when the mission or focus of funding agencies changes.

Federal S&T Budget

Alternative concepts have been used to isolate and describe fractions of federal support that could be associated with scientific achievement and technological progress. In a 1995 report, a National Academy of Sciences (NAS) committee proposed an alternative method of measuring the federal government's S&T investment (NAS 1995). According to the committee members, this approach, called the federal science and technology (FS&T) budget, might provide a better way to track and evaluate trends in public investment in R&D. The FS&T concept differed from the traditional federal R&D data definitions used earlier in this section in that it did not include major systems development supported by DOD and DOE, and it contained not only research but also some development and some R&D plant.

Beginning with the FY 2000 budget, OMB has presented its concept for an FS&T budget (figure 4-13). Whereas the NAS FS&T compilation included only R&D, OMB's FS&T budget was compiled from easily tracked programs and included some non-R&D programs, such as NSF education programs and staff salaries at NIH and NSF.

In the 2006 Budget of the United States, OMB's FS&T budget is less than half the total federal R&D budget because it excludes funding for defense development, testing, and evaluation. It includes nearly all budgeted federal support

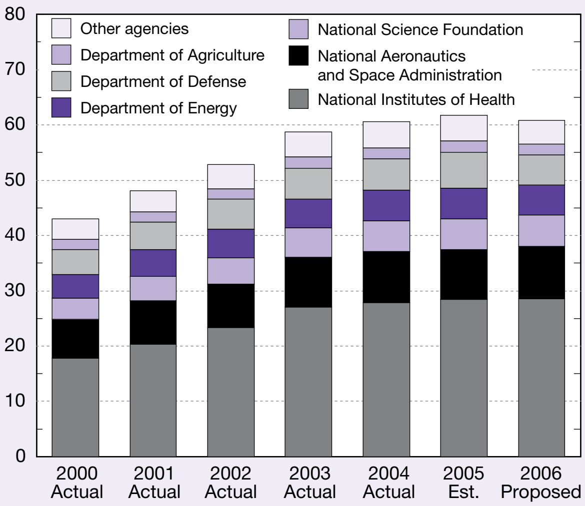
Table 4-9
Budget authority for R&D, by federal agency and character of work (proposed levels): FY 2006
(Millions of current dollars)

Agency	Total discretionary budget authority	Total R&D	Basic research	Applied research and development	R&D share of discretionary budget (%)
All federal government	840,306	127,506	26,608	100,898	15.2
Department of Defense	419,341	70,789	1,319	69,470	16.9
Department of Health and Human Services	68,858	28,684	15,246	13,438	41.7
National Aeronautics and Space Administration	16,456	8,943	2,199	6,744	54.3
Department of Energy	23,441	7,430	2,762	4,668	31.7
National Science Foundation	5,606	3,756	3,480	276	67.0
Department of Agriculture	19,366	1,876	788	1,088	9.7
Department of Homeland Security	29,342	1,257	112	1,145	4.3
Department of Commerce	9,403	924	71	853	9.8
Department of Transportation	11,815	789	41	748	6.7
Department of Veterans Affairs	31,274	786	315	471	2.5
Department of Interior	10,643	579	30	549	5.4
Environmental Protection Agency	7,571	569	70	499	7.5
Other	187,190	1,124	175	949	0.6

SOURCE: U.S. Office of Management and Budget, *Budget of the United States Government, Fiscal Year 2006* (2005).

Science and Engineering Indicators 2006

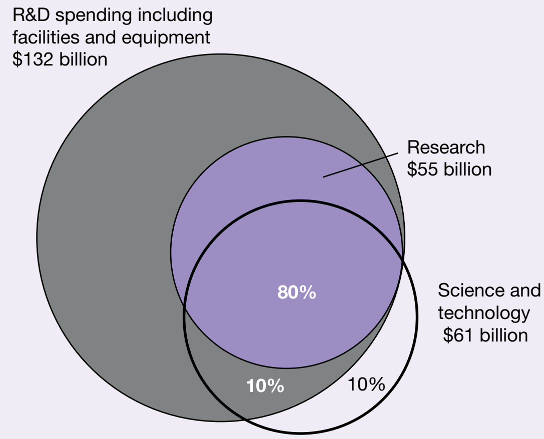
Figure 4-13
Federal science and technology budget, by agency: FY 2000–06



SOURCES: U.S. Office of Management and Budget, Analytical Perspectives, *Budget of the United States Government, Fiscal Year 2002, Fiscal Year 2003, Fiscal Year 2004, Fiscal Year 2005, and Fiscal Year 2006.*

Science and Engineering Indicators 2006

Figure 4-14
Federal funding concepts in budget proposal: FY 2006



NOTE: Percents represent shares of the federal science and technology budget rounded to the nearest 10%.

SOURCE: U.S. Office of Management and Budget, *Analytical Perspectives, Budget of the United States Government: Fiscal Year 2006* (2005).

Science and Engineering Indicators 2006

for basic research in FY 2004, more than 80% of federally supported applied research, and about half of federally supported nondefense development.

As shown in figure 4-14, federal R&D in the 2006 budget proposal, which includes expenditures on facilities and equipment, would reach a level of $132 billion. Of this amount, $55 billion would be devoted to basic and applied research alone. The FS&T budget would reach $61 billion and would include most of the research budget. However, differences in the definition of research and FS&T imply that not all research would be included in FS&T and vice versa. Moreover, a small proportion (10%) of FS&T funds would fall outside the traditional definition of federal R&D spending.

Federal R&E Tax Credit

Background

One of the better-known indirect federal incentives for fostering industrial R&D is the research and experimentation (R&E) tax credit.[29] The traditional justification for incentives for research is that results from these activities, especially more basic or long-term research, are often hard to capture privately because others might benefit directly or indirectly from them. Therefore, businesses might engage in levels of research below those that would be beneficial to the nation as a whole. Across advanced economies, R&D tax credits vary in terms of how they are structured or targeted, their effect on public budgets, and their effectiveness in stimulating innovation (Bloom, Griffith, and Van Reenan 2002; OECD 2003).[30]

The federal R&E tax credit was established by the Economic Recovery Tax Act of 1981, one of several policy tools put in place in the 1980s to address perceived problems in the competitive position of U.S. companies (Guenther 2005). The credit is subject to periodic extensions given its temporary status. It was renewed most recently by the Working Families Tax Relief Act of 2004 through 31 December 2005.[31]

The credit is designed to stimulate company R&D over time by reducing after-tax costs. Specifically, companies that qualify for the credit can deduct or subtract from corporate income taxes an amount equal to 20% of qualified research expenses above a base amount.[32] For established companies, the base amount depends on historical expenses over a statutory base period relative to gross receipts, whereas startup companies follow other provisions. An alternative R&E credit has been available since 1996. This credit has a lower base amount and a maximum statutory rate of 3.75%. The alternative credit benefits established companies that have smaller annual increases relative to their base period (Hall 2001). Companies may select only one of these two credits on a permanent basis, unless the Internal Revenue Service (IRS) authorizes a change. Both types of R&E credit include provisions for basic research payments to qualified universities or scientific research organizations.

Tax Credit Claims

According to data from the IRS' Statistics of Income (SOI), R&E tax credit claims reached an estimated $6.4 billion in 2001 ($6.2 billion in constant or inflation-adjusted dollars), compared with the all-time high of $7.1 billion in 2000 (table 4-10).[33] From 1990 to 2001, the annual dollar amount of R&E credit claims grew twice as fast as industry-funded

Table 4-10
Federal research and experimentation tax credit claims and corporate tax returns claiming credit: 1990–2001

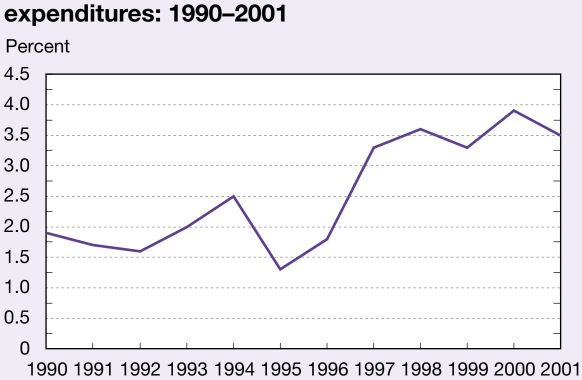
	Tax credit claims ($ millions)		
Year	Current	Constant	Tax returns
1990..........	1,547	1,896	8,699
1991..........	1,585	1,877	9,001
1992..........	1,515	1,754	7,750
1993..........	1,857	2,101	9,933
1994..........	2,423	2,684	9,150
1995..........	1,422	1,544	7,877
1996..........	2,134	2,274	9,709
1997..........	4,398	4,609	10,668
1998..........	5,208	5,399	9,849
1999..........	5,281	5,396	10,019
2000..........	7,079	7,079	10,495
2001..........	6,356	6,207	10,388

NOTE: Data exclude IRS forms 1120S (S corporations), 1120-REIT (Real Estate Investment Trusts), and 1120-RIC (Regulated Investment Companies). Constant dollars based on calendar year 2000 gross domestic product price deflator.

SOURCE: Internal Revenue Service, Statistics of Income program, special tabulations.

Science and Engineering Indicators 2006

Figure 4-15
Research and experimentation tax credit claims as percentage of industry-funded R&D expenditures: 1990–2001



SOURCES: U.S. Internal Revenue Service, Statistics of Income program, special tabulations; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of Research and Development Resources: 2003*, NSF 05-308 (2005).

Science and Engineering Indicators 2006

R&D, after adjusting for inflation (NSF/SRS 2005), but growth in credit claims varied throughout the decade. From 1990 to 1996, companies claimed between $1.5 billion and $2.5 billion in R&E credits annually; since then, annual R&E credits have exceeded $4 billion (table 4-10). However, R&E tax credit claims still accounted for less than 4% of industry-funded R&D expenditures as of 2001 (figure 4-15).

Data are available on the industry classification of companies that claim the R&E tax credit for 1998–2001 using the new North American Industry Classification System (NAICS) (appendix table 4-33). Since 1998, corporate tax returns classified in five industries accounted for 80% or more of R&E credit claims. In 2001, the top five industries accounted for 80% of credit claims ($5.1 billion of the $6.4 billion):

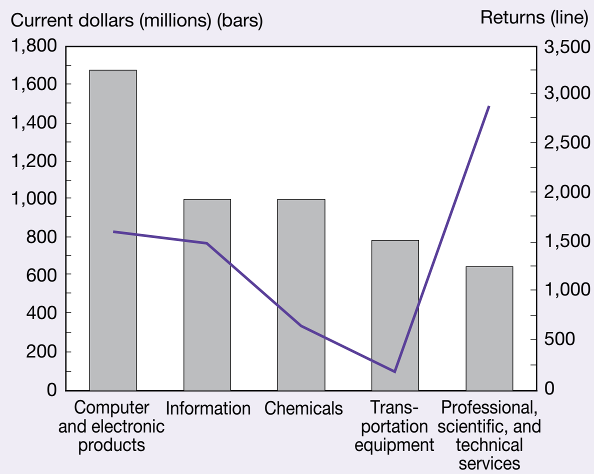
- Computer and electronic products (26%)
- Information, including software (16%)
- Chemicals, including pharmaceuticals and medicines (16%)
- Transportation equipment, including motor vehicles and aerospace (12%)
- Professional, scientific, and technical services, including computer services and R&D services (10%)

The number of corporate tax returns claiming the R&E tax credit grew at a slower rate than their dollar R&E credit claims, fluctuating between 8,000 and 10,000 tax returns over most of the 1990s (table 4-10). In 2001, companies in the professional, scientific, and technical services industry filed more corporate tax returns claiming the R&E tax credit than did any other industry. That industry represented about 28% of all returns claiming the credit, followed by computer and electronic products and information, each with about 15% (figure 4-16).

Technology Linkages: Contract R&D, Public-Private Partnerships, and Industrial Alliances

Increasingly, industrial innovation involves a combination of R&D performed internally and a host of activities with external partners (Adams 2005, pp 131–3). Technology

Figure 4-16
Industries with largest research and experimentation tax credit claims and corporate tax returns claiming credit: 2001



SOURCE: U.S. Internal Revenue Service, Statistics of Income program, special tabulations. See appendix table 4-33.

Science and Engineering Indicators 2006

activities or transactions with external partners (such as contract R&D and technology alliances) may reduce costs, expedite projects, or complement internal capabilities, but they may also present strategic and management challenges compared to in-house R&D (Cassiman and Veugelers 2002). At the same time, firms are likely to benefit more from a combination of innovation strategies than from any single tool.

At the macro level, a systems approach to innovation recognizes the importance of cross-sector linkages between R&D performers and users involving different levels of knowledge (e.g., scientific findings, technological practices) and goals (e.g., commercialization, public health, or student training). Public policies in the United States and other advanced economies, concerned with enhancing the prospects of technology-based economic growth, have evolved to address the many dimensions of industrial innovation. In the United States, several policies have facilitated R&D collaboration among industry, universities, and federal laboratories (see sidebar "Major Federal Legislation Related to Cooperative R&D and Technology Transfer").

This section discusses trends affecting selected indicators of industrial technology linkages—contracted-out R&D, industrial technology alliances, and federal technology programs—including the following key findings:

- The average annual growth rate of contracted-out R&D from 1993 to 2003 was double the growth rate of in-house company-funded R&D, after adjusting for inflation, indicating an increasing role for external sources of technology. For manufacturing companies, contracted-out R&D grew almost three times as fast as R&D performed internally.
- Industrial technology alliances worldwide reached an all-time annual peak in 2003 with 695 alliances. These alliances involve mostly companies from the United States, Europe, and Japan that focus to a large extent on biotechnology and information technology products, services, or techniques. Alliances involving only U.S.-owned companies have represented the largest share of alliances in most years since 1980, followed by alliances between U.S. and European companies.
- Public-private partnerships include a combination of joint funding, collaborative activities, or procurement policies. For example, federal agencies participated in a total of 2,936 cooperative research and development agreements (CRADAs) with industrial firms and other

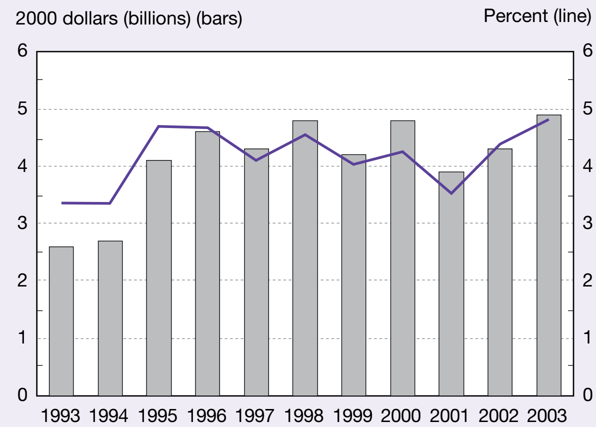
Major Federal Legislation Related to Cooperative R&D and Technology Transfer

- **Stevenson-Wydler Technology Innovation Act (1980)**—required federal laboratories to facilitate the transfer of federally owned and originated technology to state and local governments and the private sector.
- **Bayh-Dole University and Small Business Patent Act (1980)**—permitted government grantees and contractors to retain title to federally funded inventions and encouraged universities to license inventions to industry. The act is designed to foster interactions between academia and the business community.
- **Small Business Innovation Development Act (1982)**—established the Small Business Innovation Research (SBIR) program within the major federal R&D agencies to increase government funding of research that has commercialization potential within small high-technology companies.
- **National Cooperative Research Act (1984)**—encouraged U.S. firms to collaborate on generic, precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures. The act was amended in 1993 by the National Cooperative Research and Production Act (NCRPA), which let companies collaborate on production activities as well as research activities.
- **Federal Technology Transfer Act (1986)**—amended the Stevenson-Wydler Technology Innovation Act to authorize cooperative research and development agreements (CRADAs) between federal laboratories and other entities, including other federal agencies, state or local governments, universities and other nonprofit organizations, and industrial companies.
- **Omnibus Trade and Competitiveness Act (1988)**—established the Competitiveness Policy Council to develop recommendations for national strategies and specific policies to enhance industrial competitiveness. The act created the Advanced Technology Program and the Manufacturing Technology Centers within the National Institute for Standards and Technology to help U.S. companies become more competitive.
- **National Competitiveness Technology Transfer Act** (1989)—amended the Stevenson-Wydler Act to allow government-owned, contractor-operated laboratories to enter into CRADAs.
- **National Cooperative Research and Production Act (1993)**—relaxed restrictions on cooperative production activities, enabling research joint venture participants to work together in the application of technologies they jointly acquire.
- **Technology Transfer Commercialization Act (2000)**—amended the Stevenson-Wydler Act and the Bayh-Dole Act to improve the ability of government agencies to monitor and license federally owned inventions.

organizations in FY 2003, up 4.3% from a year earlier, but still below the 3,500 peak in FY 1996. DOD and DOE executed three-fourths of CRADAs in FY 2003; HHS participated in another 9% of the total.

- Federal programs focused on small firms or on early-stage technologies have been in place in the United States since the 1980s. The Small Business Innovation Research (SBIR) program and its sister program, the Small Business Technology Transfer Program (STTR), set aside a portion of existing federal R&D funds for small businesses. From FY 1983 to FY 2003, SBIR has awarded over $15 billion to 76,346 projects in areas such as computers and electronics, information services, materials, energy, and life sciences. DOD and HHS combined have provided between 60% and 80% of total annual SBIR funds since the program's inception. The Advanced Technology Program (ATP), housed at DOC's National Institute of Standards and Technology, was created to promote the development and commercialization of generic technologies through a competitive process on a cost-share basis with industry. Through FY 2004, ATP has awarded 768 projects with a combined funding of $4.37 billion involving over 1,500 participants; these include startups, established companies, and universities.

Figure 4-17
Manufacturing R&D expenditures contracted out in United States and ratio to company-funded R&D performed within companies: 1993–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series). See appendix table 4-34.

Science and Engineering Indicators 2006

Contract R&D Expenses

In 2003, R&D-performing companies in the United States reported $10.2 billion (including $5.2 billion reported by manufacturers) in R&D contracted out to other domestic companies, compared with $183.3 billion in company-funded R&D performed internally, according to NSF's Survey of Industrial Research and Development (appendix table 4-34).[34]

A comparison between contracted-out and in-house R&D expenditures over time provides an indication of the importance of external R&D sources in a global competitive environment characterized by rapid technological developments, demands for innovative products, and cost and time constraints. The average annual growth rate of contracted-out R&D from 1993 to 2003 (9.4%, after adjusting for inflation) was about double the growth rate of in-house company-funded R&D (4.9%). For manufacturing companies, contracted-out R&D grew almost three times as fast as R&D performed internally, after adjusting for inflation. In 2003, the ratio of contracted-out R&D to in-house R&D was 5.7% for the aggregate of all industries, compared with 3.7% in 1993 (appendix table 4-34). The ratio for manufacturing in 2003 was 4.8%, lower than for the aggregate of all industries, but slightly above its previous peak in the mid-1990s (figure 4-17).

Chemical companies reported $2.8 billon in contracted-out R&D in 2003, of which $2.7 billion was reported by pharmaceuticals and medicines (appendix table 4-35).[35] The latter sector had the highest ratio of contracted-out R&D to R&D performed internally among major R&D-performing industries (17.1%, or $2.7 billion compared with $15.9 billion in company-funded R&D performed internally). The second highest ratio among major R&D-performing industries was reported by scientific R&D services, with 14.5% ($1.5 billion in contracted-out R&D compared with $10.5 billion R&D performed internally). Transportation equipment and computer and electronic product companies reported 4.3% and 1.4% in contracted-out R&D expenses, respectively.

Industrial Technology Alliances

Industrial technology alliances are one of several tools aimed at the codevelopment of new products or capabilities.[36] Firm-specific drivers for R&D collaboration include cost and risk reductions afforded by pooling resources, as well as strategic or long-term considerations regarding the acquisition of innovation capabilities or entry into new product markets (Miotti and Sachwald 2003; Sakakibara 2001). Other factors include the increased complexity and industry-relevance of scientific research, especially in sectors such as biotechnology, and the policy environment, notably antitrust regulation and intellectual property protection.[37] In the United States, restrictions on multifirm cooperative research were loosened by the National Cooperative Research Act (NCRA) in 1984 (Public Law 98-462) after concerns about the technological leadership and international competitiveness of American firms in the early 1980s.[38] More recently, federal patent and trademark law was amended in order to facilitate patenting inventions resulting from collaborative efforts across different companies or organizations.[39] R&D collaborations share a number of challenges with other business collaborations, including management and coordination issues, and they also present unique issues due to the rising

strategic value of innovation in an increasingly knowledge-based economy (Narula 2003).

Trends in the number of R&D technology alliances being formed provide an indication of firms partnering to develop and subsequently exploit new technologies. NSF funds two databases on technology alliances with different sources and scope: the Cooperative Research (CORE) database and the Cooperative Agreements and Technology Indicators database, Maastricht Economic Research Institute on Innovation and Technology (CATI-MERIT). CORE records U.S. alliances registered at the U.S. Department of Justice pursuant to the National Cooperative Research and Production Act (NCRPA).[40] CATI-MERIT covers domestic and international technology agreements and is based on public announcements, tabulated according to the country of ownership of the parent companies involved.[41]

Registered U.S. Cooperative Research Agreements

There were 22 industrial R&D alliances newly registered in 2003, according to the CORE database, for a total of 913 registered agreements since 1985. Fifteen percent (133 of 913) of these alliances involved a U.S. university as a research member, whereas 12% (111 of 913) included a federal laboratory. The number of newly registered alliances has declined annually in 5 of the last 7 years since the 1995 peak (figure 4-18). Trends in the CORE database are illustrative only, because the registry is not intended to be a comprehensive count of cooperative activity by U.S.-based firms.[42]

The CORE database now provides the industrial distribution of alliances based on the NAICS code for 446 of the 524 alliances from 1994 to 2003 (appendix table 4-36). Of these 446 alliances, two-thirds were classified in four manufacturing industries: electrical equipment, appliances, and components; transportation equipment; chemical (which includes pharmaceuticals); and computer and electronic products. Another 31 alliances (or 7%) were classified in professional, scientific, and technical services (which includes R&D services).

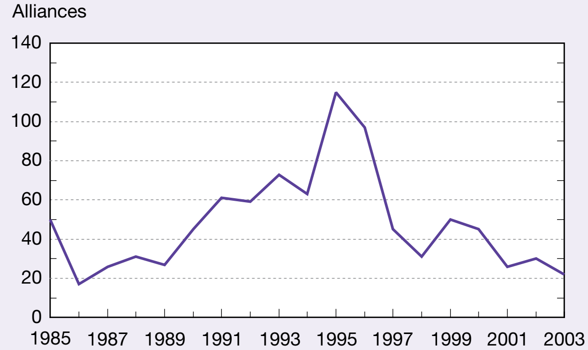
Domestic and International Technology Alliances

According to the CATI-MERIT database, new industrial technology alliances worldwide reached an all-time peak in 2003 with 695 alliances. These alliances involve mostly companies from the United States, Europe, and Japan focusing to a large extent on biotechnology and information technology products, services, or techniques (figure 4-19; appendix table 4-37).[43] Other technology areas include advanced materials, aerospace and defense, automotive, and (nonbiotechnology) chemicals.[44] In the 1990s information technology dominated R&D alliance activity (figure 4-20). However, the share of biotechnology alliances increased steadily over the decade, surpassing information technology alliances by 2000 and reaching 63% of alliances in 2002 and 53% in 2003.

Alliances involving only U.S.-owned companies have represented the largest share of alliances in most years since 1980, followed by alliances between U.S. and European companies (figure 4-21). However, the annual share of U.S.-Japan alliances declined from a peak of 21% of CATI-MERIT alliances in the early 1980s to 10% or less since the mid-1990s. The annual share of alliances formed exclusively among European companies has fluctuated between 10% and 20% since the late 1980s (figure 4-22). Other pairings account for single-digit shares in the database.

The apparent attractiveness of U.S. companies as global R&D partners has been attributed to the comparative advantage of the United States in certain high-technology sectors (Miotti and Sachwald 2003). At the same time, foreign direct investment by U.S. MNCs and overseas R&D by their

Figure 4-18
Industrial technology alliances registered under National Cooperative Research and Production Act: 1985–2003

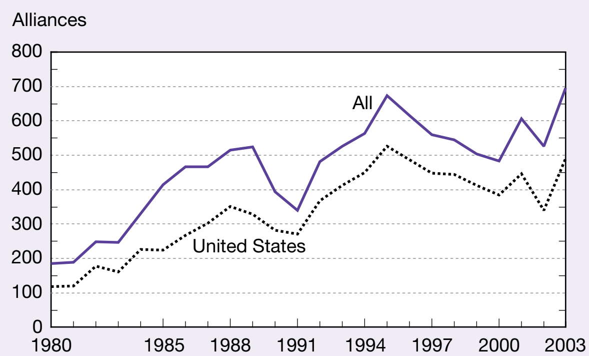


NOTE: Data are annual counts of new alliances.

SOURCE: University of North Carolina–Greensboro, Cooperative Research (CORE) database, special tabulations.

Science and Engineering Indicators 2006

Figure 4-19
Worldwide industrial technology alliances and those with at least one U.S.-owned company: 1980–2003

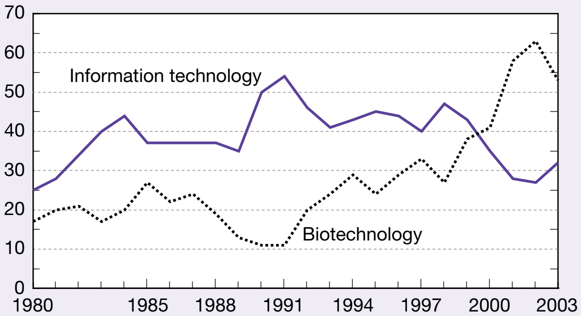


NOTE: Data are annual counts of new alliances.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

Science and Engineering Indicators 2006

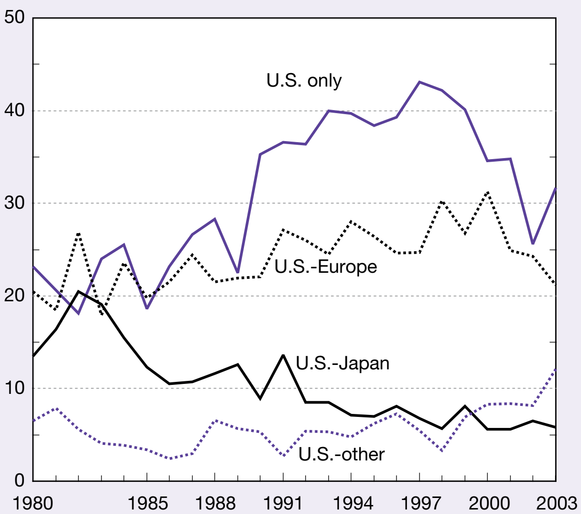
Figure 4-20
Information technology and biotechnology shares of industrial technology alliances: 1980–2003



SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

Science and Engineering Indicators 2006

Figure 4-21
Share of industrial technology alliances involving at least one U.S. company, by country/region of partner: 1980–2003

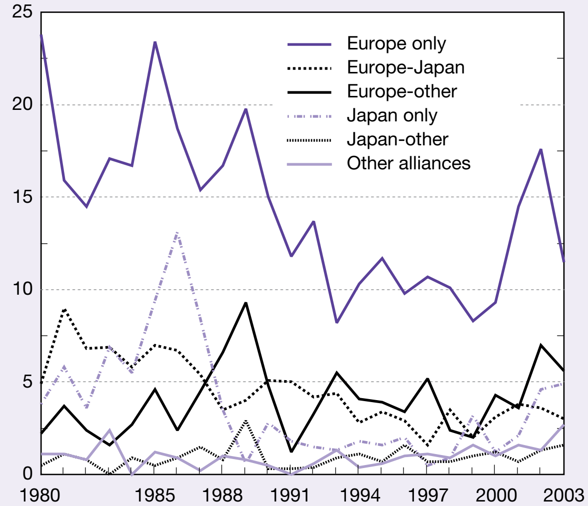


SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

Science and Engineering Indicators 2006

foreign affiliates (see "R&D Investments by Multinational Corporations" in this chapter) have increased the pool of potential U.S.-owned R&D partners available internationally.

Figure 4-22
Share of industrial technology alliances among non-U.S. companies, by country/region of partner: 1980–2003



SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

Science and Engineering Indicators 2006

Technology-Based Public-Private Partnerships

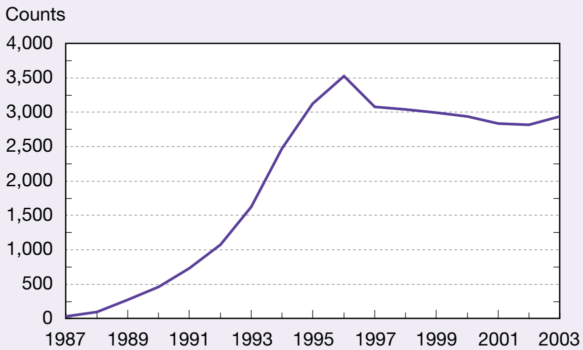
Public-private partnerships involve cooperative R&D among industry, universities, and government laboratories. They can facilitate technology transfer from the research laboratory to the market in support of both public agency mission as well as technology-based regional or national economic growth (NRC 2003). Partnerships may include a combination of joint funding, collaborative activities, or procurement policies ranging from formal R&D agreements between industrial companies and government laboratories, to research or science parks, to programs targeted for small firms and/or early-stage technologies. This section reviews CRADAs and other federal technology transfer indicators, the SBIR program, and the ATP.

Federal Laboratory Technology Transfer and CRADAs

Federal laboratories, whether run by federal agencies themselves or by contractors,[45] represent a key component of the U.S. innovation system both for federal missions such as defense, health, and energy, and as a source for industry-relevant knowledge (Crow and Bozeman 1998). Technology transfer refers to the exchange or sharing of knowledge, skills, processes, or technologies across different organizations. Federal technology transfer statutes apply to federally owned or originated technology (see sidebar "Major Legislation Related to Cooperative R&D and Technology Transfer").

CRADAs are one of several technology-based industry-government collaboration tools available in the United States.[46] Federal laboratories entering into CRADAs with industrial firms and other organizations may share personnel, services, or facilities (but not funds) as part of a joint R&D project with the potential to promote industrial innovation consistent with the agency's mission. Private partners may retain ownership rights or acquire exclusive licensing rights for the developed technologies.

Figure 4-23
Federal laboratory CRADAs: FY 1987–2003



CRADA = cooperative research and development agreement

NOTES: Data for active traditional CRADAS: those legally in force at any time during fiscal year and involving collaborative R&D by federal laboratory and nonfederal partners. FY 1999 data and beyond may not be comparable with prior years because of methodological changes in data collection and processing.

SOURCES: U.S. Department of Commerce, Office of the Secretary, *Summary Report on Federal Laboratory Technology Transfer: 2002 Report to the President and the Congress Under the Technology Transfer and Commercialization Act* (2002); and *Summary Report on Federal Laboratory Technology Transfer: FY 2003 Activity Metrics and Outcomes, 2004 Report to the President and the Congress Under the Technology Transfer and Commercialization Act* (2004). See appendix table 4-38.

Science and Engineering Indicators 2006

Simple CRADA counts offer a limited but illustrative window for viewing overall trends and agency participants.[47] Data on these and other federal technology transfer activities are available from the DOC, pursuant to federal technology transfer statutes (U.S. DOC 2004).[48] The 10 agencies reporting data were DOC, DOD, DOE, DOI, the Department of Transportation, the Environmental Protection Agency, HHS, NASA, USDA, and the Department of Veterans Affairs. Available metrics indicate substantial federal technology transfer activities, especially by agencies with the largest intramural and FFRDC R&D budgets.

Federal laboratories participated in a total of 2,936 CRADAs[49] in FY 2003, up 4.3% from a year earlier but still below the 3,500 peak in FY 1996 (figure 4-23). CRADA and other technology transfer activities are highly concentrated. DOD and DOE executed three-fourths of CRADAs in FY 2003; HHS participated in another 9% of the total.

DOE, DOD, HHS, and NASA topped metrics for inventions disclosures, patents, and invention licenses (table 4-11; appendix table 4-38).[50] An inventions disclosure documents an invention and may or may not result in a patent application. Patent and invention licenses (which include licenses of patented inventions) are indicators further along the chain of the technology transfer process in which laboratory results within an agency may find a useful application in agency missions or the marketplace.[51]

Differences in R&D funding structure (intramural versus extramural funding) and the R&D character of work across agencies may drive the agency distribution of these indicators. For example, the same four agencies had the largest FY 2003 intramural and FFRDC R&D budgets among all reporting agencies (table 4-12). Furthermore, the majority of their intramural and FFRDC R&D funds were devoted to applied research and development, similar to the distribution of industry's own R&D activities.[52]

Table 4-11
Federal laboratories technology transfer indicators, by selected agency: FY 2003

	Inventions disclosed		Patents issued		All active invention licenses	
Agency	Number	Percent distribution	Number	Percent distribution	Number	Percent distribution
All 10	4,348	100.0	1,607	100.0	3,656	100.0
Top 4	4,009	92.2	1,518	94.5	3,177	86.9
DOD	1,332	30.6	619	38.5	361	9.9
DOE	1,469	33.8	627	39.0	1,223	33.5
HHS	472	10.9	136	8.5	1,298	35.5
NASA	736	16.9	136	8.5	295	8.1

DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration

NOTES: Inventions disclosed and patents issued in FY 2003. Total active licenses are licenses active as of FY 2003, regardless of year issued.

SOURCE: U.S. Department of Commerce, Office of the Secretary, *Summary Report on Federal Laboratory Technology Transfer: FY 2003 Activity Metrics and Outcomes, 2004 Report to the President and the Congress Under the Technology Transfer and Commercialization Act* (2004). See appendix table 4-38.

Science and Engineering Indicators 2006

Table 4-12
Federal R&D obligations by selected agency, performer, and applied research and development component: FY 2003

Agency	Federal R&D obligations (current $ millions)				
	Total	Intramural and FFRDCs	Intramural and FFRDCs applied research and development	Intramural and FFRDCs share of total (%)	Applied research and development share of intramural and FFRDCs (%)
All federal agencies	93,662	30,477	23,092	32.5	75.8
DOD	42,031	11,771	11,345	28.0	96.4
DOE	7,412	5,195	3,431	70.1	66.1
HHS	26,399	5,874	2,956	22.3	50.3
NASA	7,499	3,232	2,293	43.1	70.9
Others	10,321	4,406	3,067	42.7	69.6

DOD = Department of Defense; DOE = Department of Energy; FFRDC = federally funded research and development center; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration

NOTE: Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by federal personnel.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming).

Science and Engineering Indicators 2006

Science and Technology Programs

Programs focused on small firms or on early-stage technologies have been in place in the United States since the 1980s. The intangible and uncertain nature of R&D projects presents financing challenges, even within large companies. Small or new technology-based firms are known to have additional financing constraints given the early stage of their technologies, compared to activities closer to market applications by larger or established companies (Bougheas 2004**;** Branscomb and Auerswald 2002). At the same time, the economic role of startups, corporate or university spinoffs, and technology-based entrepreneurship has been increasingly recognized in the United States and in other R&D-intensive economies (Gilbert et al 2004).

Small Business Programs. Federal agencies participating in the SBIR program reserve a portion of a their extramural R&D budget for awards to small businesses (U.S. Code Title 15, Section 631). SBIR was created by the Small Business Innovation Development Act of 1982 (Public Law 97-219) and was last reauthorized in 2000 through September 2008.[53] Statutory goals include increasing the participation of small firms and companies owned by minorities or disadvantaged individuals in the procurement of federal R&D, and the promotion of technological innovation through commercialization of federally funded projects. The 1992 SBIR reauthorization bill[54] stipulated a stronger emphasis on the technology commercialization objectives of the program (Cooper 2003; NRC 2004). As of FY 2004, a total of 11 federal agencies participate in the program, including the new Department of Homeland Security (see sidebar "The New SBIR Program at the Department of Homeland Security").

SBIR's sister program, the STTR, was created in 1992 to stimulate cooperative R&D and technology transfer involving small businesses and nonprofit organizations, including universities and FFRDCs.[55] SBIR and STTR are administered by participating agencies and coordinated by the Small Business Administration.

According to the SBIR statute, federal agencies with extramural R&D obligations exceeding $100 million must set aside a fixed percentage of such obligations for SBIR projects. This set-aside has been 2.5% since FY 1997. To obtain this federal funding, a small company applies for a Phase I SBIR grant of up to $100,000 for up to 6 months to assess the scientific and technical feasibility of ideas with commercial potential. If the concept shows further potential, the company can receive a Phase II grant of up to $750,000 over a period of up to 2 years for further development. In Phase III, the innovation must be brought to market with private-sector investment and support; no SBIR funds may be used for Phase III activities.

Through FY 2003, SBIR has awarded over $15 billion to 76,346 projects. Funded technology areas include computers and electronics, information services, materials, energy, and life sciences applications. In FY 2003 the program awarded $1.67 billion in R&D funding to 6,224 projects (figure 4-24). The upward trend in awards and funding reflects both the increased set-aside percentage over the history of the program as well as trends in federal funds for extramural R&D. DOD and HHS, combined, have provided between 60% and 80% of total annual SBIR funds since the program's inception (appendix table 4-39).

STTR involves cooperative R&D performed jointly by small businesses and nonprofit research organizations and is also structured in three phases. As of FY 2003, five federal agencies with extramural R&D budgets exceeding $1 billion participate in the program: DOD, NSF, DOE, NASA,

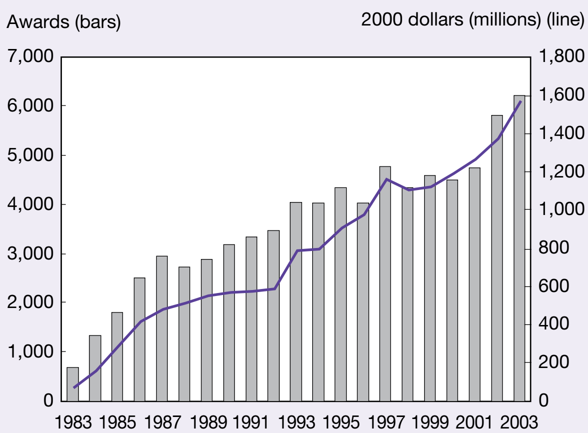
The New SBIR Program at the Department of Homeland Security

The Department of Homeland Security (DHS), established by the Homeland Security Act of 2002 and formed in January 2003, held its first SBIR competition in FY 2004 at its Homeland Security Advanced Research Projects Agency (HSARPA). Research topics of interest to DHS include chemical and biological sensors, ship compartment inspection devices, personal protective equipment and materials for emergency responders, and modeling and simulation technology.

According to DHS, "the FY 2005 SBIR funding level will be approximately $23 million…an increase from the FY 2004 funding level of just under $20 million.…The additional funding will also be useful as HSARPA begins a technology assistance program which can provide either technical assistance or commercialization support to the small businesses who gain DHS SBIR awards."* DHS also has implemented a Fast Track process for SBIR projects that successfully complete a Phase I project and receive a commitment for matching funds from outside investors for an eventual Phase II award.

*http://www.hsarpasbir.com/WhatsNew.asp. Accessed June 2005.

Figure 4-24
SBIR awards and funding: 1983–2003



SBIR = Small Business Innovation Research Program

SOURCE: U.S. Small Business Administration, *Small Business Innovation Research Program Annual Report* (various years). See appendix table 4-39.

Science and Engineering Indicators 2006

and HHS. Starting in FY 2004, the required set-aside rose from 0.15% to 0.3%, compared with a 2.5% set aside for SBIR. From FY 1994 to FY 2003, STTR awarded over $640 million to 3,422 projects. In FY 2003, the five participating agencies awarded $92 million, of which DOD and HHS represented a combined 80% (appendix table 4-40).

The Advanced Technology Program. The ATP, housed at DOC's National Institute of Standards and Technology (NIST), was established by the Omnibus Trade and Competitiveness Act of 1988 to promote the development and commercialization of generic or broad-based technologies.[56] The program provides funding for high-risk R&D projects through a competitive process on a cost-share basis with private-company participants. ATP projects are classified in five major technology areas: biotechnology, electronics, information technology, advanced materials and chemistry, and manufacturing, and applications span from nanotechnology, health, and energy to assistive technologies.

Through FY 2004, ATP has awarded funds for 768 projects with a combined funding of $4.37 billion, about equally split between the program and its participants. The projects have involved over 1,500 participants, which include established companies and startups as well as universities and other nonprofit institutions, organized as single company efforts or joint ventures (appendix table 4-41). In FY 2004, 59 R&D projects were initiated, totaling $270 million in combined program and industry funds. The program received $177 million in FY 2004 and $140 million in FY 2005. The administration's FY 2006 budget calls for the suspension of new awards (U.S. OMB 2005).

International R&D Comparisons

Increasingly, the international competitiveness of a modern economy is defined by its ability to generate, absorb, and commercialize knowledge. Although it is no panacea, scientific and technological knowledge has proven valuable in addressing the challenges countries face in a variety of areas such as sustainable development, economic growth, health care, and agricultural production. Nations benefit from R&D performed abroad, but domestic R&D performance is an important indicator of a nation's innovative capacity and its prospects for future growth, productivity, and S&T competitiveness. This section compares international R&D spending patterns. Topics include absolute expenditure trends, measures of R&D intensity, the structure and focus of R&D performance and funding across sectors, and government research-related priorities and policies.

Most of the R&D data presented in this section are from the Organisation for Economic Co-operation and Development (OECD), the most reliable source for such international comparisons.[57] However, an increasing number of non-OECD countries and organizations now collect and publish R&D statistics, which are cited at various points in this section. No R&D-specific currency exchange rates exist, but for comparison purposes international R&D data have been converted to U.S. dollars with purchasing power parity (PPP) exchange rates (see sidebar "Comparing International R&D Expenditures").

Comparing International R&D Expenditures

If countries do not share a common currency, some conversion must be made in order to compare their R&D expenditures. Unfortunately, comparisons of international research and development statistics are hampered by the lack of R&D-specific exchange rates. The only rates consistently compiled and available for a large number of countries over an extended period of time are market exchange rates (MERs) and purchasing power parities (PPPs).

Market exchange rates. At their best, MERs represent the relative value of currencies for goods and services that are traded across borders; that is, MERs measure a currency's relative international buying power. However, MERs may not accurately reflect the true cost of goods or services that are not traded internationally. In addition, fluctuations in MERs as a result of currency speculation, political events such as wars or boycotts, and official currency intervention, which have little or nothing to do with changes in the relative prices of internationally traded goods, greatly reduce their statistical utility.

PPP exchange rates. PPPs were developed because of the MER shortcomings described above (Ward 1985). PPPs take into account the cost differences across countries of buying a similar basket of goods and services in numerous expenditure categories, including nontradables. The PPP basket is therefore assumed to be representative of total GDP across countries.

Although the goods and services included in the market basket used to calculate PPP rates differ from the major components of R&D costs (fixed assets as well as wages of scientists, engineers, and support personnel), they still result in a more suitable domestic price converter than one based on foreign trade flows. Exchange rate movements bear little relationship to changes in the cost of domestically performed R&D. The adoption of the euro as the common currency for many European countries provides a useful example: although Germany and Portugal now share a common currency, the real costs of most goods and services are substantially less in Portugal.

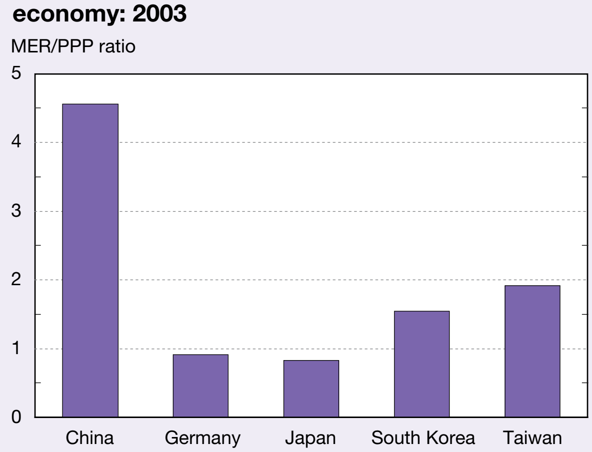
PPPs are therefore the preferred international standard for calculating cross-country R&D comparisons wherever possible and are used in all official R&D tabulations of the Organisation of Economic Co-operation and Development (OECD).

PPPs for developing economies. Because MERs tend to understate the domestic purchasing power of developing countries' currencies, PPPs can produce substantially larger R&D estimates than MERs do for these countries. For example, China's 2002 R&D expenditures are $16 billion using MERs but are $72 billion using PPPs. Figure 4-25 shows the relative difference between MERs and PPPs for a few countries.

Although PPPs are available for developing countries such as India and China, there are several reasons why they may be less useful for converting R&D expenditures than in more developed countries:

- It is difficult or impossible to assess the quality of PPPs for some countries, most notably China. Although PPP estimates for OECD countries are quite reliable, PPP estimates for developing countries are often rough approximations. The latter estimates are based on extrapolation of numbers published by the United Nations International Comparison Program and by Professors Robert Summers and Alan Heston of the University of Pennsylvania and their colleagues.
- The composition of the "market basket" used to calculate PPPs likely differs substantially between developing and developed countries. The structural differences in the economies of these countries, as well as disparities in income, may result in a market basket of goods and services in a developing country that is quite different from the market basket of a developed country, particularly as far as these baskets relate to the various costs of R&D.
- R&D performance in developing countries is often concentrated geographically in their most advanced cities and regions in terms of infrastructure and educated workforce. The costs of goods and services in these areas can be substantially greater than for the country as a whole.

Figure 4-25
Market exchange rate/purchasing power parity exchange rate ratios, selected countries/ economy: 2003



MER = market exchange rate; PPP = purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004). See appendix table 4-2.

Science and Engineering Indicators 2006

Figure 4-26
R&D expenditures and share of world total, by region: 2000

NOTE: R&D estimates from 80 countries in billions of purchasing power parity dollars.

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004); Iberoamerican Web of Science and Technology Indicators, http://www.ricyt.edu.ar, accessed 1 April 2005; and United Nations Educational, Scientific and Cultural Organization (UNESCO), Institute for Statistics, http://www.uis.unesco.org, accessed 7 April 2005. See appendix table 4-57.

Science and Engineering Indicators 2006

Global R&D Expenditures

Worldwide R&D performance is concentrated in a few developed nations. In 2000, global R&D expenditures totaled at least $729 billion, half of which was accounted for by the two largest countries in terms of R&D performance, the United States and Japan.[58] As figure 4-26 illustrates, over 95% of global R&D is performed in North America, Asia, and Europe. Yet even within each of these regions, a small number of countries dominate R&D performance: the United States in North America; Japan and China in Asia; and Germany, France, and the United Kingdom in Europe.

Wealthy, well-developed nations, generally represented by OECD member countries, perform most of the world's R&D, but several lesser-developed nations now report higher R&D expenditures than most OECD members. In 2000, Brazil performed an estimated $13.6 billion of R&D, roughly half the amount performed in the United Kingdom (RICYT 2004). India performed an estimated $20.0 billion in 2000, making it the seventh largest country in terms of R&D in that year, ahead of South Korea (UNESCO/UIS 2005). China was the fourth largest country in 2000 in terms of R&D performance, with $48.9 billion of R&D, only slightly less than the $50.9 billion of R&D performed in Germany (OECD 2004). In 2002, an estimated $72.0 billion of R&D was performed in China, making it the third largest country in terms of R&D performance. Given the lack of either R&D-specific exchange rates (see sidebar "Comparing International R&D Expenditures") or accepted qualitative measures of international R&D (see sidebar "Qualitative Comparisons of International R&D"), it is difficult to draw conclusions from these absolute R&D figures.

OECD and G-7 R&D Expenditures

The 30 OECD countries represented 82% of global R&D, or $602 billion, in 2000. Although global R&D estimates are not available for later years, the R&D performance of OECD countries grew to $652 billion in 2002. The G-7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) performed over 83% of OECD R&D in 2002. The three largest R&D performers, the United States, Japan, and Germany, account for over two-thirds of the OECD's R&D. The United States accounts for 43% of OECD R&D, a slight drop in share from 2000 when it performed 44% of all OECD R&D. Outside of the G-7 countries, South Korea is the only country that accounted for a substantial share of the OECD total (3.5% in 2002, up from 3.1% in 2000).

More money was spent on R&D activities in the United States in 2002 than in the rest of the G-7 countries combined (figure 4-27).[59] In terms of relative shares, U.S. R&D expenditures in 1984 reached historical highs of 55% of the G-7 total and 47% of the OECD total. As a proportion of the G-7 total, U.S. R&D expenditures declined steadily to a low of 48% in 1990. After the early 1990s, the U.S. percentage of

Qualitative Comparisons of International R&D

Data on R&D expenditures are often used to make international comparisons, in part because of the relative ease of comparing monetary data across countries. But although the cost of R&D in two countries can be compared, it is significantly more difficult to assess the quality of the R&D being performed in the two locations. As with other economic indicators, R&D expenditures are only proxy measures, and they do not contain all of the information policymakers and researchers need to answer their questions about science, technology, innovation, and competitiveness. In order to assess a country's R&D activities, a variety of factors could be considered in addition to quantitative data on R&D expenditures. Following are examples of factors that may relate to a country's R&D performance and innovation capabilities:

- **Culture of cooperation between sectors.** The number and quality of linkages between the various R&D-performing sectors can be used as a measure of how well a country leverages its innovation infrastructure.
- **Human capital.** The availability of a high-skilled workforce is essential for a competitive national R&D system. The ability of a country to retain its highly skilled scientists and engineers is as important as its ability to train scientists and engineers in its education system. Just as foreign companies can relocate R&D activities to lower-wage countries, mobile, skilled workers can relocate to countries with higher wages.
- **Intellectual property protection.** Strong intellectual property laws help firms to capture benefits from R&D investments. Although foreign firms may invest in R&D in countries with weak intellectual property protection, such as China and, until recently, India, the R&D performed there may be less innovative than that performed in the firms' home countries.
- **Legal restrictions on research.** Cultural pressure and government regulations can influence the nature of a country's research portfolio and be important considerations when comparing countries' R&D performance in specific fields of research.
- **Market for new technology.** The presence of a sophisticated, demanding, and wealthy domestic market can be a strong motivator for firms to invest heavily in R&D. The growth of the U.S. market for pharmaceuticals compared to Europe's is a contributing factor to the increasing attractiveness of the United States as a locus for pharmaceutical R&D. Similarly, the pervasiveness of mobile communications technology in Finnish and Japanese societies has helped these countries remain world leaders in this market.
- **Quality of research institutions.** The quality of research institutions (universities and government facilities) in a country, as defined by quantitative measures (such as publication output and number of prize-winning faculty) as well as qualitative measures (such as peer rankings), is an important factor when making international comparisons of R&D activity.
- **Research infrastructure.** Certain types of research require extremely specialized and expensive facilities and instrumentation. The availability of advanced research infrastructure and instrumentation, from radio telescopes to supercomputers, can influence the nature and quality of research performed in a country.

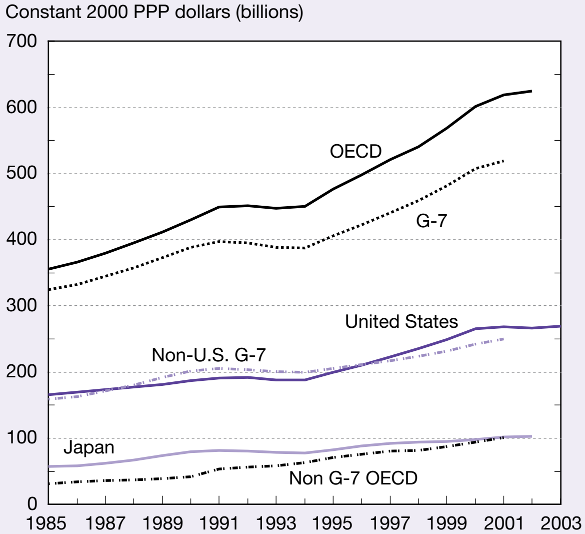
total G-7 R&D expenditures grew as a result of a worldwide slowing in R&D performance that was more pronounced in other countries. Although U.S. R&D spending idled or declined for several years in the early to mid-1990s, the reduction in real R&D spending in most of the other G-7 countries was more striking. In Japan, Germany, and Italy, inflation-adjusted R&D spending fell for 3 consecutive years (1992, 1993, and 1994) (OECD 2004).[60] R&D spending rebounded in the late 1990s in several G-7 countries, but the recovery was most robust in the United States. By 2000, the U.S. share of total G-7 R&D had grown to 52%. The subsequent slowdown in the technology market in 2001 and 2002 has had a global reach, but its impact on R&D was more pronounced in the United States than in the other G-7 countries, resulting in a decline in the U.S. share of G-7 R&D in 2001 and 2002.

Indicators of R&D Intensity

International comparisons of absolute R&D expenditures are complicated by the fact that countries vary widely in terms of the sizes of their population and economy. For example, although Germany and China had roughly equivalent R&D expenditures in 2000, China's population was over 15 times as large and its economy was over twice as large as Germany's in that year. Policymakers commonly use various measures of R&D intensity to account for these size differences when making international comparisons.

One of the first and now one of the more widely used indicators of a country's R&D intensity is the ratio of R&D spending to GDP, the main measure of a nation's total economic activity (Steelman 1947). Policymakers often use this ratio for international benchmarking and goal setting (see sidebar "European Union Strategy for R&D and Economic Competitiveness").

Figure 4-27
R&D expenditures of United States and G-7 and OECD countries: 1985–2003



OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTE: Non-U.S. G-7 countries: Canada, France, Germany, Italy, Japan, and United Kingdom.

SOURCE: OECD, *Main Science and Technology Indicators* (2004). See appendix table 4-42.

Science and Engineering Indicators 2006

Normalized indicators, such as R&D/GDP ratios, are useful for international comparisons because they both account for size differences between countries and obviate the need for exchange rates. However, even normalized indicators are not always comparable from one country to another. This occurs most often when the variable being used to normalize the indicator differs across countries. For example, the structure of national economies, and hence GDP, varies greatly. As figure 4-28 shows, the agricultural and industrial sectors account for less than one-third of GDP in the United States and the other G-7 countries (Canada, France, Germany, Italy, Japan, and the United Kingdom). These sectors represent similarly small shares of the labor force. In less-developed nations, such as India and China, the agricultural and industrial sectors account for more than half of GDP and an even larger share of the labor force (estimated to be 72% in China and 77% in India) (CIA 2005). Structural differences such as this can result in significant country-to-country variation in terms of R&D indicators. For several years, economists have debated whether or not R&D should be included as part of the national accounts (see sidebar "Indicators Development on R&D Within the National Accounts: The BEA/NSF R&D Satellite Account Project").

Total R&D/GDP Ratios

The ratio of R&D expenditures to GDP is a useful indicator of the intensity of R&D activity in relation to other economic activity and can be used to gauge a nation's commitment to R&D at different points in time. In the United States, the slowdown in GDP growth in 2001 preceded the decline of U.S. R&D in 2002. This resulted in U.S. R&D to GDP ratios of 2.7% in 2001 (a recent high) and 2.6% in 2002 (figure 4-29). Following the 2002 decline, R&D grew more rapidly than GDP in the United States resulting in an R&D to GDP ratio of 2.7% in 2003.[61] The U.S. economy expanded at a faster pace in 2004, and R&D as a proportion of GDP remained at 2.7%.[62]

Since 1953, U.S. R&D expenditures as a percentage of GDP have ranged from a minimum of 1.4% (in 1953) to a maximum of 2.9% (in 1964). Most of the growth over time in the R&D/GDP ratio can be attributed to steady increases in nonfederal R&D spending.[63] Nonfederally financed R&D, the majority of which is company financed, increased from

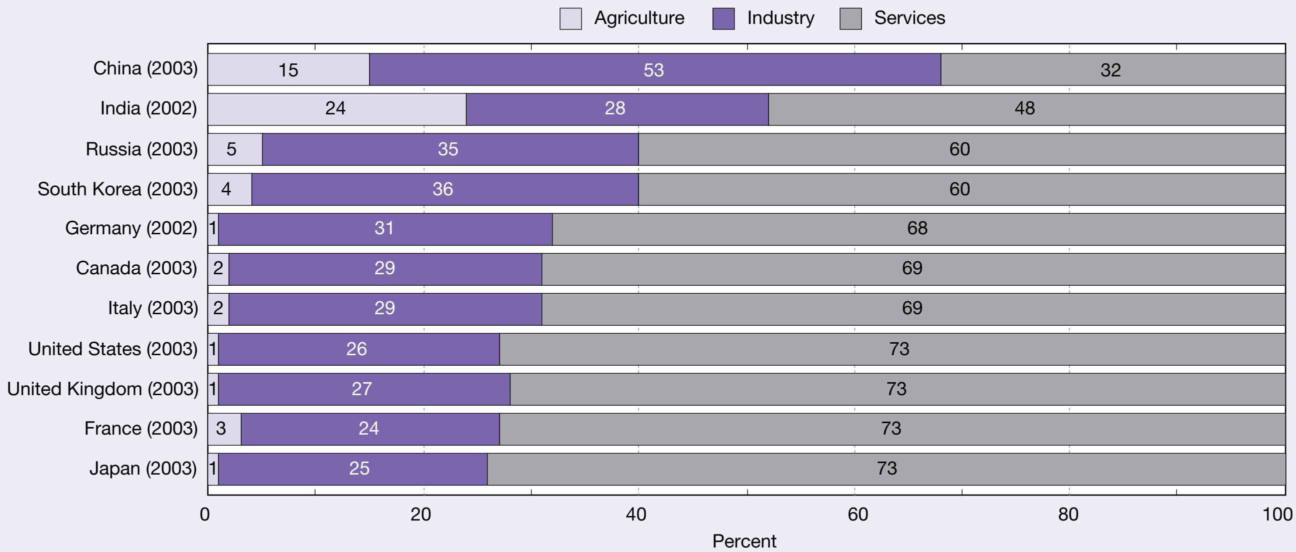
European Union Strategy for R&D and Economic Competitiveness

In March 2000, the Lisbon European Council set out a 10-year strategy to make the EU the "most competitive and dynamic knowledge-based economy in the world by 2010." A key element of the Lisbon Strategy, as it is known, is the goal to develop a more robust European Research Area. The Lisbon Strategy defined an open process of target setting and benchmarking. Each member country was expected to determine how best to achieve each target while learning from the experiences of other members.

In March 2002, the Barcelona European Council reviewed member states' progress towards the Lisbon goal. The Council determined that, to meet the goal, a target for investments in R&D equal to 3% of EU GDP must be reached by 2010, with at least two-thirds of the R&D funding coming from the private sector (a proportion similar to that of the United States). This target was set to close the large gap in R&D investment between the EU and the United States. Although two EU members (Sweden and Finland) have already met the 3% target, the EU as a whole is not on track to meet the ambitious goals set by the European Council in 2000 and 2002.

Responding to the Barcelona target in late 2002, the European Round Table of Industrialists (ERT), an association of leaders from 42 companies that represent 13% of total European R&D spending, expressed doubts as to whether either part of the R&D target was realistic. ERT noted that an internal survey of their member companies revealed few with expectations of substantially increasing their R&D investment in Europe in the coming years and concluded that "unless there is a dramatic reappraisal of Europe's approach to R&D and its framework conditions for business, the gap between the Barcelona target and the real world will not be bridged by 2010" (ERT 2002).

Figure 4-28
Composition of gross domestic product for selected countries, by sector: 2002 or 2003



SOURCE: Central Intelligence Agency, *The World Fact Book 2004*, http://www.cia.gov/cia/publications/factbook/index.html, accessed 31 March 2005.

Science and Engineering Indicators 2006

Indicators Development on R&D Within the National Accounts: The BEA/NSF R&D Satellite Account Project

In June 2004, the National Science Foundation (NSF) Division of Science Resources Statistics entered into a multiyear agreement with the U.S. Bureau of Economic Analysis (BEA) to produce an updated and expanded R&D satellite account by the end of FY 2007. A satellite account provides estimates of expenditures on R&D that are designed to be used in conjunction with the national income and product accounts (NIPA) measures (Carson et al. 1994). A satellite account framework recognizes the investment characteristics of R&D in terms of its role in long-term productivity and growth. According to Fraumeni and Okubo (2004), "construction of the partial R&D satellite account within a NIPA framework allows for the estimation of the impact of R&D on GDP and other macroeconomic aggregates as well as the estimation of the contribution of R&D to economic growth.…"

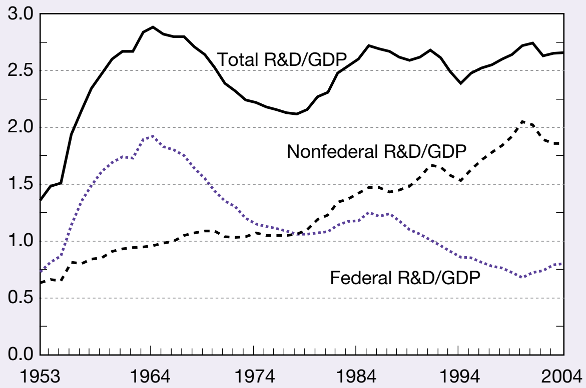
The project will include methodology to translate NSF R&D expenditure data collected based on the Frascati Manual (OECD 2002b) to gross output that is consistent with the 1993 System of National Accounts (SNA) (CEC et. al 1993; OECD 2001). The project is also expected to generate information useful in a separate effort by the OECD's Canberra Working Group on Capital Measurements, which includes the United States, studying, among other issues, the conceptual and statistical feasibility of capitalizing R&D expenditures.

0.6% of GDP in 1953 to an estimated 1.9% of GDP in 2004 (down from a high of 2.1% of GDP in 2000). The increase in nonfederally financed R&D as a percentage of GDP illustrated in figure 4-29 is indicative of the growing role of S&T in the U.S. economy.

Historically, most of the peaks and valleys in the U.S. R&D/GDP ratio can be attributed to changing priorities in federal R&D spending. The initial drop in the R&D/GDP ratio from its peak in 1964 largely reflects federal cutbacks in defense and space R&D programs. Gains in energy R&D activities between 1975 and 1979 resulted in a relative stabilization of the ratio. Beginning in the late 1980s, cuts in defense-related R&D kept federal R&D spending from keeping pace with GDP growth, whereas growth in nonfederal sources of R&D spending generally kept pace with or exceeded GDP growth. Since 2000, defense-related R&D spending has surged, and federal R&D spending growth has outpaced GDP growth. (See the discussion of defense-related R&D earlier in this chapter.)

For many of the G-8 countries (i.e., the G-7 countries plus Russia), the latest R&D/GDP ratio is no higher now than it was at the start of the 1990s, which ushered in a period of slow growth or decline in their overall R&D efforts (figure 4-30). The two exceptions, Japan and Canada, both exhibit substantial increases on this indicator between 1990 and 2002. In Japan this indicator declined in the early 1990s

Figure 4-29
R&D share of gross domestic product: 1953–2004

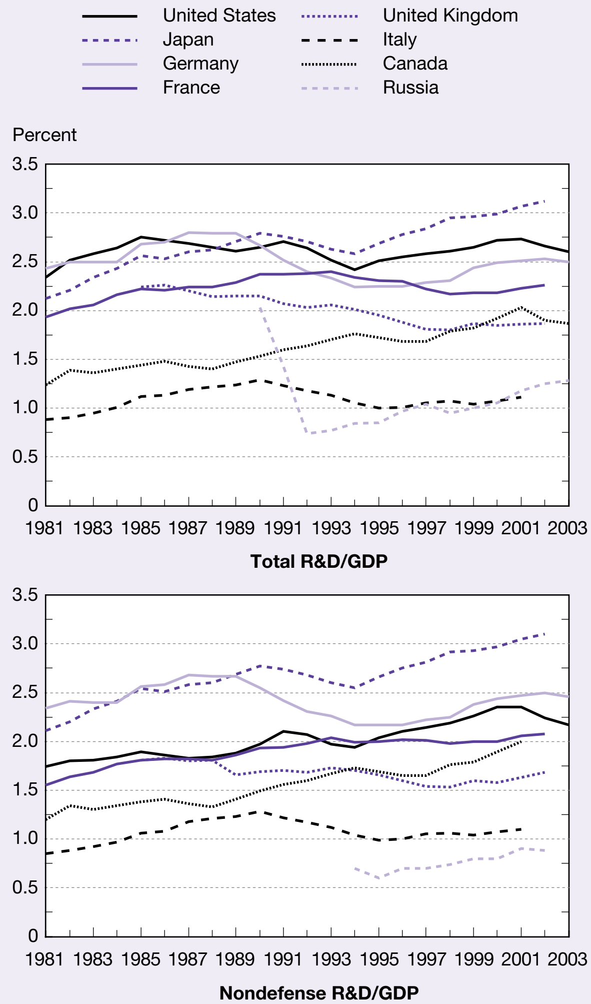


GDP = gross domestic product

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-1 and 4-3.

Science and Engineering Indicators 2006

Figure 4-30
R&D share of gross domestic product, by selected countries: 1981–2003



GDP = gross domestic product

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004). See appendix tables 4-42 and 4-43.

Science and Engineering Indicators 2006

as a result of reduced or level R&D spending by industry and government, a pattern similar to that exhibited by the United States. Japan's R&D/GDP ratio subsequently rose to 3.1% in 2002, the result of a resurgence of industrial R&D in the mid-1990s coupled with anemic economic conditions. In the 5 years between 1997 and 2002, real GDP in Japan grew only 1.8%, so relatively small increases in R&D expenditures resulted in a rise in its R&D/GDP ratio.[64] By contrast, over the same period real GDP grew 21.8% in Canada; hence, the rise in its R&D/GDP ratio is more indicative of robust R&D growth.

Geopolitical events also affect R&D intensity indicators as evidenced by Germany and Russia. Germany's R&D/GDP ratio fell from 2.8% at the end of the 1980s, before reunification, to 2.2% in 1994. Its R&D/GDP has since risen to 2.5% in 2003. The end of the Cold War and collapse of the Soviet Union had a drastic effect on Russia's R&D intensity. R&D performance in Russia was estimated at 2.0% of GDP in 1990; that figure dropped to 1.4% in 1991 and then dropped further to 0.7% in 1992. The severity of this decline is compounded by the fact that Russian GDP contracted in each of these years. Both Russia's R&D and GDP exhibited strong growth after 1998. In the 5 years between 1998 and 2003, Russia's R&D doubled and its R&D/GDP ratio rose from 1.0% to 1.3%.

Overall, the United States ranked fifth among OECD countries in terms of reported R&D/GDP ratios (table 4-13), but several of its states have R&D intensities over 4%. Massachusetts, a state with an economy larger than Sweden's and twice that of Israel's, has reported an R&D intensity at or above 5% since 2001 (see the section entitled "Location of R&D Performance"). Israel (not an OECD member country), devoting 4.9% of its GDP to R&D, currently leads all countries, followed by Sweden (4.3%), Finland (3.5%), Japan (3.1%), and Iceland (3.1%). In general, nations in Southern and Eastern Europe tend to have R&D/GDP ratios of 1.5% or lower, whereas Nordic nations and those in Western Europe report R&D spending shares greater than 1.5%. This pattern broadly reflects the wealth and level of economic development for these regions. A strong link exists between countries with high incomes that emphasize the production of high-technology goods and services and those that invest heavily in R&D activities (OECD 2000).[65] The private sector in low-income countries often has a low concentration of high-technology industries, resulting in low overall R&D spending and therefore low R&D/GDP ratios. Because of the business sector's dominant role in global R&D funding and performance, R&D/GDP ratios are most useful when comparing countries with national S&T systems of comparable maturity and development.

Table 4-13
R&D share of gross domestic product, by country/economy: selected years, 1998 and 2000–03

Country/economy	Share (%)	Country/economy	Share (%)
Total OECD (2002)	2.26	New Zealand (2001)	1.16
European Union-25 (2002)	1.86	Ireland (2001)	1.13
Israel (2003)	4.90	Italy (2001)	1.11
Sweden (2001)	4.27	Brazil (2000)	1.04
Finland (2002)	3.46	Spain (2002)	1.03
Japan (2002)	3.12	Hungary (2003)	0.95
Iceland (2002)	3.09	Portugal (2002)	0.94
United States (2003)	2.67	Turkey (2002)	0.66
South Korea (2003)	2.64	Greece (2001)	0.65
Switzerland (2000)	2.57	Cuba (2002)	0.62
Denmark (2002)	2.52	Poland (2002)	0.59
Germany (2003)	2.50	Slovak Republic (2003)	0.59
Belgium (2003)	2.33	Chile (2001)	0.57
Taiwan (2002)	2.30	Argentina (2003)	0.41
France (2002)	2.26	Panama (2001)	0.40
Austria (2003)	2.19	Costa Rica (2000)	0.39
Singapore (2002)	2.15	Mexico (2001)	0.39
Netherlands (2001)	1.88	Romania (2002)	0.38
Canada (2003)	1.87	Bolivia (2002)	0.26
United Kingdom (2002)	1.87	Uruguay (2002)	0.22
Luxembourg (2000)	1.71	Peru (2003)	0.11
Norway (2002)	1.67	Colombia (2002)	0.10
Australia (2000)	1.54	Trinidad and Tobago (2001)	0.10
Slovenia (2002)	1.53	Ecuador (1998)	0.09
Czech Republic (2003)	1.34	El Salvador (1998)	0.09
Russian Federation (2003)	1.28	Nicaragua (2002)	0.07
China (2002)	1.22		

OECD = Organisation for Economic Co-operation and Development

NOTES: Civilian R&D only for Israel and Taiwan. Data for latest available year in parentheses.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series); OECD, *Main Science and Technology Indicators* (2004); and Iberoamerican Network of Science and Technology Indicators, http://www.ricyt.edu.ar, accessed 1 May 2005.

Science and Engineering Indicators 2006

Outside the European region, R&D spending has intensified considerably since the early 1990s. Several Asian countries, most notably South Korea and China, have been particularly aggressive in expanding their support for R&D and S&T-based development. In Latin America and the Pacific region, other non-OECD countries also have attempted to increase R&D investments substantially during the past several years. Even with recent gains, however, most non-European (non-OECD) countries invest a smaller share of their economic output in R&D than do OECD members (with the exception of Israel). All Latin American countries for which such data are available report R&D/GDP ratios at or below 1% (table 4-13). This distribution is consistent with broader indicators of economic growth and wealth.

Nondefense R&D Expenditures and R&D/GDP Ratios

Another indicator of R&D intensity, the ratio of nondefense R&D to GDP, is useful when comparing nations with different financial investments in national defense. Although defense-related R&D does result in spillovers that produce social benefits, nondefense R&D is more directly oriented toward national scientific progress, standard-of-living improvements, economic competitiveness, and commercialization of research results. Using this indicator, the relative position of the United States falls below that of Germany and just above France among the G-7 nations (figure 4-30). This is because the United States devotes more of its R&D to defense-related activities than most other countries. In 2002 approximately 16% of U.S. R&D was defense related, whereas less then 1% of the R&D performed in Germany and Japan was defense related. Both of these countries rely heavily on international alliances for national defense. Approximately 10% of the United Kingdom's total R&D was defense related in 2002.

Since the end of the Cold War, the relative share of defense-related R&D has diminished markedly in several countries. Between 1988 and 2002, the defense share of R&D fell from 31% to 16% in the United States and from 19% to 8% in France. Between 1989 and 2002, the defense share of R&D fell from 23% to 10% in the United Kingdom. The defense-related share of R&D is higher in Russia (30% in 2002), where, unlike in the G-7 countries, the government funds the majority of national R&D (see the section entitled "International R&D by Performer and Source of Funds").

Basic Research/GDP Ratios

R&D involves a wide range of activities, ranging from basic research to the development of marketable goods and services. Basic research generally has low short-term returns, but it builds intellectual capital and lays the groundwork for future advances in S&T. The relative investment in basic research as a share of GDP therefore indicates differences in national priorities, traditions, and incentive structures with respect to S&T. Estimates of basic research often involve a greater element of subjective assessment than other R&D indicators; thus, only half of the OECD member countries report these data at the national level. Nonetheless, where these data exist, they help differentiate the national innovation systems of different countries in terms of how their R&D resources contribute to advancing scientific knowledge and developing new technologies.

High basic research/GDP ratios generally reflect the presence of robust academic research centers in the country and/or a concentration of high-technology industries (such as biotechnology) with patterns of strong investment in basic research (see "International R&D by Performer and Source of Funds"). Of the OECD countries for which data are available, Switzerland has the highest basic research/GDP ratio at 0.7% (figure 4-31). This is significantly higher than either the U.S. ratio of 0.5% or the Japanese ratio of 0.4%. Switzerland, a small high-income country boasting the highest number of Nobel prizes, patents, and science citations per capita worldwide, devoted more than 60% of its R&D to basic and applied research in 2000 despite having an industrial R&D share (74%) comparable to the United States and Japan. The differences among the Swiss, U.S., and Japanese character-of-work shares reflect both the high concentration of chemical and pharmaceutical R&D in Swiss industrial R&D as well as the "niche strategy" of focusing on specialty products adopted by many Swiss high-technology industries.

China, despite its growing investment in R&D, reports among the lowest basic research/GDP ratios (0.07%), below Argentina (0.10%) and Mexico (0.12%) (figure 4-32). With its emphasis on applied research and development aimed at

Figure 4-31
Basic research share of gross domestic product, by country/economy: Selected years, 2000–02

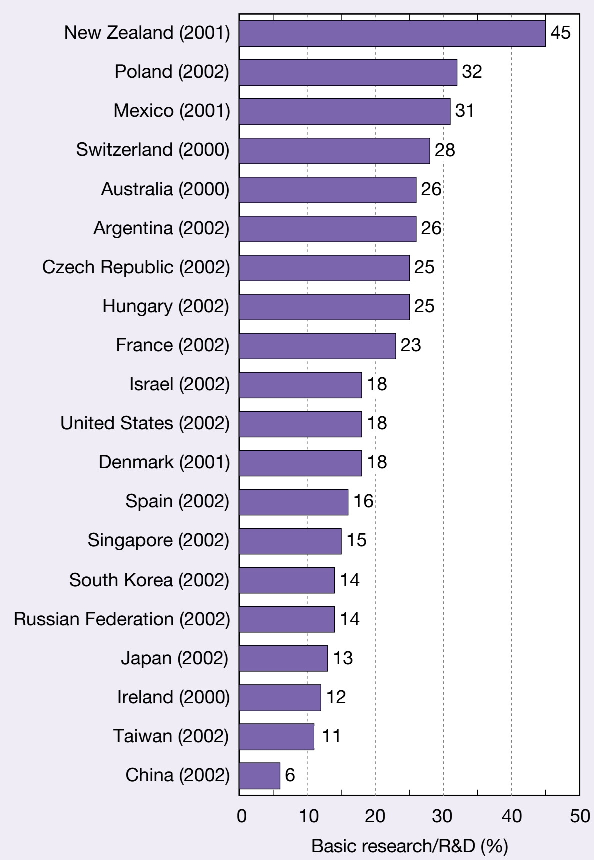
GDP = gross domestic product

NOTE: Data are for years in parentheses.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004).

Science and Engineering Indicators 2006

Figure 4-32
Basic research share of R&D, by country/economy: Selected years, 2000–02

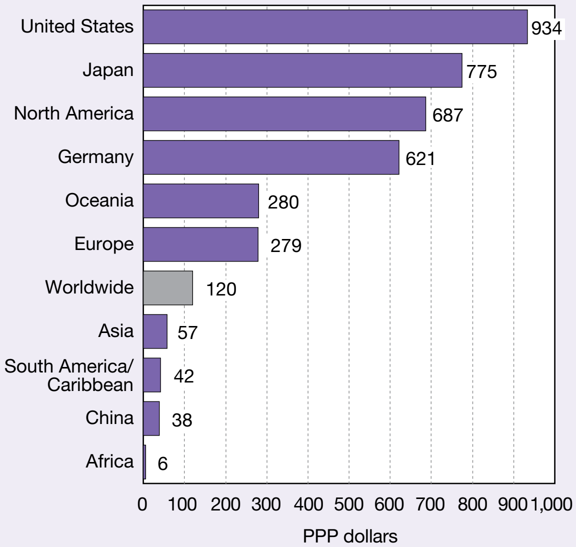


NOTE: Data are for years in parentheses.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004).

Science and Engineering Indicators 2006

Figure 4-33
R&D expenditures per capita, by country/region: 2000



PPP = purchasing power parity

NOTE: R&D estimates from 80 countries.

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004); Iberoamerican Web of Science and Technology Indicators, http://www.ricyt.edu.ar, accessed 1 April 2005; United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics, http://www.uis.unesco.org, accessed 7 April 2005; and United Nations Population Division, Department of Economic and Social Affairs, *World Population Prospects: The 2004 Revision,* http://esa.un.org/unpp, and *World Urbanization Prospects: The 2003 Revision,* http://www.un.org/esa/population/publications/wup2003/2003WUP.htm, accessed 9 April 2005. See appendix table 4-57.

Science and Engineering Indicators 2006

short-term economic development, China follows the pattern set by Taiwan, Singapore, South Korea, and Japan. In each of these countries or economies, basic research accounts for 15% or less of total R&D.

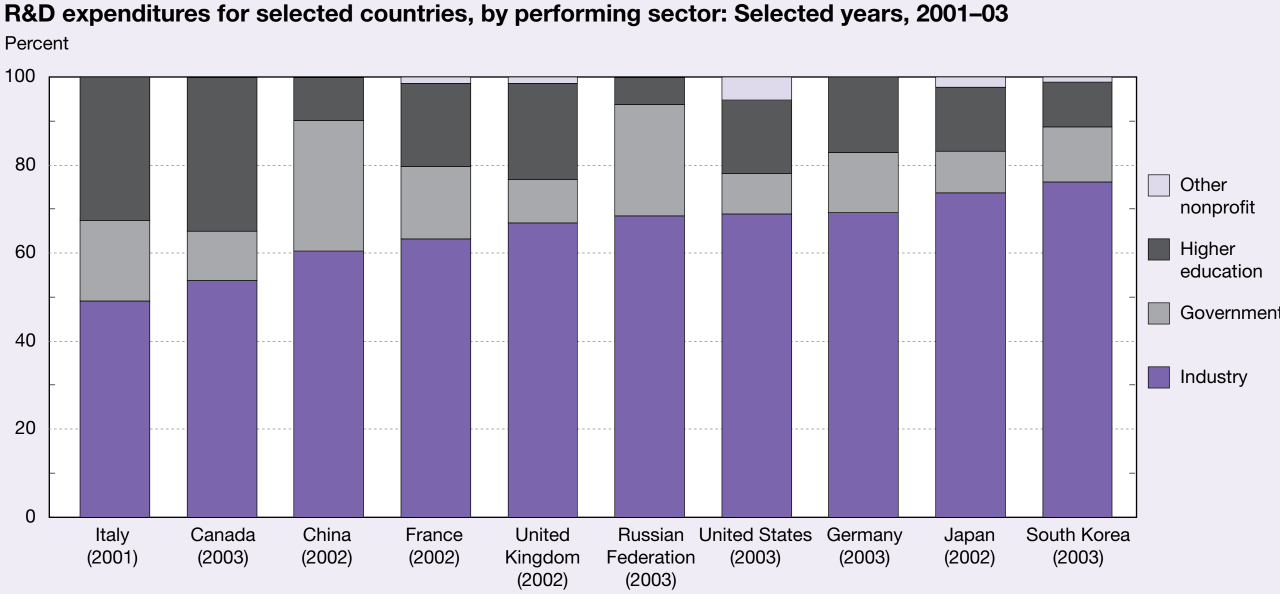
R&D per Capita

Although R&D as a percentage of GDP is the most commonly used indicator for international comparisons of S&T, regional differences in R&D intensity are even more pronounced using the indicator of R&D expenditures per capita (figure 4-33). Although China and Germany reported similar R&D expenditures in 2000, on a per capita basis Germany's R&D was over 16 times China's. Because the salaries of scientists and engineers are a large component of R&D expenditures, high R&D per capita is proportionate both to the relative number of researchers working in a country as well as the wages these researchers are earning. Regions with a concentration of wealthy countries, such as North America and Europe, far outstrip lesser-developed regions such as Africa and South America on both of these measures.

International R&D by Performer and Source of Funds

R&D performance patterns by sector are broadly similar across countries, but national sources of support differ considerably. In each of the G-8 countries the industrial sector is the largest performer of R&D (figure 4-34). Industry's share of R&D performance ranged from 49% in Italy to over 73% in Japan and South Korea; it was 69% in the United States. In most countries industrial R&D is financed primarily by the business sector. A notable exception is the Russian Federation, where

Figure 4-34
R&D expenditures for selected countries, by performing sector: Selected years, 2001–03

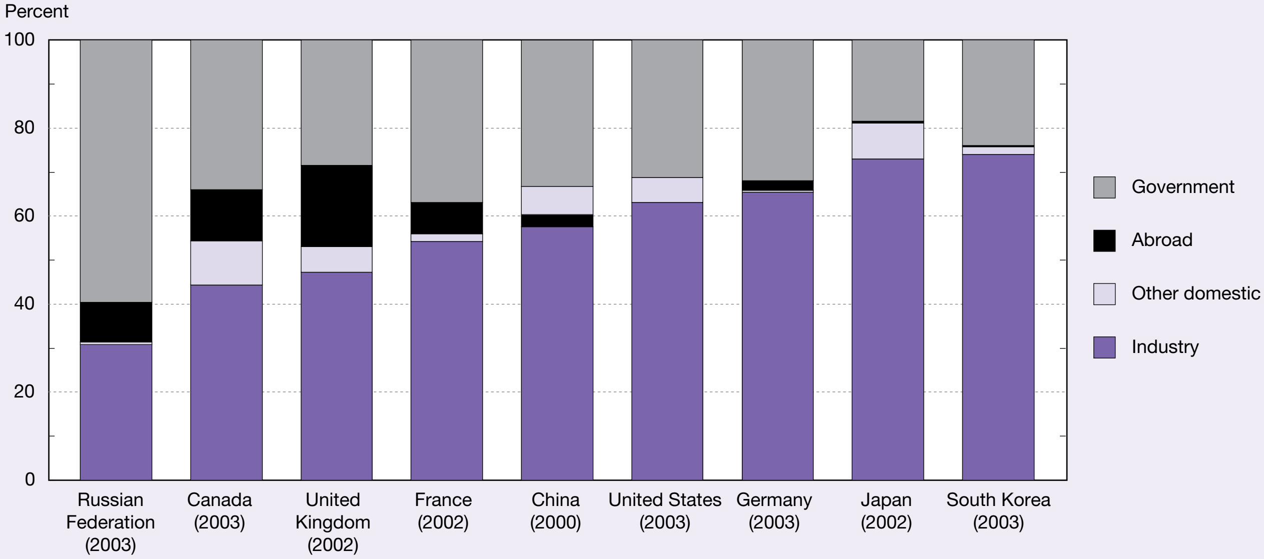


NOTES: Data are for years in parentheses.

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004). See appendix table 4-44.

Science and Engineering Indicators 2006

Figure 4-35
R&D expenditures for selected countries, by source of funds: Selected years, 2000–03



NOTES: Data are for years in parentheses. Separate data on foreign sources of R&D funding unavailable for United States but included in sector totals. In most other countries, "foreign sources of funding" is a distinct and separate funding category. For some countries (such as Canada), foreign firms are source of a large amount of foreign R&D funding, reported as funding from abroad. In United States, industrial R&D funding from foreign firms reported as industry. Data unavailable for Italy.

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004). See appendix table 4-44.

Science and Engineering Indicators 2006

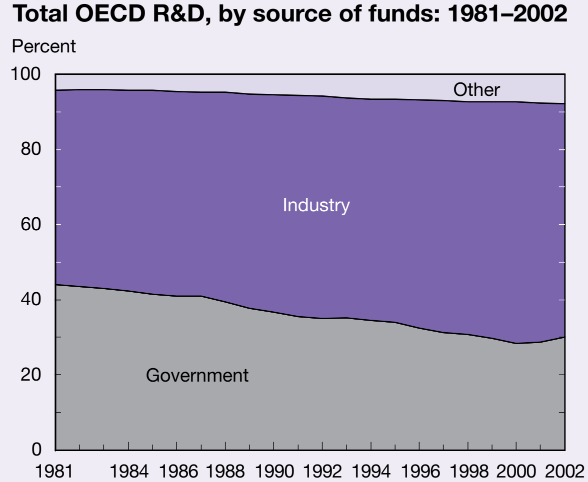
government was the largest source of industrial R&D funding in 2001 (NSB 2004).

In all of the G-8 countries except Russia, the academic sector was the second largest R&D performer (representing from 15% to 35% of R&D performance in each country). In Russia, government is the second largest R&D performer, accounting for 25% of its R&D performance in 2003. Government-performed R&D is even more prominent in China, where it accounted for an estimated 30% of Chinese R&D performance in 2002.

Government and industry together account for over three-quarters of the R&D funding in each of the G-8 countries, although their respective contributions vary (figure 4-35).[66] Among these countries the industrial sector provided as much as 73% of R&D funding in Japan to as little as 31% in Russia. Government provided the largest share of Russia's R&D (60%), as it has in Italy in past years (more than 50% in 1999). In the remaining six G-8 member nations, government was the second largest source of R&D funding, ranging from 19% of total R&D funding in Japan to 37% in France.

In nearly all OECD countries, the government's share of total R&D funding has declined over the past two decades, as the role of the private sector in R&D grew considerably (figure 4-36). In 2002, 30% of all R&D funds were derived from government sources, down from 44% in 1981.[67] The relative decline of government R&D funding is the result of budgetary constraints, economic pressures, and changing priorities in government funding (especially the relative reduction in defense R&D in several of the major R&D-performing countries, notably France, the United Kingdom, and the United States). This trend also reflects the absolute growth in industrial R&D funding, irrespective of government R&D spending patterns.

Figure 4-36
Total OECD R&D, by source of funds: 1981–2002



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators* (2004). See appendix table 4-46.

Science and Engineering Indicators 2006

Canada and the United Kingdom both report relatively large amounts of R&D funding from abroad (12% and 18%,

respectively), much of which originates from foreign business enterprises (figure 4-35). Businesses in the United States also receive foreign R&D funding; however, these data are not separately reported in U.S. R&D statistics and are included in the figures reported for industry. Therefore the industry share of R&D funding for the United States is overstated compared with the industry shares for countries where foreign sources of R&D funding are reported separately from domestic sources (see "Industrial Sector"). In the United States companies include foreign sources of R&D funding in the category "company and other nonfederal sources" when responding to the U.S. Survey of Industrial R&D.

Industrial Sector

The structure of industrial R&D varies substantially among countries in terms of both sector concentration and sources of funding. Because industrial firms account for the largest share of total R&D performance in each of the G-8 countries and most OECD countries, differences in industrial structure can help explain international differences in more aggregated statistics such as R&D/GDP. For example, countries with higher concentrations of R&D-intensive industries (such as communications equipment manufacturing) are likely to also have higher R&D/GDP ratios than countries whose industrial structures are weighted more heavily toward less R&D-intensive industries.

Sector Focus

Using internationally comparable data, in 2002 no one industry accounted for more than 11% of total business R&D in the United States (figure 4-37; appendix table 4-58). This is largely a result of the size of business R&D expenditures in the United States, which makes it difficult for any one sector to dominate. However, the diversity of R&D investment by industry in the United States is also an indicator of how the nation's accumulated stock of knowledge and well-developed S&T infrastructure have made it a popular location for R&D performance in a broad range of industries.

Compared with the United States, many of the other countries shown in figure 4-37 display much higher industry and sector concentrations. In countries with less business R&D, high sector concentrations can result from the activities of one or two large companies. This pattern is notable in Finland, where the radio, television, and communications equipment industry accounted for almost half of business R&D in 2002. This high concentration likely reflects the activities of one company, Nokia, the world's largest manufacturer of cellular phones (see also table 4-6 in sidebar "R&D Expenses of Public Corporations"). By contrast, South Korea's high concentration (46% of business R&D in 2003) of R&D in this industry is not the result of any one or two companies, but reflects the structure of its export-oriented economy. South Korea is one of the world's top producers of electronic goods, and its top two export commodities are semiconductors and cellular phones (see sidebar "R&D in the ICT Sector").

Other industries also exhibit relatively high concentrations of R&D by country. Automotive manufacturers rank among the largest R&D-performing companies in the world (see sidebar "R&D Expenses of Public Corporations"). Because of this, the countries that are home to the world's major automakers also boast the highest concentration of R&D in the motor vehicles industry. This industry accounts for 29% of Germany's business R&D, 27% of the Czech Republic's, and 19% of Sweden's, reflecting the operations of automakers such as DaimlerChrysler and Volkswagen in Germany, Skoda in the Czech Republic, and Volvo and Saab in Sweden. Japan, France, South Korea, and Italy are also home to large R&D-performing firms in this industry.

The pharmaceuticals industry is less geographically concentrated than the automotive industry, but is still prominent in several countries. The pharmaceuticals industry accounts for over 20% of business R&D in the United Kingdom, Belgium, and Denmark. The United Kingdom is the largest performer of pharmaceutical R&D in Europe and is home to GlaxoSmithKline, the second largest pharmaceutical company in the world in terms of R&D expenses in 2002 and 2003 (table 4-6).

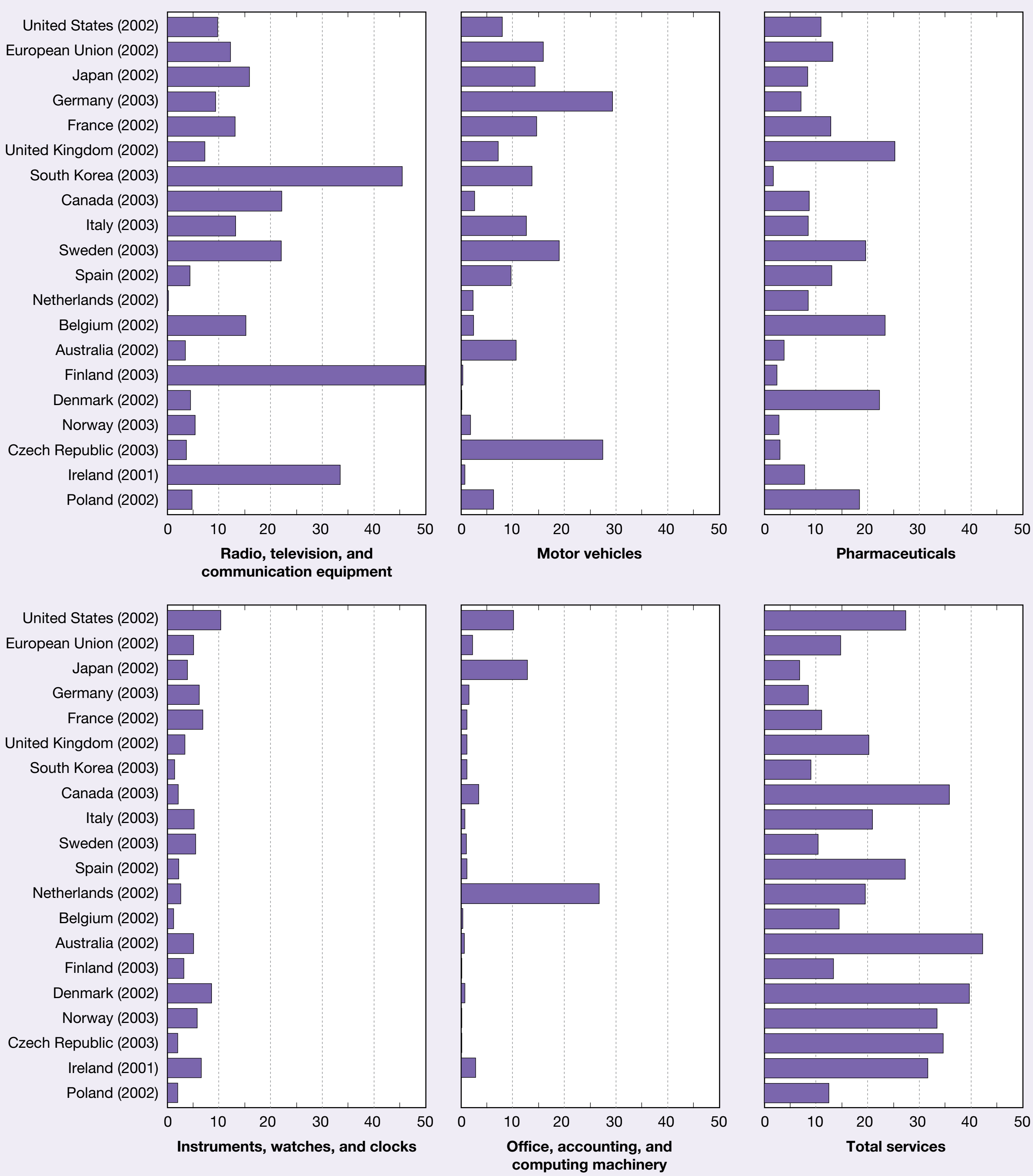
The office, accounting, and computing machinery industry represents only a small share of business R&D in most countries, with the United States and Japan accounting for over 90% of this industry's R&D among OECD countries (appendix table 4-58). Only the Netherlands reports a high concentration of business R&D in this industry (27% in 2002), most likely representing the activities of Royal Philips Electronics, the largest electronics company in Europe.

One of the more significant trends in both U.S. and international industrial R&D activity has been the growth of R&D in the service sector. In the European Union (EU), service-sector R&D has grown from representing 8% of business R&D in 1992 to 15% in 2002 (figure 4-40). In 2002, the EU's service-sector R&D nearly equaled that of its motor vehicles industry and more than doubled that of its aerospace industry. According to national statistics for recent years, the service sector accounted for less than 10% of total industrial R&D performance in only three of the countries shown in figure 4-37 (Germany, South Korea, and Japan). Among the countries listed in figure 4-37, the service sector accounted for as little as 7% of business R&D in Japan to as much as 42% in Australia, and it accounted for 27% of total business R&D in the United States.[68] Information and communications technologies (ICT) services account for a substantial share of the service R&D totals (see sidebar "R&D in the ICT Sector").

Sources of Industrial R&D Funding

Most of the funding for industrial R&D in each of the G-8 countries is provided by the business sector. In most OECD countries government financing accounts for a small and declining share of total industrial R&D performance (figure 4-41). In 1981, government provided 22% of the funds used by industry in conducting R&D within OECD countries,

Figure 4-37
Share of industrial R&D, by industry sector and selected country/European Union: Selected years, 2001–03



NOTES: Countries listed in descending order by amount of total industrial R&D. Data for years in parentheses.

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm (2004). See appendix table 4-58.

Science and Engineering Indicators 2006

R&D in the ICT Sector

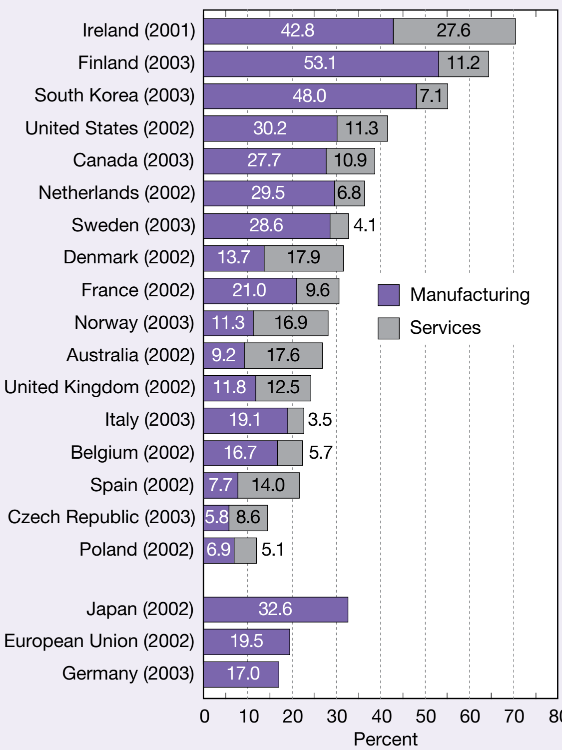
Information and communications technologies (ICTs) play an increasingly important role in the economies of Organisation for Economic Co-operation and Development (OECD) member countries. Both the production and use of these technologies contribute to output and productivity growth. Compared with other industries, ICT industries are among the most research and development intensive, with their products and services embodying increasingly complex technology. Because R&D data are often unavailable for detailed industries, for the purpose of this analysis ICT industries include the following ISIC (International Standard Industrial Classification) categories:

- Manufacturing industries: 30 (office, accounting, and computer machinery), 32 (radio, television, and communications equipment), and 33 (instruments, watches, and clocks)
- Services industries: 64 (post and communications) and 72 (computer and related activities) (OECD 2002a)

The ICT sector accounted for over one-quarter of total business R&D in 12 of the 20 OECD countries shown in figure 4-38, and more than half of total business R&D in Ireland, Finland, and South Korea. ICT industries accounted for 42% of the business R&D in the United States and at least 33% of Japanese business R&D. Of the other G-7 countries, Canada comes closest to matching the ICT R&D concentration of the United States and Japan.

Although the U.S. concentration of R&D in manufacturing ICT industries was much lower than in several other OECD member countries, the United States still accounted for 49% of all OECD-wide R&D expenditures in ICT manufacturing in 2002 (figure 4-39). Japan and South Korea, which have historically emphasized ICT manufacturing, together accounted for 29% of the total, with the larger OECD members making up the bulk of the remainder.

Figure 4-38
Industrial R&D, by information and communications technologies sector, by selected country/European Union: Selected years, 2001–03

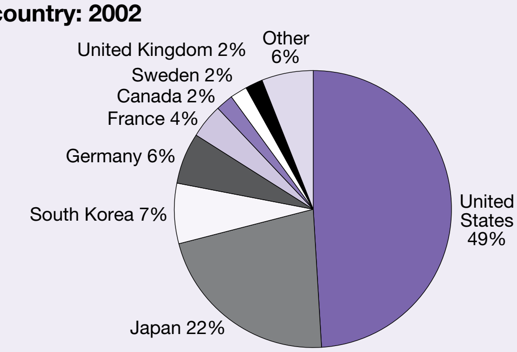


NOTE: Data are for years in parentheses. Information and communications technologies service-sector R&D data not available for European Union, Germany, and Japan.

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm (March 2005).

Science and Engineering Indicators 2006

Figure 4-39
OECD-wide information and communications technologies manufacturing R&D, by selected country: 2002



OECD = Organisation for Economic Co-operation and Development

NOTE: Figure based on only 19 OECD countries. Data for Germany are for 2001.

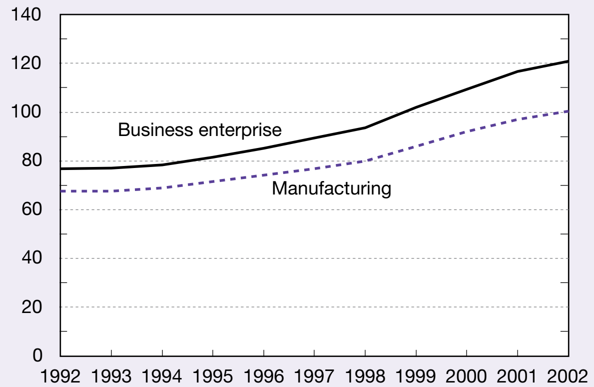
SOURCE: OECD, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm (March 2005).

Science and Engineering Indicators 2006

whereas, by 2002, government's funding share of industrial R&D had fallen to 7%. Among G-7 countries, government financing shares ranged from as little as 1% of industrial R&D performance in Japan in 2002 to 14% in Italy in 2003 (appendix table 4-44). In the United States in 2003, the federal government provided about 10% of the R&D funds used by industry, and the majority of that funding was obtained through DOD contracts.

Foreign sources of funding for business R&D increased in many countries between 1981 and 2003 (figure 4-42). The role of foreign funding varied from country to country, accounting for less than 1% of industrial R&D in Japan

Figure 4-40
European Union industrial R&D performance: 1992–2002

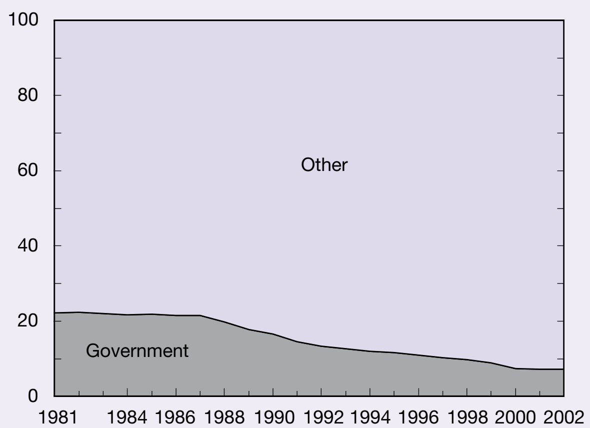


PPP = purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm (2004).

Science and Engineering Indicators 2006

Figure 4-41
OECD industry R&D, by source of funds: 1981–2002



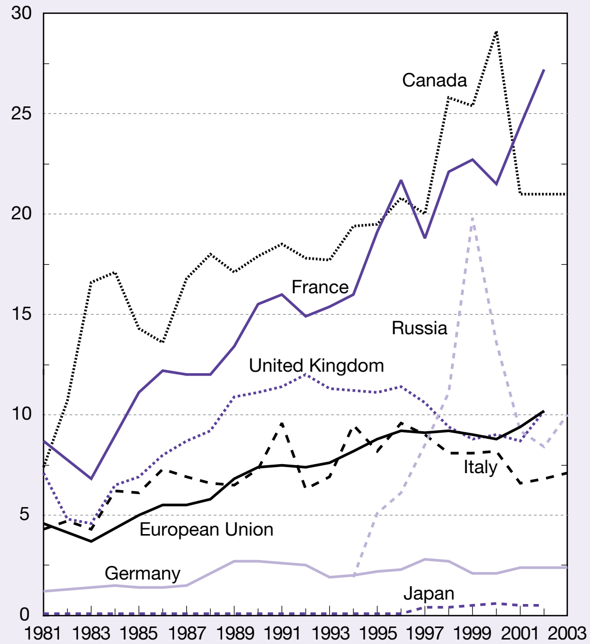
OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators* (2004). See appendix table 4-46.

Science and Engineering Indicators 2006

to as much as 29% in Canada in 2000. This foreign funding predominantly came from foreign corporations but also included funding from foreign governments and other foreign organizations. The growth of this funding primarily reflects the increasing globalization of industrial R&D activities. For European countries, however, the growth in foreign sources of R&D funds may also reflect the expansion of coordinated European Community efforts to foster cooperative shared-cost research through its European Framework Programmes.[69] Although the pattern of foreign funding has seldom been smooth

Figure 4-42
Industrial R&D financed, by foreign sources: 1981–2003



NOTE: Data not available for all countries for all years.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004). See appendix table 4-45.

Science and Engineering Indicators 2006

over time, it accounted for more than 20% of industry's domestic performance totals in Canada from 1996 to 2003 and in the United Kingdom from 1998 to 2002. Foreign funding as a share of Russian industrial R&D grew rapidly from 2% in 1994 to 20% in 1999, but it has since fallen to 10% in 2003. There are no data on foreign funding sources of U.S. R&D performance. However, the importance of international investment for U.S. R&D is highlighted by the fact that approximately 14% of funds spent on industrial R&D performance in 2002 were estimated to have come from majority-owned affiliates of foreign firms investing domestically (see figure 4-46 in "R&D Investments by Multinational Corporations").

Academic Sector

In many OECD countries, the academic sector is a distant second to industry in terms of national R&D performance. Among G-8 countries, universities accounted for as little as 6% of total R&D in Russia to as much as 35% in Canada; they accounted for 17% of U.S. total R&D (figure 4-43).[70] The academic sector plays a relatively small role in the national R&D of the largest Asian R&D-performing countries, accounting for 14% or less of R&D in Japan, China, South Korea, and Taiwan. Each of these countries also reports relatively low

Figure 4-43
Academic R&D share of total R&D, by selected country/economy or OECD: Selected years, 2000–03

OECD = Organisation for Economic Co-operation and Development

NOTE: Data are for years in parentheses.

SOURCE: OECD, *Main Science and Technology Indicators* (2004).

Science and Engineering Indicators 2006

Government Funding Mechanisms for Academic Research

Because U.S. universities generally do not maintain data on departmental research, U.S. totals are understated relative to the R&D effort reported for other countries. The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants provided by all levels of government to the academic sector. These funds can support departmental R&D programs that are not separately budgeted. The U.S. federal government does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. However, some state government funding probably does support departmental research at public universities in the United States.

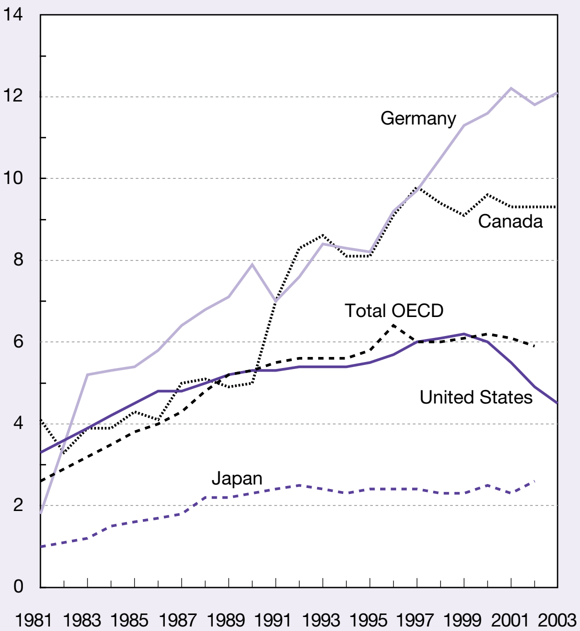
Whereas GUF block grants are reported separately for Japan, Canada, and European countries, the United States does not have an equivalent GUF category. In the United States, funds to the university sector are distributed to address the objectives of the federal agencies that provide the R&D funds. Nor is GUF equivalent to basic research. The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through large block grants that are used at the discretion of each individual higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds for which can be assigned to specific socioeconomic categories). In the United States, the federal government (although not necessarily state governments) is much more directly involved in choosing which academic research projects are supported than are national governments in Europe and elsewhere. In each of the European G-7 countries, GUF accounts for 50% or more of total government R&D to universities and for roughly 45% of the Canadian government academic R&D support. These data indicate not only relative international funding priorities but also funding mechanisms and philosophies regarding the best methods for financing academic research.

amounts of basic research as a share of total R&D (figure 4-32). The relative size of the academic sector's R&D in a country tends to correlate with the basic research share reported by that country because academic R&D is usually more focused on basic research than industry R&D.

Source of Funds

For most countries, the government is now, and historically has been, the largest source of academic research funding (see sidebar "Government Funding Mechanisms for Academic Research"). However, in each of the G-7 countries for which historical data exist, the government's share has declined since 1981, and industry's share has increased. This trend has been most evident in Germany, where the industry-funded share of academic R&D is twice that of all OECD members combined, and in Canada (figure 4-44).

Figure 4-44
Academic R&D financed by industry, by selected country/OECD: 1981–2003



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators* (2004). See appendix table 4-46.

Science and Engineering Indicators 2006

Industry's share of academic R&D funding is greatest in Russia (28% in 2003) and China (32% in 2000).

S&E Fields

Most countries supporting a substantial level of academic R&D (at least $1 billion PPPs in 1999) devote a larger proportion of their R&D to engineering and social sciences than does the United States (table 4-14). Conversely, the U.S. academic R&D effort emphasizes the medical sciences and natural sciences relatively more than do many other OECD countries.[71] The latter observation is consistent with the emphases in health and biomedical sciences for which the United States (and in particular NIH and U.S. pharmaceutical companies) is known.

Government R&D Priorities

Analyzing public expenditures for R&D by major socioeconomic objectives shows how government priorities differ considerably across countries and change over time.[72] Within the OECD, the defense share of governments' R&D financing declined from 43% in 1986 to 29% in 2001 (table 4-15). Much of this decline was driven by the United States, where the defense share of the government's R&D budget dropped from 69% in 1986 to 50% in 2001. The defense share of the U.S. government's R&D budget is projected to have grown to 57% in 2005 ($75 billion).

Notable shifts also occurred in the composition of OECD countries' governmental nondefense R&D support over the

Table 4-14
Share of academic R&D expenditures, by country and S&E field: Selected years, 2000–02
(Percent distribution)

Field	United States (2001)	Japan (2002)	Germany (2001)	Spain (2002)	Netherlands (2001)	Australia (2000)	Sweden (2001)	Switzerland (2002)
Academic R&D expenditure (2000 PPP $ billions)	32.0	14.3	8.5	2.6	2.2	2.1	2.0	1.4
Academic R&D	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NS&E	93.8	68.1	78.2	78.2	73.2	73.3	77.8	47.6
Natural sciences	40.4	11.7	29.2	37.7	17.8	25.9	18.4	19.9
Engineering	15.3	25.5	19.7	22.6	22.3	16.0	25.5	9.8
Medical sciences	31.1	26.7	25.1	12.3	27.7	24.1	28.6	17.9
Agricultural sciences	7.1	4.3	4.1	5.5	5.5	7.4	5.3	NA
Social sciences and humanities	NA	31.9	20.9	21.8	23.6	26.7	19.1	14.7
Social sciences	6.2	NA	8.6	14.7	NA	19.8	13.1	NA
Humanities	NA	NA	12.3	7.1	NA	6.9	6.0	NA
Academic NS&E								
NS&E	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Natural sciences	43.0	17.1	37.4	48.3	24.3	35.3	23.6	41.8
Engineering	16.3	37.4	25.2	28.9	30.4	21.8	32.8	20.5
Medical sciences	33.1	39.2	32.1	15.8	37.9	32.8	36.8	37.6
Agricultural sciences	7.5	6.3	5.3	7.0	7.5	10.1	6.8	NA

NA = detail not available but included in totals
NS&E = natural sciences and engineering; PPP = purchasing power parity

NOTES: Detail may not add to total because of rounding. Data for years in parentheses.

SOURCES: Organisation for Economic Co-operation and Development, Science and Technology Statistics database (2005).

Science and Engineering Indicators 2006

Table 4-15
Government R&D support for defense and nondefense purposes, all OECD countries: 1981–2001
(Percent)

Year	Defense	Nondefense	Nondefense R&D budget shares: Health and environment	Economic development programs	Civil space	Other purposes
1981	34.6	65.4	19.2	37.6	9.6	33.6
1982	36.9	63.1	18.9	37.8	8.3	35.0
1983	38.7	61.3	18.8	36.9	7.5	36.8
1984	40.8	59.2	19.6	36.1	7.8	36.6
1985	42.4	57.6	20.0	35.8	8.4	35.8
1986	43.4	56.6	20.0	34.7	8.6	36.8
1987	43.2	56.8	20.8	32.5	9.6	37.1
1988	42.6	57.5	21.1	30.8	10.0	38.1
1989	41.2	58.8	21.4	29.9	10.8	37.9
1990	39.3	60.8	21.8	28.8	11.7	37.8
1991	36.3	63.7	21.7	28.1	11.8	38.4
1992	35.3	64.7	22.0	27.0	11.9	39.1
1993	35.2	64.8	22.0	26.1	12.1	39.8
1994	32.9	67.1	22.2	25.1	12.3	40.3
1995	31.2	68.8	22.5	24.4	12.1	41.0
1996	30.9	69.1	22.6	24.4	11.9	41.1
1997	30.8	69.2	22.9	24.6	11.4	41.1
1998	30.0	70.0	23.6	22.8	11.4	42.3
1999	29.4	70.6	24.5	23.3	10.7	41.6
2000	28.3	71.7	24.5	21.8	10.0	43.8
2001	28.6	71.4	26.2	22.1	10.0	41.6

OECD = Organisation for Economic Co-operation and Development

NOTE: Nondefense R&D classified as other purposes consists largely of general university funds and nonoriented research programs.

SOURCE: OECD, *Main Science and Technology Indicators* (2004).

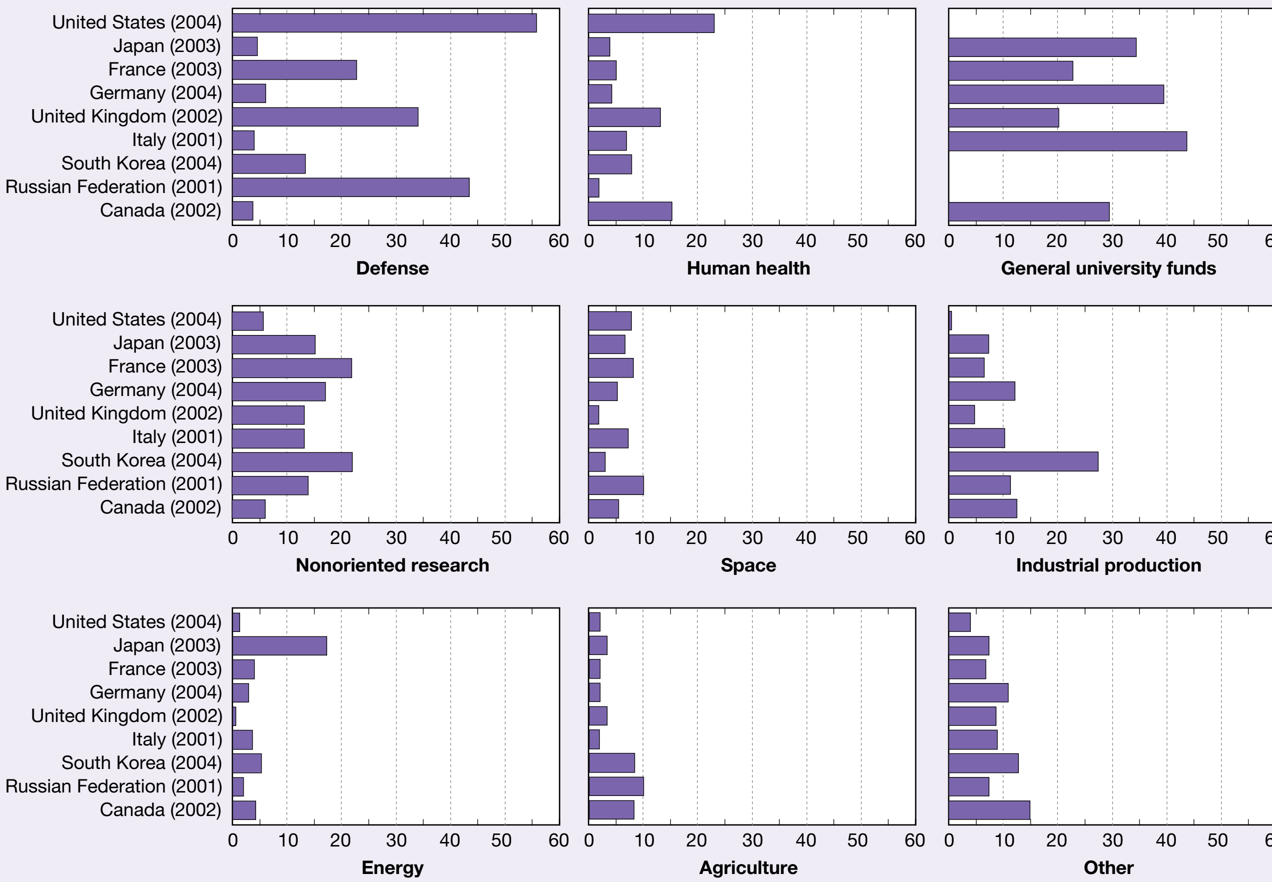
Science and Engineering Indicators 2006

past two decades. In terms of broad socioeconomic objectives, government R&D shares increased most for health and the environment.[73] Growth in health-related R&D financing was particularly strong in the United States, whereas many of the other OECD countries reported relatively higher growth in environmental research programs. In 2001 the U.S. government devoted 24% of its R&D budget to health-related R&D, making such activities second in magnitude only to defense. Conversely, the relative share of government R&D support for economic development programs declined considerably in the OECD, from 38% in 1981 to 22% in 2001. Economic development programs include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy, all activities for which privately financed R&D is more likely to be provided without public support.

Differing R&D activities are emphasized in each country's governmental R&D support statistics (figure 4-45). As noted above, defense accounts for a relatively smaller government R&D share in most countries than in the United States. In recent years, the defense share was relatively high in Russia, the United Kingdom, and France at 44%, 34%, and 23%, respectively, but was 6% or less in Germany, Italy, Canada, and Japan. In 2004, South Korea expended 13% of its government R&D budget on defense-related activities.

Japan committed 17% of its governmental R&D support to energy-related activities, reflecting the country's historical concern over its high dependence on foreign sources of energy. Canada, Russia, and South Korea all allocate two to three times as much of their R&D budgets to agriculture than the other countries in figure 4-45. Space R&D is emphasized most in France and Russia (8% and 10%, respectively), whereas industrial production R&D accounted for 10% or more of governmental R&D funding in Canada, Germany, Italy, Russia, and South Korea. Industrial production and technology is the leading socioeconomic objective for R&D in South Korea, accounting for 27% of all government R&D. This funding is primarily oriented toward the development of science-intensive industries and is aimed at increasing economic efficiency and technological development.[74] Industrial technology programs accounted for less than 1% of the U.S. total. This figure, which includes mostly R&D funding by NIST, is understated relative to most other countries as a result of data compilation differences. In part, the low U.S. industrial development share reflects the expectation that firms will finance industrial R&D activities with their own funds; in part, government R&D that may be indirectly useful to industry is often funded with other purposes in mind such as defense and space (and is therefore classified under other socioeconomic objectives).

Figure 4-45
Government R&D support, by socioeconomic objectives for G-8 countries and South Korea: Selected years, 2001–04
Percent



NOTES: Countries listed in descending order by amount of total government R&D. Data are for years in parentheses. R&D classified according to its primary government objective, although may support several complementary goals, e.g., defense R&D with commercial spinoffs classified as supporting defense, not industrial development.

SOURCE: Organisation for Economic Co-operation and Development, special tabulations (2005). See appendix table 4-47.

Science and Engineering Indicators 2006

Compared with other countries, France and South Korea invested relatively heavily in nonoriented research at 22% of government R&D appropriations. The U.S. government invested 6% of its R&D budget in nonoriented research, largely through the activities of NSF and DOE.

R&D Investments by Multinational Corporations

Multinational corporations (MNCs) have been expanding R&D outside their home countries in recent decades (see sidebar "Foreign Direct Investment in R&D"). R&D investments by MNCs, within their affiliates or with external partners in joint ventures and alliances, support the development of new products, services, and technological capabilities. These investments also serve as channels of knowledge spillovers and technology transfer that can contribute to economic growth and enhance competitiveness. International R&D links are particularly strong between U.S. and European companies, especially in pharmaceutical, computer, and transportation equipment manufacturing. More recently, certain developing or newly industrialized economies are emerging as hosts of U.S.-owned R&D, including China, Israel, and Singapore.

U.S. Affiliates of Foreign Companies

U.S. affiliates of foreign companies have a substantial presence in the U.S. economy. Their value added as percent of total U.S. private industry value added grew from 4.9% in 1997 to 5.7% in 2002 (Zeile 2004). Within U.S. affiliates, the largest industries in terms of value added were wholesale trade (16.8%), which includes large affiliates with substantial secondary operations in manufacturing, chemicals (9.6%), transportation equipment (7.6%), and computer and electronic products (4.9%) in 2002 (Zeile 2004:198). Economic

Foreign Direct Investment in R&D

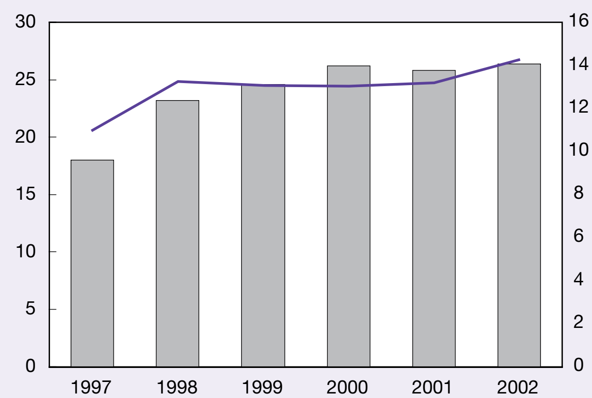
Direct investment refers to the ownership of productive assets outside the home country by multinational corporations (MNCs). More specifically, the U.S. Bureau of Economic Analysis (BEA) defines direct investment as ownership or control of 10% or more of the voting securities of a business in another country. A company located in one country but owned or controlled by a parent company in another country is known as an affiliate. Affiliate data used in this section are for majority-owned affiliates, i.e., those in which the ownership stake of parent companies is more than 50%. Statistics on R&D by affiliates of foreign companies in the United States and by foreign affiliates of U.S. MNCs and their parent companies are part of operations data obtained from BEA's Survey of Foreign Direct Investment in the United States (FDIUS) and BEA's Survey of U.S. Direct Investment Abroad (USDIA), respectively. Operations data exclude depository institutions and are on a fiscal-year basis.

Global R&D supports a range of objectives, from production to technology adaptation to development of new products or services (Kumar 2001; Niosi 1999). The location decision for global R&D sites is driven by (1) market-based and science-based factors, ranging from cost considerations and the pull of large markets to the search for location-specific expertise (von Zedtwitz and Gassmann 2002); (2) the balance between home- and overseas-based advantages in advancing corporate technology goals (Bas and Sierra 2002); and (3) the focus of R&D in terms of research or development. Barriers or challenges include intellectual property protection and coordination and management issues (EIU 2004).

activities by U.S. affiliates of foreign companies, including production, employment, and R&D among others, reflect the combined effect of new investment flows, either as new facilities or through mergers and acquisitions, as well as changes in their existing U.S. operations.[75] According to BEA, new investments flows in the United States by foreign direct investors (measured as investment outlays for businesses established or acquired) increased substantially between 1998 and 2000, before declining consecutively in 2001 and 2002, along with sluggish U.S. economic activity and slower worldwide mergers and acquisitions (Anderson 2004).[76]

R&D expenditures by majority-owned U.S. affiliates of foreign companies (henceforth, U.S. affiliates) grew substantially in the late 1990s, concurrently with large investments inflows, followed by smaller but still significant increases in the early 2000s. In 2002, R&D performed by majority-owned U.S. affiliates reached $27.5 billion, an increase of 2.3% from 2001 (after adjusting for inflation) (appendix table 4-48). By comparison, total U.S. industrial R&D performance (which

Figure 4-46
R&D performed by U.S. affiliates of foreign companies and share of total U.S. industry R&D: 1997–2002



NOTE: Affiliates' data are for majority-owned companies and are preliminary estimates for 2002.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series); and U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series).

Science and Engineering Indicators 2006

includes all companies located in the United States regardless of ownership status) declined by 5.6%, after adjusting for inflation. U.S. affiliates' R&D expenditures accounted for 14.2% of total U.S. industrial R&D performance in 2002 compared with just above 13% from 1998 to 2001 (figure 4-46). Of the $27.5 billion in R&D performed by U.S. affiliates in 2002, $24.9 billion was performed for affiliates themselves; $2.1 billion for others (including their foreign parents and affiliates of the same company located outside the United States); and $555 million was performed for the U.S. federal government (appendix table 4-50).

Manufacturing accounted for about three-fourths of U.S. affiliates' R&D, including 29% in chemicals, 18% in computer and electronic products, and 12% in transportation equipment (table 4-16; appendix table 4-49). U.S. affiliates owned by European parent companies accounted for three-fourths ($20.7 billion of $27.5 billion) of U.S. affiliates R&D in 2002 (figure 4-47), reflecting their sizable investment shares in the U.S. economy and their focus in R&D-intensive industries. German-owned affiliates classified in transportation equipment performed $2.4 billion of R&D in 2002, which represented 75% of all U.S. affiliates' R&D in this industry and 42% of total R&D performed by German-owned U.S. affiliates (table 4-16). On the other hand, Swiss- and British-owned affiliates were notable within chemicals, which includes pharmaceuticals and medicines, performing a combined 57% of chemicals R&D by U.S. affiliates.

Majority-owned U.S. affiliates of foreign companies employed 128,100 R&D personnel in 2002, up 0.6% from 2001.[77] Over the same period, affiliates' overall employment

Table 4-16
R&D performed by majority-owned affiliates of foreign companies in United States, by selected NAICS industry of affiliate and country/region: 2002
(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing	
Country/region	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Trans-portation equipment	Information	Professional, technical, scientific services
All countries	27,508	20,228	7,997	1872	4,885	396	3,183	723	964
Canada	1,583	1154	33	3	D	D	D	D	41
Europe	20,735	16,151	7,514	1605	2653	333	2,950	482	322
France	2,620	2,026	977	29	537	124	96	209	29
Germany	5,659	5,136	1,395	1110	79	24	2394	D	0
Netherlands	1,773	1,684	451	164	872	2	33	0	33
Switzerland	3,295	2,770	2,506	35	20	D	0	D	D
United Kingdom	5,459	3,797	2,055	63	1112	16	289	113	D
Asia/Pacific	3,263	1,283	386	D	465	19	125	D	600
Japan	D	1,218	383	63	432	19	125	D	599
Latin America/other Western Hemisphere	1,035	848	0	184	D	D	0	—	0
Middle East	D	D	D	0	57	0	0	11	0
Africa	35	D	D	0	0	0	0	D	0

— = ≤ $500,000; D = data withheld to avoid disclosing operations of individual companies
NAICS = North American Industry Classification System

NOTES: Preliminary 2002 estimates for majority-owned (>50%) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Expenditures included for R&D conducted by foreign affiliates, whether for themselves or others under contract. Expenditures excluded for R&D conducted by others for affiliates under contract.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/bea/di/di1fdiop.htm. See appendix tables 4-48 and 4-49.

Science and Engineering Indicators 2006

declined by 3.1%. Manufacturing affiliates represented 41% of affiliates' overall employment but over three-fourths of R&D employment in 2002, consistent with their large share in R&D expenditures. For trends in R&D employment in all U.S. affiliates of foreign companies in the 1990s, see NSF/SRS (2004b).

U.S. MNCs and Their Overseas R&D

In 2002, majority-owned foreign affiliates of U.S. MNCs (henceforth, foreign affiliates), performed $21.2 billion in R&D abroad, up 5.6% from 2001, after adjusting for inflation.[78] Except for 2001, R&D expenditures by foreign affiliates increased annually from 1994 to 2002 (table 4-17). After modest increases through 1998, affiliates' R&D expenditures accelerated in 1999, in part due to international mergers and acquisitions.

U.S. MNCs comprise U.S. parent companies plus their foreign affiliates.[79] From 1994 to 2002, more than 85% of the combined global R&D expenditures by U.S. MNCs were performed at home (table 4-17). However, R&D expenditures by foreign affiliates grew at a faster rate (average annual rate of 7.5%) over this period than did R&D expenditures by their U.S. parent companies at home (5.3%). Consequently, the share of foreign affiliates' R&D expenditures within the global MNC increased from 11.5% in 1994 to 13.3% in 2002.[80]

Furthermore, the geographic distribution of these expenditures has evolved to reflect the extent of globalization (figure 4-48). In 1994, major developed economies or regions (Canada, Europe, and Japan) accounted for 90% of overseas R&D expenditures by U.S. MNCs. By 2001, this combined share was down to 80%.[81] The change reflects modest expenditures growth in European locations, compared with larger increases in Asia (outside Japan) and in Israel. Nevertheless, affiliates located in Europe accounted for at least 60% of these R&D expenditures in 2001 and in 2002, led by the United Kingdom and Germany (figure 4-47; appendix table 4-51).

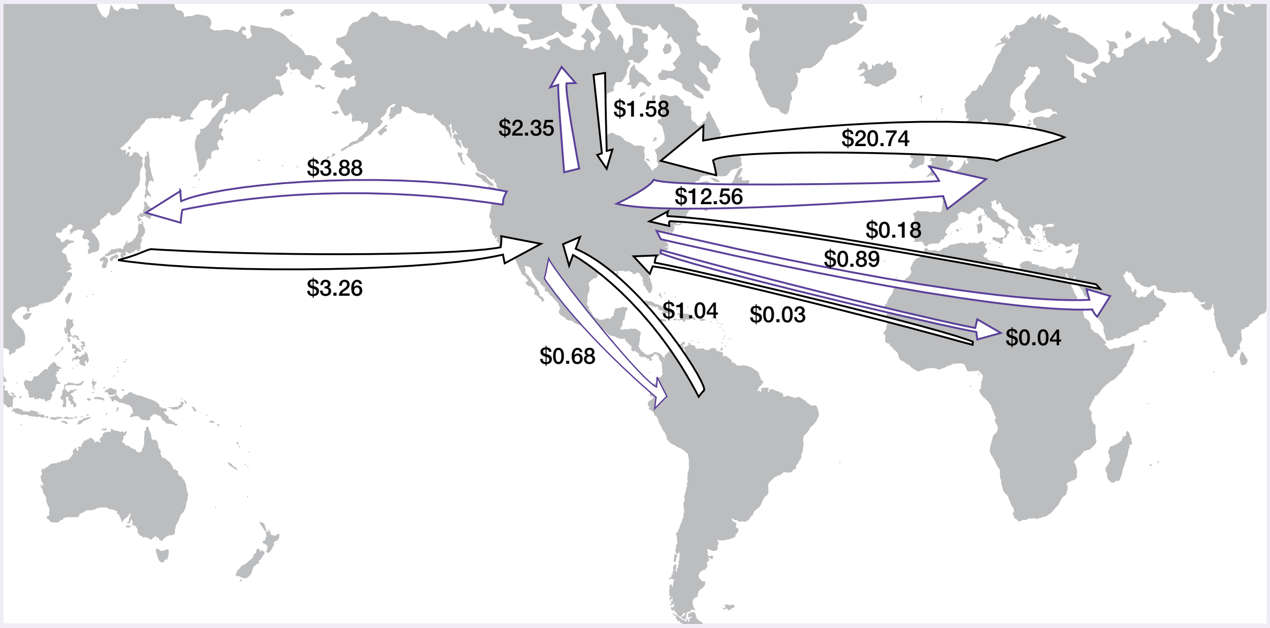
R&D expenditures by foreign affiliates in mainland China and Singapore accelerated in 1999, exceeding half a billion dollars annually since 2000. By 2002, they became, respectively, the second and third largest Asia-Pacific hosts of U.S. R&D after Japan and ahead of Australia, according to available data (appendix table 4-51).[82]

Brazil and Mexico have represented around 80% or more of R&D expenditures by U.S. MNCs in Latin America since 1994. Finally, Israel and South Africa represent virtually all of the R&D expenditures by U.S. MNCs in their respective regions over the same period (appendix table 4-51).

Three manufacturing industries accounted for most foreign affiliate R&D in 2002: transportation equipment (28%), computer and electronic products (25%), and chemicals (including pharmaceuticals) (23%) (table 4-18; appendix table

Figure 4-47
R&D performed by U.S. affiliates of foreign companies in U.S. by investing region and by foreign affiliates of U.S. multinational corporations by host region: 2002 or latest year

(Billions of current dollars)



NOTES: Preliminary estimates for 2002. Regional totals for foreign affiliates of U.S. multinational corporations located in Europe and in Latin America and other Western Hemisphere are sums computed by National Science Foundation based on available country data for those regions. Data for foreign affiliates located in Africa and for U.S. affiliates of foreign companies from Middle East are for 2001.

SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States; and Survey of U.S. Direct Investment Abroad. See appendix tables 4-48 and 4-51.

Science and Engineering Indicators 2006

Table 4-17
R&D performed by parent companies of U.S. multinational corporations and their majority-owned foreign affiliates: 1994–2002

	R&D performed (current U.S. $ millions)			Shares of MNC (%)	
Year	U.S. parents	MOFAs	Total MNCs	U.S. parents	MOFAs
1994	91,574	11,877	103,451	88.5	11.5
1995	97,667	12,582	110,249	88.6	11.4
1996	100,551	14,039	114,590	87.7	12.3
1997	106,800	14,593	121,393	88.0	12.0
1998	113,777	14,664	128,441	88.6	11.4
1999	126,291	18,144	144,435	87.4	12.6
2000	135,467	20,457	155,924	86.9	13.1
2001	143,017	19,702	162,719	87.9	12.1
2002	137,968	21,151	159,119	86.7	13.3

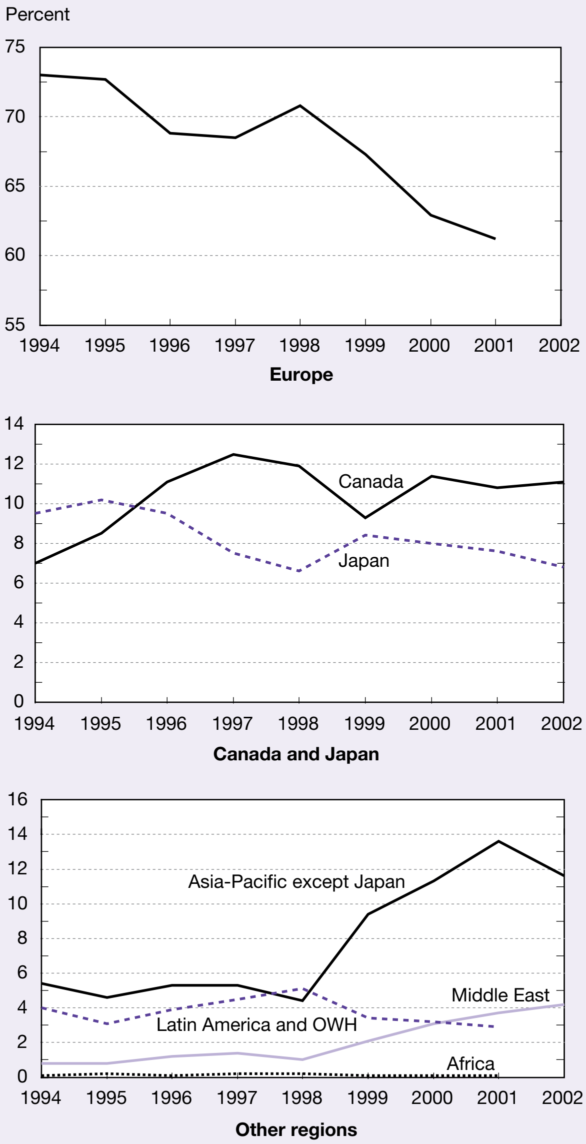
MNC = multinational corporation; MOFA = majority-owned foreign affiliate

NOTES: Detail may not add to total because of rounding. MOFAs are affiliates in which combined ownership of all U.S. parents is >50%. See appendix tables 4-51 and 4-53.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm.

Science and Engineering Indicators 2006

Figure 4-48
Regional shares of R&D performed abroad by foreign affiliates of U.S. MNCs: 1994–2002



MNC = multinational corporation; OWH = other Western Hemisphere

NOTES: Data for majority-owned affiliates. Preliminary estimates for 2002. Preliminary estimates for regional totals for Africa, Europe, and Latin America and other Western Hemisphere are not available.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series). See appendix table 4-51.

Science and Engineering Indicators 2006

4-52). The largest nonmanufacturing R&D-performing industry was professional, technical, and scientific services (which include R&D and computer services), with 6% of the total. The industry distribution in European locations is similar to the average across all host countries, whereas half of affiliates' R&D expenditures in Canada and Japan are performed by affiliates classified in transportation equipment and chemicals, respectively. More than half of foreign affiliates' R&D located in the Asia-Pacific region and in Israel was performed by affiliates classified in computer and electronic products.[83]

Comparison of R&D Expenditures by U.S. Affiliates of Foreign Companies and Foreign Affiliates of U.S. MNCs

From 1997 to 2002, R&D expenditures by U.S. affiliates of foreign companies grew faster than did R&D expenditures of foreign affiliates of U.S. MNCs (9.8% average annual growth rate and 7.7%, respectively). The difference between these two indicators of international R&D activity in the United States and activity by U.S. MNCs overseas jumped by $5 billion to $7.7 billion at the start of the movement by foreign MNCs in 1998 toward large U.S. investments. Since then, this difference has remained between $5.7 and $6.7 billion (figure 4-49), or close to 3% of total U.S. industrial R&D. At the regional level, R&D expenditures by European-owned companies in the United States accounted for most of this difference. Within chemical manufacturing (which includes pharmaceuticals and medicines), affiliates of foreign companies in the United States performed $3.2 billion more in R&D expenditures compared with foreign affiliates of U.S. MNCs. Conversely, foreign affiliates of U.S. MNCs classified in transportation equipment performed $2.7 billion more in R&D expenditures compared with transportation equipment affiliates of foreign companies in the United States. For information on an ongoing project investigating the development of integrated statistical information on these U.S. and cross-border R&D investments, see sidebar "Indicators Development on R&D by MNCs."

Table 4-18
R&D performed overseas by majority-owned foreign affiliates of U.S. parent companies, by selected NAICS industry of affiliate and country/region: 2002
(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing	
Country/region	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Transportation equipment	Information	Professional, technical, scientific services
All countries	21,151	18,696	4,819	642	5,278	418	5,898	507	1,237
Canada	2,345	2,272	438	25	510	13	1,170	29	16
Europe	D[a]	11,718	3,305	488	2,175	271	4,321	260	D
France	1,480	1,386	693	38	241	20	211	D	32
Germany	3,603	3,376	259	149	683	138	1,855	3	32
Sweden	1,316	1,296	86	32	12	D	D	0	D
Switzerland	405	162	48	16	48	D	D	2	D
United Kingdom	3,735	3,238	1,168	140	636	14	954	38	400
Asia/Pacific	3,881	3,530	890	85	2,024	D	D	D	D
Australia	329	286	68	5	21	—	130	0	28
China	646	609	33	2	D	D	1	D	D
Japan	1,433	1,283	732	50	375	D	25	D	D
South Korea	167	149	10	11	90	2	27	8	6
Singapore	589	578	11	—	550	5	D	1	5
Taiwan	70	D	16	9	25	0	D	D	1
Latin America/other Western Hemisphere	D[a]	633	172	33	71	D	189	D	D
Brazil	306	298	68	28	30	D	D	D	3
Mexico	284	185	49	5	2	1	D	0	D
Middle East	889	520	2	9	498	0	0	56	D
Israel	889	520	2	9	498	0	0	56	D
Africa	D[a]	25	12	2	0	0	D	—	—

— = ≤ $500,000; D = data withheld to avoid disclosing operations of individual companies
NAICS = North American Industry Classification System

[a]Corresponding values for 2001 were $12,060 million (Europe), $562 million (Latin America/other Western Hemisphere), and $29 million (Africa).

NOTES: Preliminary 2002 estimates for majority-owned (>50%) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Expenditures included for R&D conducted by foreign affiliates, whether for themselves or others under contract. Expenditures excluded for R&D conducted by others for affiliates under contract.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm. See appendix table 4-51.

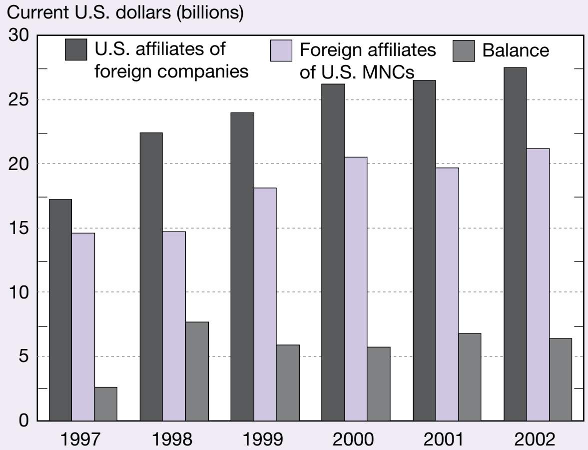
Science and Engineering Indicators 2006

Indicators Development on R&D by MNCs

In recognition of the increasing international dimensions of U.S. R&D, the National Science Foundation (NSF) Division of Science Resources Statistics proposed and funded a 3-year exploratory project aimed at the integration of statistical information from the Bureau of Economic Analysis' (BEA's) international investment surveys with the NSF Survey of Industrial Research and Development, which is conducted by the U.S. Census Bureau.

The study demonstrated the feasibility of linking companies covered in the BEA MNC surveys with those covered by the NSF Survey of Industrial R&D. The study also generated statistical benefits by expanding the sampling frame of participant surveys. Further, the project confirmed that, for the most part, the data reported to the U.S. Census Bureau and BEA are comparable, and it also documented definitional and methodological differences that warrant further statistical and analytical investigation. If future links are undertaken, integrated data may support a richer analysis of R&D patterns, including MNCs' R&D spending by character of work and by state location.

Figure 4-49
R&D by U.S. affiliates of foreign companies and foreign affiliates of U.S. MNCs: 1997–2002



MNC = multinational corporation

NOTES: Data for majority-owned affiliates. Balance is R&D by U.S. affiliates of foreign companies minus R&D of foreign affiliates of U.S. MNCs.

SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series); and Survey of U.S. Direct Investment Abroad (annual series). See appendix tables 4-48 and 4-51.

Science and Engineering Indicators 2006

Conclusion

The rapid growth in R&D investment in the United States from 1994 to 2000 fell victim to stock market decline and slower economic pace in the first years of the 21st century. As a result, U.S. R&D experienced its first decline in almost 50 years in 2002. The decline lasted only 1 year as R&D growth accelerated in 2003 and 2004.

Reaction to acts of terrorism and military mobilizations have reversed a declining trend in the U.S. government's share of defense-related R&D. Other countries throughout the world have maintained their focus on nondefense R&D and have attempted to take proactive steps toward intensifying and focusing their national R&D activity. These steps range from increasing general government spending to fostering high-technology industrial clusters.

The locus of R&D activities is also shifting as a reflection of broad technological changes and new scientific research opportunities. Industrial R&D is increasingly undertaken in service (versus manufacturing) industries, and much of the industrial R&D growth has occurred in biotechnology and information technology. Moreover, federal research funds have shifted markedly toward the life sciences over the past decade.

Cross-country R&D investments through MNCs continue to be strong between U.S. and European companies. At the same time, certain developing or newly industrialized economies are emerging as significant hosts of U.S.-owned R&D, including China, Israel, and Singapore. U.S. MNCs continued expanding R&D activity overseas, but foreign MNCs in the United States have increased their R&D expenditures even more.

The significance of these trends for the R&D enterprise, national competitiveness, and public policy is difficult to assess. For example, MNC trends reflect the combined effect of different investment strategies including mergers and acquisitions, the establishment of new facilities, and changes in existing laboratories, service centers, and manufacturing plants. Furthermore, no information exists below aggregate R&D expenditures for MNC data.

In part to address these challenges, NSF, in partnership with the U.S. Census Bureau, which conducts the NSF Survey of Industrial Research and Development, and BEA, which conducts the international investment surveys, completed a study aimed at developing a methodology to integrate information from the different surveys. The study demonstrated the feasibility of linking this information. If future links are undertaken, integrated data may yield new indicators such as MNCs' R&D spending by character of work and by state location. A separate statistical project between NSF and BEA, which also publishes GDP and other national economic accounts data, is directed at integrating R&D expenditure data into national accounts methodology by means of a satellite account for R&D. A satellite account framework recognizes the investment characteristics of R&D, facilitating the measurement and assessment of its role in long-term productivity and economic growth. Additional investigations on the role of partnerships, joint ventures, and transactions in R&D services are warranted in an increasingly diffused web of R&D and innovation players across the globe.

Notes

1. Growth in the R&D/GDP ratio does not necessarily imply increased R&D expenditures. For example, the rise in R&D/GDP from 1978 to 1985 was due as much to a slowdown in GDP growth as it was to increased spending on R&D activities.

2. Expenditures R&D performance are used as a proxy for actual R&D performance. In this chapter, the phrases *R&D performance* and *expenditures for R&D performance* are interchangeable.

3. See appendix table 4-1 for the GDP implicit price deflators used to adjust expenditures to account for inflation.

4. For most manufacturing industries, the U.S. Small Business Administration defines *small firm* as one with 500 or fewer employees. The share of company-financed R&D performed by these firms grew from 10% in 1990 to a peak of 20% in 1999.

5. FFRDCs are R&D-performing organizations that are exclusively or substantially financed by the federal government either to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered either by an industrial firm, a university, or a

nonprofit institution. In some of the statistics provided in this chapter, FFRDCs are included as part of the sector that administers them. In particular, statistics on the industrial sector often include industry-administered FFRDCs because some of the statistics from the NSF Survey of Industrial Research and Development before 2001 cannot be separated from the FFRDC component.

6. Recent methodological improvements in the estimation of total academic R&D have resulted in a break in the time series. Data for years before 1998 are slightly overstated compared with the data for later years. See NSF/SRS (forthcoming) for details on the changes to methodology.

7. These findings are based on performer-reported R&D levels. In recent years, increasing differences have been detected in data on federally financed R&D as reported by federal funding agencies and by performers of the work (most notably, industrial firms and universities). This divergence in R&D totals is discussed later in this chapter. (See sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures.")

8. The latest data available on the state distribution of R&D performance are for 2003. In 2003, $277.5 billion of the $291.9 billion total U.S. R&D could be attributed to expenditures within individual states, with the remainder falling under an undistributed "other/unknown" category. Approximately two-thirds of the R&D that could not be associated with a particular state was R&D performed by the nonprofit sector.

9. Rankings do not take into account the margin of error of estimates from sample surveys. NSF, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2005. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

10. GSP is often considered the state counterpart of the nation's GDP. GSP is estimated by summing the *value added* of each industry in a state. Value added for an industry is equivalent to its gross output (sales or receipts and other operating income, commodity taxes, and inventory change) minus its intermediate inputs (consumption of goods and services purchased from other U.S. industries or imported). U.S. Bureau of Economic Analysis, *Gross State Product* (Washington, DC, 2003). (See http://www.bea.gov/bea/regional/docs/Regional_GSP.pdf)

11. Federal intramural R&D includes costs associated with the administration of intramural and extramural programs by federal personnel as well as actual intramural R&D performance. This explains the large amount of federal intramural R&D reported within the District of Columbia.

12. http://www.thirdfrontier.com/overview.asp

13. For most manufacturing industries, the U.S. Small Business Association has established a size standard of 500 employees. The NSF Survey of Research and Development in Industry does not sample companies with fewer than five employees because of concerns over respondent burden.

14. A similar measure of R&D intensity is the ratio of R&D to *value added* (sales minus the cost of materials). Value added is often used in studies of productivity because it allows analysts to focus on the economic output attributable to the specific industrial sector in question by subtracting materials produced in other sectors. For a discussion of the connection between R&D intensity and technological progress, see, for example, R. Nelson, Modeling the connections in the cross section between technical progress and R&D intensity, *RAND Journal of Economics* 19(3) (Autumn 1988):478–85.

15. Industry-level estimates are complicated by the fact that each company's R&D is reported in only one industry. (See sidebar, "Industry Classification Complicates Analysis.")

16. Details on how companies are assigned industry codes in the NSF Survey of Industrial Research and Development can be found on the NSF website (http://www.nsf.gov/statistics/nsf02312/sectb.htm#frame). NSF, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

17. Lower bound analyst estimates will be given in cases where disclosure of company-reported data or classification issues prevents the publication of total estimates from survey data.

18. Methodological differences between the PhRMA Annual Membership Survey and the NSF Survey of Industrial Research and Development make it difficult to directly compare estimates from the two surveys. For example, the PhRMA survey definition of R&D includes Phase IV clinical trials whereas the NSF survey definition does not.

19. Although disclosure of federal R&D funding prohibited the precise tabulation of total R&D performance for this industry, total R&D was at least $27.4 billion in 2003.

20. The introduction of a more refined industry classification scheme in 1999 allowed more detailed reporting in nonmanufacturing industries. For the cited 2003 statistic, the R&D of companies in software, other information, and computer systems design and related services industries were combined. These three industries provided the closest approximation to the broader category cited for earlier years without exceeding the coverage of the broader category.

21. NAICS-based R&D estimates are only available back to 1997. Estimates for 1997 and 1998 were bridged from a different industry classification scheme. Total R&D for this sector has grown from $9.2 billion in 1997 to $17.6 billion in 2003.

22. Company annual reports accessed 25 March 2005 at http://www.sec.gov/edgar.shtml. Because R&D expenses reported on financial documents differ from the data reported on the NSF Survey of Industrial Research and Development, direct comparisons of these sources are not possible. See C. Shepherd and S. Payson, *U.S. R&D Corporate R&D* (Washington, DC: National Science Foundation, 2001) for an explanation of the differences between the two.

23. FASB, SFAS 123 (Dec. 2004) (http://www.fasb.org/pdf/fas123r.pdf).

24. Microsoft Corporation, 2004 Microsoft Annual Report, Note 13.

25. DOD reports development obligations in two categories: *advanced technology development,* which is similar in nature to development funded by most other agencies, and *major systems development,* which includes demonstration and validation, engineering and manufacturing development, management and support, and operational systems development for major weapon systems.

26. In 2005, 73% of all federal research funding was allocated through competitive merit review processes. Fifteen percent was merit reviewed, but competition was limited to a select pool of applicants such as federal laboratories or FFRDCs. Seven percent was awarded to performers for inherently unique research without competitive selection. The remaining 4% was allocated to specific performers at the request of Congress (U.S. OMB 2005).

27. Since 2003 one new FFRDC has been established: the Homeland Security Institute in Arlington, Virginia.

28. Most of the $2.5 trillion federal budget is reserved for mandatory items such as Social Security, Medicare, pension payments, and payments on the national debt. See appendix table 4-28 for historical data on federal outlays and R&D.

29. For tax purposes, R&D expenses are restricted to the somewhat narrower concept of research and experimental (R&E) expenditures. Such expenditures are limited to experimental or laboratory costs aimed at the development or improvement of a product in connection with the taxpayer's business. Furthermore, the R&E tax-credit applies to a subset of R&E expenses based on additional statutory requirements. See Section 41 of the U.S. Internal Revenue Code (U.S. Code of Federal Regulations, Title 26). For further details on the R&E tax credit and a separate tax R&E incentive, the R&E tax expensing allowance, see NSF/SRS (2005) and references therein.

30. Both indirect incentives and direct federal funding are federal expenses. Tax incentives generate tax expenditures: government revenue losses due to tax exclusions or deductions. For estimates of tax expenditures arising from the R&E tax credit, see OMB (2005).

31. Public Law No. 108-311, Title III, Section 301. The R&E tax credit was not in place for activities conducted from July 1995 to June 1996.

32. The effective rate is considered to be lower than this statutory rate due in part to limitations involving other business credits and allowances.

33. Exclude data from IRS tax forms 1120S (S corporations), 1120-REIT (Real Estate Investment Trusts), and 1120-RIC (Regulated Investment Companies). The latest available data for R&E claims at the time of this writing were for 2001.

34. In this section, the term contract R&D is used generically to denote a transaction with external parties involving R&D payments or income, regardless of the actual legal form of the transaction. Data in this section cover R&D contract expenses paid by U.S. R&D performers (using company and other nonfederal R&D funds) to other domestic companies. Data on contract R&D expenses by domestic companies that do not perform internal R&D or that contract out R&D to companies located overseas are not available.

35. Three-fourths of contracted-out R&D paid by pharmaceutical companies was performed by other private companies. The balance was performed by universities and colleges, other nonprofit organizations, and other organizations. Further analysis for other industries is precluded by large amounts of undistributed contract R&D expenses.

36. For conceptual, policy, and measurement issues regarding indicators of technology alliances, J.E. Jankowski, A.N. Link, and N.S. Vonortas, *Strategic Research Partnerships: Proceedings From an NSF Workshop*, NSF 01-336 (Arlington, VA: National Science Foundation, 2001); and B. Bozeman and J.S. Dietz. 2001. Strategic research partnerships: Constructing policy-relevant indicators, *Journal of Technology Transfer* 26:385–93.

37. Further, industrial technology alliances have been found to be countercyclical, whereby companies turn to partners to leverage scarce or more costly investment opportunities in the face of a slower economy (Brod and Link 2001; Link, Paton, and Siegel. 2002; Vonortas and Hagedoorn 2003).

38. As amended by the National Cooperative Research and Production Act (NCRPA) of 1993 (Public Law 103-42). See U.S. Code Title 15, Chapter 69.

39. The amendment was instituted by the Cooperative Research and Technology Enhancement (CREATE) Act of 2004 (Public Law 108-453) and applies to patents resulting from joint research as long as the claimed invention is within the scope of a written contract, grant, or cooperative agreement and made by or on behalf of the parties to the agreement.

40. To gain protection from antitrust litigation, the statute requires firms engaging in research joint ventures in the United States to register these agreements with the Department of Justice. Trends in the CORE database are illustrative only since the registry is not intended to be a comprehensive count of cooperative activity by U.S.-based firms. No data on alliance duration or termination date are available. This database is compiled by A.N. Link, University of North Carolina-Greensboro.

41. CATI-MERIT is a literature-based database that draws on sources such as newspapers, journal articles, books, and specialized journals that report on business events. It includes business alliances with an R&D or technology component such as joint research or development agreements, R&D contracts, and equity joint ventures. Agreements involving small firms and certain technology fields are likely to be underrepresented. Another limitation is that the database draws primarily from English-language materials. No data on alliance duration or termination date are available. This database is maintained by J. Hagedoorn, MERIT, the Netherlands.

42. Furthermore, the decision to enter into an R&D agreement is separate from the decision to register. Using CORE data from 1985–98, Link et al. (2002) found that registrations

were inversely related to the U.S. business cycle and global market shares, used as proxies for conditions that may impact the perceived antitrust climate and the strategic decision to register.

43. See Hagedoorn (2002) for summary of CATI alliances since 1960 and Hagedoorn and van Kranenburg (2003) for a detailed statistical characterization of the data. For analytical purposes, data referring to alliances established in more recent decades are considered more reliable given the increased coverage of R&D agreements in the public sources of the database (see Vonortas and Hagedoorn 2003).

44. Some alliances may be classified in more than one technology. The vast majority of the alliances have been formed as contractual or nonequity alliances since the late 1990s (Appendix table 4-37). See Hagedoorn (2002) for the significance of the shift toward nonequity agreements.

45. Federal laboratories are facilities owned, leased, or otherwise used by a federal agency [15 USC 3710a(d)(2)]. They include, for example, intramural laboratories (e.g., the laboratories owned by NIH's National Cancer Institute) and government-owned contractor-operated laboratories such as some of DOE's FFRDCs. For general information on FFRDCs see footnote 5 and appendix table 4-25.

46. Other types of collaboration include patent licensing, technical assistance, materials and other technical standards development, and use of instrumentation or other equipment.

47. Other data of interest include CRADA-specific agency and industry funding, nature of joint activities, R&D outputs, and industrial impact. For empirical results on some of these indicators from one-time surveys or selected laboratories see Adams, Chiang, and Jensen (2003) and Bozeman and Wittmer (2001).

48. Data for FY 1999 and beyond may not be comparable with prior years because of methodological changes in data collection and processing.

49. Data are for active traditional CRADAS: those legally in force under the authority of 15 U.S. Code Sec. 3710a at any time during the fiscal year. NASA collaborative R&D agreements under the National Aeronautics and Space Act of 1958 are not included. "Traditional" CRADAS are those involving collaborative R&D, in contrast with "nontraditional" CRADAs or those established for special purposes such as material transfer or technical assistance.

50. Note that the latter indicators are not limited to CRADA activity.

51. For more on patents as S&T indicators see chapter 6.

52. At the same time, basic research is also an important component of industry collaborations with federal labs. See J. Rogers and B. Bozeman. 1997. Basic research and the success of federal Lab-industry partnerships, *Journal of Technology Transfer* 22(3):37–48.

53. The 2000 reauthorization bill (Public Law 106-554) also requested that the National Research Council conduct a 3-year SBIR study at five federal agencies with SBIR budgets exceeding $50 million (DOD, HHS, NASA, DOE, and NSF). The study is currently in progress. See NRC (2004) and http://www7.nationalacademies.org/sbir/index.html.

54. Title I of the Small Business Research and Development Enhancement Act, Public Law 102-564.

55. STTR was created by Small Business Technology Transfer Act of 1992 (Title II of the Small Business Research and Development Enhancement Act, Public Law 102-564). It was last reauthorized by the Small Business Technology Transfer Program Reauthorization Act of 2001 (Public Law 107-50) through FY 2009.

56. Public Law 100-418; 15 U.S. Code Section 278n.

57. OECD maintains R&D expenditure data that can be categorized into three periods: (1) 1981 to the present (data are properly annotated and of good quality); (2) 1973 to 1980 (data are probably of reasonable quality, and some metadata are available); and (3) 1963 to 1972 (data are questionable for most OECD countries [with notable exceptions of the United States and Japan], many of which launched their first serious R&D surveys in the mid-1960s). The analyses in this chapter are limited to data for 1981 and subsequent years. The 30 current members of the OECD are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

58. The global R&D figure is estimated based on data for 80 countries compiled from three sources. Estimates for 31 countries were taken from OECD data, estimates for 18 additional countries were taken from RICYT data, and estimates for the remaining 25 countries were taken from UNESCO reports.

59. Because U.S. universities generally do not maintain data on departmental research, U.S. totals are understated relative to the R&D effort reported for other countries. The national totals for Europe, Canada, and Japan include the research component of GUF block grants provided by all levels of government to the academic sector. These funds can support departmental R&D programs that are not separately budgeted. The U.S. federal government does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. However, a fair amount of state government funding probably does support departmental research at public universities in the United States. See sidebar, "Government Funding Mechanisms for Academic Research."

60. The United Kingdom similarly experienced 3 years of declining real R&D expenditures, but its slump took place in 1995, 1996, and 1997. The falling R&D totals in Germany were partly a result of specific and intentional policies to eliminate redundant and inefficient R&D activities and to integrate the R&D efforts of the former East Germany and West Germany into a united German system.

61. Growth in the R&D/GDP ratio does not necessarily imply increased R&D expenditures. For example, the rise in R&D/GDP from 1978 to 1985 was due as much to a slowdown

in GDP growth as it was to increased spending on R&D activities.

62. A significant contributor to GDP growth in 2003 and 2004 was increased private domestic investment in information processing equipment and software. Because increased demand for high-technology goods and services is an incentive for increased R&D expenditures, this component of GDP is a useful indicator of private R&D expenditures by information technology businesses.

63. Nonfederal sources of R&D tracked by NSF include industrial firms, universities and colleges, nonprofit institutions, and state and local governments.

64. In Japan, real GDP declined in both 1998 and 2002.

65. See OECD (1999) for further discussion of these and other broad R&D indicators.

66. In accordance with international standards, the following sectors are recognized sources of funding: all levels of government combined, business enterprises, higher education, private nonprofit organizations, and funds from abroad. Italy's distribution of R&D by source of funds was not available for 2000. In earlier years, government sources accounted for more than half of Italy's R&D, industry accounted for more than 40%, and foreign sources funded the remainder.

67. Among all OECD countries, in 2002 the government sector accounted for the highest funding share in Poland (61%) and the lowest share in Japan (18%).

68. Some of the R&D reported in the trade industry for the United States was redistributed for this analysis.

69. Since the mid-1980s, European Community (EC) funding of R&D has become increasingly concentrated in its multinational Framework Programmes for Research and Technological Development (RTD), which were intended to strengthen the scientific and technological bases of community industry and to encourage it to become more internationally competitive. EC funds distributed to member countries' firms and universities have grown considerably. The EC budget for RTD activities has grown steadily from 3.7 billion European Currency Units (ECU) in the First Framework Programme (1984–87) to 17.5 billion ECU for the Sixth Framework Programme (2003–06). The institutional recipients of these funds tend to report the source as "foreign" or "funds from abroad." Eurostat. 2001. *Statistics on Science and Technology in Europe: Data 1985–99.* Luxembourg: European Communities.

70. OECD data for the U.S. academic sector includes the R&D of university-administered FFRDCs. These FFRDCs performed an estimated $7.3 billion of R&D in 2003.

71. In international S&E field compilations, the natural sciences comprise math and computer sciences, physical sciences, environmental sciences, and all life sciences other than medical and agricultural sciences.

72. Data on the socioeconomic objectives of R&D funding are generally derived from national budgets. Because budgets each have their own distinct methodology and terminology, these R&D funding data may not be as comparable as other types of international R&D data.

73. Health and environment programs include human health, social structures and relationships, control and care of the environment, and exploration and exploitation of the Earth.

74. Historically, Russia has also devoted a large share of government R&D to industrial development. Fully 27% of the government's 1998 R&D budget appropriations for economic programs were used to assist in the conversion of the country's defense industry to civil applications (American Association for the Advancement of Science and Centre for Science Research and Statistics, 2001).

75. For the purposes of BEA FDI surveys, the United Sates includes the 50 states, Washington, DC, Puerto Rico, and all U.S. territories and possessions.

76. New investments more than doubled from 1997 to 1998 to $215 billion, reaching a peak at $336 billion in 2000. In 2001, new investments decreased by more than one-half and have been in the $50–$60 billion range in 2002 and 2003, closer to the levels in the late 1980s and mid-1990s (Anderson 2004).

77. R&D employment data from BEA measure the number of scientist and engineers devoting the majority of their time to R&D.

78. BEA data on overseas R&D and other foreign operations of U.S. MNCs are converted to U.S. dollars using market exchange rates according to *Statement of Financial Accounting Standards No. 52 - Foreign Currency Translation* (U.S. Financial Accounting Standards Board). Constant or inflation-adjusted dollar expenditures are not available. See appendix tables 4-55 and 4-56 for selected data from the NSF Survey of Industrial Research and Development on overseas R&D expenditures by companies with R&D activities in the 50 U.S. states and Washington, DC.

79. BEA defines a parent company of a U.S. multinational corporation (MNC) as an entity (individual, branch, partnership, or corporation), resident in the United States, that owns or controls at least 10% of the voting securities, or equivalent, of a foreign business enterprise. See appendix tables 4-53 and 4-54.

80. R&D employment data for foreign affiliates from BEA are available only in 5-year intervals. According to the latest available data as of early 2005, U.S. MNCs employed a global R&D workforce of 770,300, or close to 3% of their employees in 1999 (NSF/SRS 2004b). U.S. parent companies employed 84% (646,800) of their R&D workers domestically; the remaining 16% (123,500) worked abroad for their foreign affiliates. For analysis of trends in overall overseas employment by affiliates of U.S. MNCs, see Mataloni (2004).

81. Preliminary regional totals for Africa, Europe, and Latin American and Western Hemisphere are not available for 2002.

82. Since the late 1990s, majority-owned affiliates appear to be the preferred investment mode for U.S. MNCs in mainland China, at the expense of alliances or joint ventures (NSF/SRS 2004a).

83. For further analysis, see Moris (2005).

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Applied research: Research aimed at gaining the knowledge or understanding to meet a specific, recognized need; in industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Basic research: Research aimed at gaining more comprehensive knowledge or understanding of the subject under study without specific applications in mind.

Development: Systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

Federally funded research and development center: R&D-performing organizations exclusively or substantially financed by the federal government either to meet a particular R&D objectives or, in some instances, to provide major facilities at universities for research and associated training purposes; each FFRDC is administered either by an industrial firm, a university, or a nonprofit institution.

Foreign affiliate: Company located overseas but owned by a U.S. parent.

Foreign direct investment: Ownership or control of 10% or more of the voting securities (or equivalent) of a business located outside the home country.

General university fund (GUF): block grants provided by all levels of government in Europe, Canada, and Japan to the academic sector that can be used to support departmental R&D programs that are not separately budgeted; the U.S. federal government does not provide research support through a GUF equivalent.

Gross domestic product: Market value of goods and services produced within a country.

Intellectual property: Intangible property that is the result of creativity; the most common forms of intellectual property include patents, copyrights, trademarks, and trade secrets.

Majority-owned affiliate: Company owned or controlled by more than 50% of the voting securities (or equivalent) by its parent company.

Multinational corporation: A parent company and its foreign affiliates.

National income and product accounts: Economic accounts that display the value and composition of national output and the distribution of incomes generated in its production.

Parent company of a multinational corporation: Company that owns or controls at least 10% of the voting securities (or equivalent) of a foreign affiliate.

Public-private partnership: Type of industrial technology linkage involving at least one public or nonprofit organization such as a university, research institute, or government laboratory; such a partnership may engage in technology codevelopment or cooperative R&D, technology transfer, technology assistance, joint or grant funding, or public procurement and may take the form of a cooperative agreement, grant or procurement programs, professional or student internship or exchange, technology-based business incubator, or research and science parks.

R&D: According to the Organisation for Economic Co-operation and Development, creative work "undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and the use of this stock of knowledge to devise new applications."

R&D employees: Scientists and engineers who perform R&D functions.

R&D plant expenditures: Acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Research and experimental expenditures: Experimental or laboratory costs aimed at the development or improvement of a product (defined to include any pilot model, process, formula, or technique) in connection with a taxpayer's business.

Technology alliance: Type of industrial technology linkage aimed at codevelopment of new products or capabilities through R&D collaboration.

Technology transfer: Exchange or sharing of knowledge, skills, processes, or technologies across different organizations.

U.S. affiliate: Company located in the United States but owned by a foreign parent.

Value-added: Sales minus the cost of materials.

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Chapter 5
Academic Research and Development

List of Sidebars

List of Tables

List of Figures

Highlights

Financial Resources for Academic R&D

In 2004, U.S. academic institutions spent $42 billion on research and development. Between 1970 and 2004, average annual growth in R&D was stronger for the academic sector than for any other R&D-performing sector except the nonprofit sector.

- ♦ During this period, academic R&D rose from about 0.2% to about 0.4% of the gross domestic product.
- ♦ Academic performers are estimated to account for 54% of U.S. basic research, about 33% of total (basic plus applied) research, and 14% of all R&D estimated to have been conducted in the United States in 2004.

All reported sources of support for academic R&D—federal, industrial, state and local, and institutional—increased fairly continuously in absolute dollar terms between 1972 and 2003, even after adjusting for inflation. However, the long-term trends of a declining share of support from the federal government and an increasing share from industry showed signs of reversing at the end of this period.

- ♦ The federal government provided 62% of academic R&D expenditures in 2003, substantial growth from the 58% share of support provided in 2000. The federal share of support had been in decline since the early 1970s, when it reached a high of 69%.
- ♦ Institutions themselves contributed 19% of funds in 2003, compared with 11% in 1972.
- ♦ Industry's share of academic R&D support grew rapidly during the 1970s and 1980s, fluctuated around 7% of the total during the 1990s, and declined substantially thereafter to 5% in 2003 as a result of absolute constant dollar declines in support in 2002 and 2003.

Between 1973 and 2003, there was a substantial relative shift in the share of academic R&D funds received by different science and engineering fields. However, all gained substantially in terms of absolute dollars, even after adjusting for inflation.

- ♦ The life sciences (59% share in 2003), engineering (15% share), and the computer sciences (3% share) experienced share increases. However, the engineering share declined between 1993 and 2003.
- ♦ The physical sciences (8% share in 2003); earth, atmospheric, and ocean sciences (6% share); social sciences; and psychology (6% combined shares) had share losses.

The historical concentration of academic R&D funds among the top research universities diminished somewhat between the early 1980s and mid-1990s but has remained relatively steady since then. Academic R&D activity is also occurring in a wider set of institutions.

- ♦ The set of institutions in the group below the top 100 academic R&D institutions in funding increased their share of total academic R&D expenditures from 17% to 20% between 1983 and 2003. This was offset by a decline in the top 10 institutions' share from 20% to 17%.
- ♦ The change in the number of institutions supported occurred almost exclusively among higher education institutions classified as Carnegie comprehensive; liberal arts; 2-year community, junior, and technical; or professional and other specialized schools.

In 2003, although about $1.8 billion in current funds was spent on R&D equipment, the share of all annual R&D expenditures spent on research equipment reached a historical low.

- ♦ After reaching a high of just above 7% in 1986, the share of R&D spent on equipment declined by about one-third to 4.5% in 2003.
- ♦ About 81% of equipment expenditures were concentrated in the life sciences (45%), engineering (20%), and the physical sciences (16%).

Research-performing colleges and universities continued to expand their stock of research space in FY 2003 with the largest increase in total research space (11%) since 1988. In addition to the traditional "bricks and mortar" research infrastructure, "cyberinfrastructure" is playing an increasingly important role in the conduct of S&E research.

- ♦ Between 1988 and 2003, little changed in the distribution of research space across S&E fields.
- ♦ Although 71% of university connections to the commodity Internet (Internet1) were at the two lowest speeds, at least 6% of the connections were at 1 gigabit/second or faster.

Doctoral Scientists and Engineers in Academia

The size of the doctoral academic S&E workforce reached an estimated 258,300 in 2003 but grew more slowly than the number of S&E doctorate holders in other employment sectors. Between 1973 and 2003 in academia, full-time faculty positions increased more slowly than postdoc and other full- and part-time positions, especially at research universities.

- ♦ The academic share of all doctoral S&E employment dropped from 55% in 1973 to 45% in 2003.
- ♦ The share of full-time faculty declined from 87% in the early 1970s to 75% in 2003. Other full-time positions rose to 14% of the total, and postdoc and part-time appointments stood at 6% and 5%, respectively.

The academic doctoral labor force has been aging during the past quarter century.

- Both the mean and median age increased almost monotonically between 1973 and 2003.
- In 2003, a growing, albeit small, fraction of employment was made up of individuals age 65 or older (4%), although the share of those 70 years or older declined for the first time since the late 1980s to just below 1%.

The demographic composition of the academic doctoral labor force experienced substantial changes between 1973 and 2003.

- The number of women in academia increased more than sevenfold between 1973 and 2003, from 10,700 to an estimated 78,500, raising their share from 9% to 30%.
- Although their numbers are increasing, underrepresented minorities—blacks, Hispanics, and American Indians/Alaska Natives—remain a small percentage of the S&E doctorate holders employed in academia.
- The number and share of Asians/Pacific Islanders entering the academic S&E doctoral workforce increased substantially between 1973 and 2003.
- The relative prominence of whites, particularly white males, in the academic S&E doctoral workforce diminished between 1973 and 2003.

Foreign-born scientists and engineers constituted 23% of scientists and engineers with U.S. doctorates in academic employment in 2003. This lower bound estimate of foreign-born doctorate holders excludes doctorates from foreign institutions.

- The share of foreign-born doctorate holders was more than double that in 1973, when it stood at 11%.
- Academic employment of foreign-born doctorate holders was highest in the computer sciences and engineering (44% and 40%, respectively), followed by mathematics (33%), the physical sciences (25%), and the life sciences (22%).

As the composition of positions in the academic workforce has changed over the years, a substantial academic researcher pool has developed outside the regular faculty ranks.

- As the faculty share of the academic workforce has declined, postdocs and others in full-time nonfaculty positions have become an increasing percentage of those doing research at academic institutions. This change was especially pronounced in the 1990s.
- A long-term upward trend is evident in the number of academically employed S&E doctorate holders whose primary activity is research relative to total academic employment of S&E doctorate holders.

In most fields, the percentage of academic researchers with federal support for their work was lower in 2003 than in the late 1980s.

- Full-time faculty were less likely to receive federal support (45%) than other full-time doctoral employees (48%). Both of these groups were less frequently supported than postdocs (78%).
- For each of the three groups mentioned above (full-time faculty, other full-time employees, and postdocs) recent doctorate recipients were less likely to receive federal support than their more-established colleagues.

Outputs of S&E Research: Articles and Patents

The worldwide S&E publications output captured in *Science Citation Index* and *Social Sciences Citation Index* grew from approximately 466,000 articles in 1988 to nearly 700,000 in 2003, an increase of 50%.

- This growth was a result of more articles published per journal and an increase in the number of journals covered by these two databases.

Worldwide growth in article output between 1988 and 2003 was strongest in the European Union (EU)-15, Japan, and the East Asia-4 (China, Singapore, South Korea, and Taiwan).

- The EU-15 share of world output surpassed that of the United States in 1998, although growth in the EU-15 and also in Japan slowed starting in the mid-1990s.
- The article output of the East Asia-4 grew more than sevenfold during this period, resulting in its share of world output rising from less than 2% to 8%.

The number of U.S. scientific publications remained essentially flat between 1992 and 2003, causing the U.S. share of world article output to decline from 38% to 30% between 1988 and 2003.

- The flattening of U.S. output—199,864 articles in 1992, 211,233 articles in 2003—in the face of continuing growth of research inputs represents a trend change from several decades' growth in number of U.S. publications.

The share of publications with authors from multiple countries—an indicator of international collaboration and the globalization of science—grew worldwide and for most countries between 1988 and 2003.

- In 2003, 20% of all articles had at least one foreign author, up from 8% in 1988.

The increase in international collaboration reflects intensified collaboration among the United States, EU-15, and Japan. It also reflects greater collaboration between these S&E publishing regions and developing countries and an emerging zone of intraregional collaboration centered in East Asia.

- The share of internationally coauthored articles at least doubled in the United States, the EU-15, and Japan.
- A pattern of intraregional collaboration emerged in East Asia in the mid-1990s centered in Japan and, increasingly, in China.

The United States has the largest share of all internationally authored papers of any single country, and its researchers collaborate with counterparts in more countries than do the researchers of any other country.

- U.S.-based authors were represented in 44% of all internationally coauthored articles in 2003 and collaborated with authors in 172 of the 192 countries that had any internationally coauthored articles in 2003.
- U.S. collaboration with the rest of the world continues to increase, but its relative share of coauthorship on other countries' internationally authored articles has declined as those countries have broadened their international ties.

As measured by the share of collaborative articles, both intrainstitutional collaboration of U.S. sectors and collaboration of these sectors with the rest of the world have increased significantly.

- The share of U.S. academic articles with at least one non-U.S. address grew from 10% to 24% between 1988 and 2003. The share of U.S. academic articles with nonacademic U.S. authors increased by 6 percentage points during this period, to 30%.

The volume of citations to S&E literature grew more than 60% between 1992 and 2003.

- The growth in citations was the greatest in the same S&E publishing regions that fueled growth of S&E publications: the EU-15, Japan, and the East Asia-4. The volume of citations to U.S. literature, however, flattened in the late 1990s.

The increase in citation volume in most regions coincided with a growing share of citations to work done outside the author's country, reflecting the growing ease of access to worldwide scientific literature.

- Citations to literature produced outside the author's home country rose from 42% of all citations in 1992 to 48% in 2003.

The number of scientific articles cited by U.S. patents, an indicator of the linkage between science and technology, rose rapidly until the late 1990s.

- These increases were heavily centered in academic-authored articles in the fields of biomedical research and clinical medicine.

The growing closeness of basic science and practical applications is also evident in the rising number of U.S. patents issued to U.S. academic institutions.

- The number of U.S. academic patents quadrupled from approximately 800 in 1988 to more than 3,200 in 2003. The increase in patents was highly concentrated in life sciences applications.

Increases in licensing income and activity suggest growing efforts by universities to commercialize their products and technology.

- Income from licensing was more than $850 million in FY 2003, more than double the amount in FY 1997, and new licenses and options increased by more than 40% during this period.

Introduction

Chapter Overview

The academic sector continues to be a major contributor to the nation's scientific and technological progress, both through the generation of new knowledge and ideas and the education and training of scientists and engineers (see chapter 2). The nation's universities and colleges continue to perform more than half of the United States' basic research. The federal share of support for overall academic research and development, which had been declining for more than three decades, recently began increasing, and in 2003 the federal government provided more than 60% of the financial resources for academic R&D.

The allocation of the national academic R&D investment has been changing over time in several ways. More than half of all academic R&D funds now go to the life sciences. This share has grown over the past several decades, prompting discussion about the appropriate distribution of funds across disciplines. The number of academic institutions receiving federal support for R&D activities increased during the past three decades, expanding the base of the academic R&D enterprise beyond the traditional research institutions. Academic science and engineering infrastructure, both research equipment and research space, also grew over the past decade. However, the percentage of total annual R&D expenditures devoted to research equipment continued to decline.

Doctoral S&E faculty in universities and colleges play a critical role in ensuring an adequate, diverse, and well-trained supply of S&E personnel for all sectors of the economy. Demographic projections point to the potential for strong enrollment growth and the continuation of several trends—notably, more minority participation, more older students, and more nontraditional students. These changes are all likely to affect not only the composition but also the role of doctoral S&E faculty in the future. Recent hiring trends suggest movement away from the full-time faculty position as the academic norm. Academia may also be approaching a period of increasing retirements due to an aging labor force. Future trends for foreign graduate students and foreign-born faculty continue to be uncertain in the wake of the events of September 11, 2001, and the growing capacity in higher education in many countries.

The number of U.S. S&E articles published in the world's leading S&E journals has remained flat since the mid-1990s, whereas the number of articles published in the European Union (EU) and several East Asian countries has grown strongly. The number of influential articles from U.S. institutions, as measured by citation frequency, has likewise remained flat. As a result, the U.S. share of the world's influential articles has declined. Article output by the academic sector, which publishes most U.S. research articles, has mirrored the overall U.S. trend, even though research inputs (specifically, academic R&D expenditures and research personnel) have continued to increase. Academic scientists and engineers collaborate extensively with colleagues in other U.S. sectors, and international collaboration has increased significantly over the past two decades. The output of academic research has increasingly extended to patent protection of research results as the number of U.S. patents and other related activities has grown over the past two decades.

In this context, and driven by financial and other pressures, universities and colleges will continue to debate questions about their organization, focus, and mission. To help provide a context for such discussions, this chapter addresses key aspects of the academic R&D enterprise, including the role of the federal government and other funders in supporting academic research; the distribution of support across the nation's universities and colleges; the allocation of funding across S&E disciplines; research equipment and facilities at academic institutions; trends in the number and composition of the academic S&E doctoral labor force; and research outputs in the form of refereed journal articles and academic patents.

Chapter Organization

The first section of this chapter discusses trends in the financial resources provided for academic R&D, including providers of support and allocations across both academic institutions and S&E fields. Because the federal government has been the primary source of support for academic R&D for more than half a century, the importance of selected agencies to both overall support and support for individual fields is explored in some detail. This section also presents data on changes in the distribution of funds among academic institutions and on the number of academic institutions that receive federal R&D support. It concludes with an examination of the status of two key elements of university research activities: equipment and infrastructure.

The next section discusses trends in the employment of academic doctoral scientists and engineers and examines the positions they hold, their activities, and demographic characteristics. The discussion of employment trends focuses on full-time faculty, postdocs, graduate students, and other positions. Differences between the nation's leading research universities and other academic institutions are considered. The involvement of women and minorities is also examined, as are shifts in the faculty age structure. Attention is given to participation in research by academic doctoral scientists and engineers, the relative balance between teaching and research, and the provision of federal support for research. The section also reviews selected demographic characteristics of recent doctorate holders entering academic employment.

The chapter concludes with an analysis of trends in two types of research outputs: S&E articles, as measured by data from a set of journals covered by the *Science Citation Index (SCI)* and the *Social Sciences Citation Index (SSCI),* and patents issued to U.S. universities. (A third major output of academic R&D, educated and trained personnel, is discussed in this chapter and in chapter 2). This section looks specifically at the volume of research (article counts), collaboration in the conduct of research (joint authorship), use in subsequent

scientific activity (citation patterns), and use beyond science (citations to the literature that are found in patent applications). It concludes with a discussion of academic patenting and some returns to academic institutions from their patents and licenses.

Financial Resources for Academic R&D

Academic R&D is a significant part of the national R&D enterprise.[1] To carry out world-class research and advance the scientific knowledge base, U.S. academic researchers require financial resources, stability of research support, and research facilities and instrumentation that facilitate high-quality work. Several funding indicators bear on the state of academic R&D, including:

- The level and stability of overall funding
- The sources of funding and changes in their relative shares
- The distribution of funding among the different R&D activities (basic research, applied research, and development)
- The distribution of funding among S&E broad and detailed fields
- The distribution of funding across institutions that perform academic R&D and the extent of their participation
- The role of the federal government as a supporter of academic R&D and the particular roles of the major federal agencies funding this sector
- The state of the physical infrastructure (research equipment and facilities)

Individually and in combination, these factors influence the evolution of the academic R&D enterprise and, therefore, are the focus of this section. The main findings are as follows:

- Continued growth in both federal and nonfederal funding of academic R&D
- A recent increase in the role of the federal government following a steady relative decline, and a corresponding relative decline in the roles of industry and state and local government
- A substantial increase in National Institutes of Health (NIH) funding relative to the other main federal funding agencies
- Continued but differential increases in funding for all fields, resulting in a relative shift in the distribution of funds, with increasing shares for the life sciences, engineering, and the computer sciences
- R&D activity occurring in a wider set of institutions, with the concentration of funds among the top research universities diminishing slightly
- The share of all annual R&D expenditures spent on research equipment reaching a historic low
- Continuous growth in academic S&E research space, particularly in the medical and biological sciences
- The increasingly important role of "cyberinfrastructure" in the conduct of S&E research.

For a discussion of the nature of the data used in this section, see sidebar, "Data Sources for Financial Resources for Academic R&D."

Academic R&D Within the National R&D Enterprise

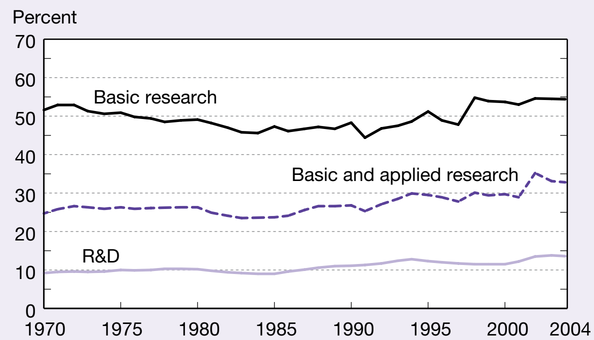
Academia is widely viewed as important to the nation's overall R&D effort, especially for its contribution to generating new knowledge through basic research. Since 1998, academia has accounted for more than half of the basic research performed in the United States.

In 2004, U.S. academic institutions spent an estimated $42 billion, or $39 billion in constant 2000 dollars, on R&D.[2] Academia's role as an R&D performer has increased during the past three decades, rising from about 10% of all R&D performed in the United States in the early 1970s to an estimated 14% in 2004 (figure 5-1). For a comparison with other countries, see chapter 4, "International R&D Comparisons."

Character of Work

Academic R&D activities are concentrated at the research (basic and applied) end of the R&D spectrum and do not include much development activity.[3] For the definitions used in National Science Foundation (NSF) surveys and a fuller discussion of these concepts, see chapter 4 sidebar, "Definitions of R&D." Recently, there has been some discussion

Figure 5-1
Academic R&D, basic and applied research, and basic research as proportion of U.S. totals: 1970–2004



NOTES: Data for 2003 and 2004 are preliminary. Because of changes in estimation procedures, character of work data before FY 1998 is not comparable with later years. Data based on annual reports by performers. For details on methodological issues of measurement, see National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *National Patterns of Research and Development Resources: Methodology Report* (forthcoming).

SOURCE: NSF/SRS, *National Patterns of R&D Resources* (annual series). See appendix table 5-1. Also see appendix tables 4-3, 4-7, 4-11, and 4-15 for data underlying percentages.

Science and Engineering Indicators 2006

Data Sources for Financial Resources for Academic R&D

The data used to describe financial and infrastructure resources for academic R&D are derived from four National Science Foundation (NSF) surveys. These surveys use similar but not always identical definitions, and the nature of the respondents also differs across the surveys. The four main surveys are as follows:

- Survey of Federal Funds for Research and Development
- Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions
- Survey of Research and Development Expenditures at Universities and Colleges
- Survey of Science and Engineering Research Facilities

The first two surveys collect data from federal agencies, whereas the last two surveys collect data from universities and colleges. (For descriptions of the methodologies of the NSF surveys, see NSF 1995a and 1995b and the Division of Science Resources Statistics website, http://www.nsf.gov/statistics/.)

Data presented in the context section, "Academic R&D Within the National R&D Enterprise," are derived from special tabulations that aggregate NSF survey data on the various sectors of the U.S. economy so that the components of the overall R&D effort are placed in a national context. These data are reported on a calendar-year basis, and the data for 2003 and 2004 are preliminary. Since 1998, these data also attempt to eliminate double counting in the academic sector by subtracting current fund expenditures for separately budgeted science and engineering R&D that do not remain in the institution reporting them but are passed through via subcontracts and similar collaborative research arrangements to other institutions. Data in subsequent sections are reported on a fiscal-year basis and do not net out the funds passed through to other institutions, and therefore differ from those reported in this section. Data on major funding sources, funding by institution type, distribution of R&D funds across academic institutions, and expenditures by field and funding source are from the Survey of Research and Development Expenditures at Universities and Colleges. For various methodological reasons, parallel data by field from the NSF Survey of Federal Funds for Research and Development do not necessarily match these numbers.

The data in the "Federal Support of Academic R&D" section come primarily from NSF's Survey of Federal Funds for Research and Development. This survey collects data on R&D obligations from 30 federal agencies. Data for FY 2004 and 2005 are preliminary estimates. The amounts reported for FY 2004 and 2005 are based on administration budget proposals and do not necessarily represent actual appropriations. Data on federal obligations by S&E field are available only through FY 2003. They refer only to research (basic and applied) rather than to research plus development.

The data in the section "Spreading Institutional Base of Federally Funded Academic R&D" are drawn from NSF's Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions. This survey collects data on federal R&D obligations to individual U.S. universities and colleges from the approximately 18 federal agencies that account for virtually all such obligations. For various methodological reasons, data reported in this survey do not necessarily match those reported in the Survey of Research and Development Expenditures at Universities and Colleges.

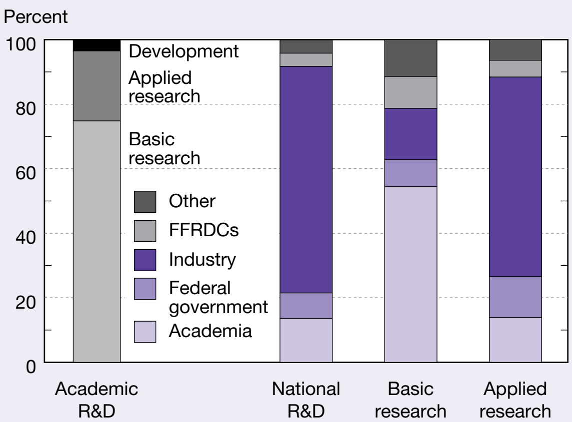
Data on research equipment are taken from the Survey of Research and Development Expenditures at Universities and Colleges. Data on research facilities and cyberinfrastructure are taken from the Survey of Science and Engineering Research Facilities. These two surveys do not cover the same populations. The minimum threshold for inclusion in the expenditures survey is $150,000 in expenditures, whereas the minimum threshold for inclusion in the facilities survey is $1 million. The facilities survey was redesigned for FY 2003 implementation and its topics broadened to include computing and networking capacity as well as research facilities. Data reported on various characteristics of research space are imputed for item nonresponse and weighted to national estimates for unit nonresponse. The data reported on networking and information technology planning are not imputed or weighted. Although terms are defined specifically in each survey, in general, *facilities expenditures* are classified as *capital* funds, are fixed items such as buildings, often cost millions of dollars, and are not included within R&D expenditures as reported here. *Research equipment and instruments* (the terms are used interchangeably) are generally movable, purchased with *current funds,* and included within R&D expenditures. Because the categories are not mutually exclusive, some large instrument systems could be classified as either facilities or equipment. Expenditures on research equipment are limited to current funds and do not include expenditures for instructional equipment. *Current funds,* as opposed to capital funds, are those in the yearly operating budget for ongoing activities. Generally, academic institutions keep separate accounts for current and capital funds.

about whether a shift away from basic research and toward the pursuit of more utilitarian, problem-oriented questions is occurring in academia. (For a brief analysis of this issue, see sidebar "Has Academic R&D Shifted Toward More Applied Work?" later in this chapter.) For academic R&D expenditures in 2004, an estimated 97% went for research (75% for basic and 22% for applied) and 3% for development (figure 5-2). From the perspective of national research (basic and applied), as opposed to national R&D, academic institutions accounted for an estimated 33% of the U.S. total in 2004. In terms of basic research alone, the academic sector is the country's largest performer, currently accounting for an estimated 54% of the national total. Between the early 1970s and early 1980s, the academic sector's basic research share declined from slightly more to slightly less than one-half of the national total. In the early 1990s, its share of the national total began to increase once again.

Growth

Between 1970 and 2004, the average annual R&D growth rate (in constant 2000 dollars) of the academic sector (4.5%) was higher than that of any other R&D-performing sector except the nonprofit sector (4.7%). (See figure 5-3 and appendix table 4-4 for time-series data by R&D-performing sector.) As a proportion of gross domestic product (GDP), academic R&D rose from 0.24% to 0.37% during this period, a 50% increase. (See appendix table 4-1 for GDP time series.) Between 2000 and 2004, average annual R&D growth was higher in the academic sector (6.3%) than in any other sector except federally funded research and development centers (6.9%).

Figure 5-2
Academic R&D expenditures, by character of work, and national R&D expenditures, by performer and character of work: 2004



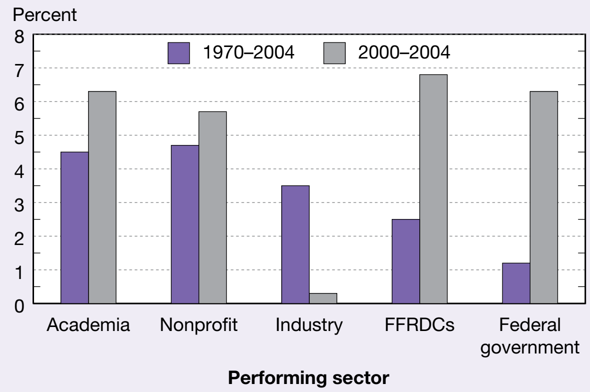
FFRDC = federally funded research and development center

NOTE: Data are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (annual series). See appendix tables 4-3, 4-7, 4-11, and 5-1.

Science and Engineering Indicators 2006

Figure 5-3
Average annual R&D growth, by performing sector: 1970–2004 and 2000–2004



FFRDC = federally funded research and development center

NOTES: R&D data are for calendar year. Data for 2003 and 2004 are estimated.

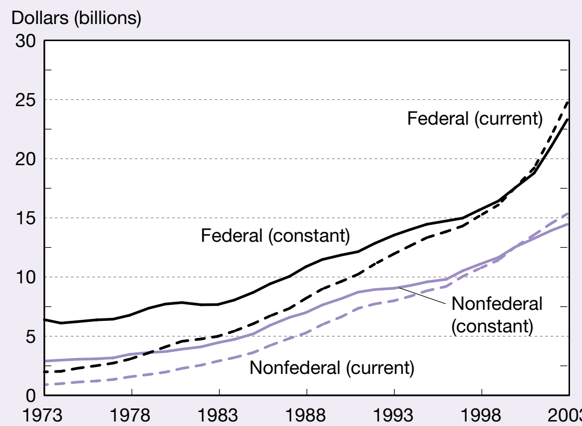
SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* special tabulations. See appendix table 4-4.

Science and Engineering Indicators 2006

Major Funding Sources

The academic sector relies on a variety of funding sources for support of its R&D activities. The federal government continues to provide the majority of funds (figure 5-4). After declining for almost three decades, with most of the decline occurring during the 1980s, its share has recently begun to increase. In 2003, the federal government accounted for

Figure 5-4
Federal and nonfederal academic R&D expenditures: 1973–2003



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 2000 dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures: Fiscal Year 2003* (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-2.

Science and Engineering Indicators 2006

about 62% of the funding for R&D performed in academic institutions, compared with its peak of 69% in 1973 and 58% in 2000 (figure 5-5; appendix table 5-2).

Federal support of academic R&D is discussed in detail later in this section. The following list summarizes the contributions of other sectors to academic R&D:[4]

- **Institutional funds.** In 2003, institutional funds from universities and colleges constituted the second largest source of funding for academic R&D, accounting for 19%, slightly below its peak of 20% in 2001 (appendix table 5-2). Institutional funds encompass two categories: (1) institutionally financed organized research expenditures and (2) unreimbursed indirect costs and related sponsored research. They do not include departmental research and thus exclude funds, notably for faculty salaries, in cases where research activities are not separately budgeted.

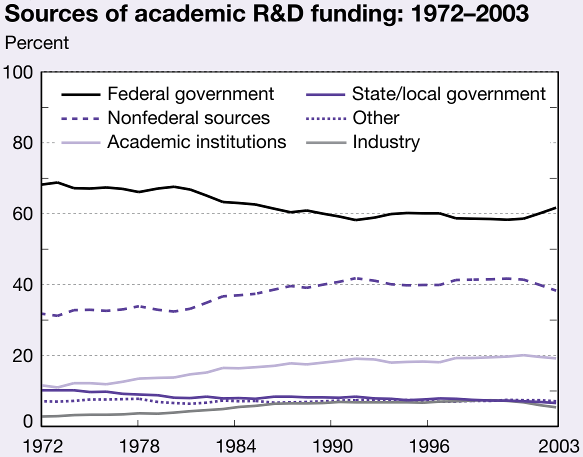
  The share of support represented by institutional funds had been increasing during the past three decades, except for a brief downturn in the early 1990s, but recently began to decline in 2001. Institutional R&D funds may be derived from (1) general-purpose state or local government appropriations (particularly for public institutions) or federal appropriations; (2) general-purpose grants from industry, foundations, or other outside sources; (3) tuition and fees; (4) endowment income; and (5) unrestricted gifts. Other potential sources of institutional funds are income from patents or licenses and income from patient care revenues. (See "Patents Awarded to U.S. Universities" later in this chapter for a discussion of patent and licensing income.)

- **State and local government funds.** State and local governments provided 7% of academic R&D funding in 2003. Between 1980 and 2001, the state and local share of academic R&D funding fluctuated between 7% and 8%. However, the share has declined every year since 1996. This share, however, only reflects funds directly targeted to academic R&D activities by state and local governments. It does not include general-purpose state or local government appropriations that academic institutions designate and use to fund separately budgeted research or cover unreimbursed indirect costs.[5] Consequently, the actual contribution of state and local governments to academic R&D is not fully captured here, particularly for public institutions. (See chapter 8 for some indicators of academic R&D by state.)

- **Industry funds.** The funds provided for academic R&D by the industrial sector grew at a faster rate than funding from any other source during the 1973–2003 period. However, actual industry funding in inflation-adjusted dollars declined in both 2002 and 2003, the first time such a decline occurred in the past three decades. As a result, industry provided only 5% of academic R&D funding in 2003, a substantial decline from its peak of 7% in 1999. Industrial support accounts for the smallest share of academic R&D funding, and support of academia has never been a major component of industry-funded R&D. In 1994, industry's contribution to academic R&D represented 1.5% of its total support of R&D compared with 1.4% in 1990, 0.9% in 1980, and 0.7% in 1973. Between 1994 and 2004, this share declined from 1.5% to 1.1%. (See appendix table 4-4 for time-series data on industry-funded R&D.)

- **Other sources of funds.** In 2003, other sources of support accounted for 7% of academic R&D funding, a level that has stayed about the same since 1972. This category of funds includes grants for R&D from nonprofit organizations and voluntary health agencies and gifts from private individuals that are restricted by the donor to the conduct of research, as well as all other sources restricted to research purposes not included in the other categories.

Figure 5-5
Sources of academic R&D funding: 1972–2003



SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures: Fiscal Year 2003* (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-2.

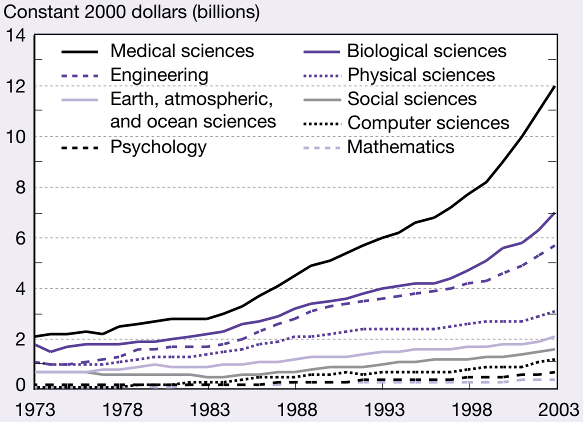
Science and Engineering Indicators 2006

Expenditures by Field and Funding Source

The distribution of academic R&D funds across S&E disciplines often is the result of numerous, sometimes unrelated, funding decisions rather than an overarching plan. Examining and documenting academic R&D investment patterns across disciplines enables interested parties to assess the balance in the academic R&D portfolio. The majority of academic R&D expenditures in 2003 went to the life sciences, which accounted for 59% of total, federal, and nonfederal academic R&D expenditures (appendix table 5-3). Within the life sciences, the medical sciences accounted for 32% of total academic R&D expenditures and the biological sciences for 18%.[6] The next largest block of total academic R&D expenditures was for engineering: 15% in 2003.

The distribution of federal and nonfederal funding of academic R&D in 2003 varied by field (appendix table 5-4). For

Figure 5-6
Academic R&D expenditures, by field: 1973–2003



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 2000 dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures: Fiscal Year 2003* (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-5.

Science and Engineering Indicators 2006

example, the federal government funded about three-quarters of academic R&D expenditures in physics, the atmospheric sciences, and aeronautical/astronautical engineering but only about one-third in economics, political science, and the agricultural sciences.

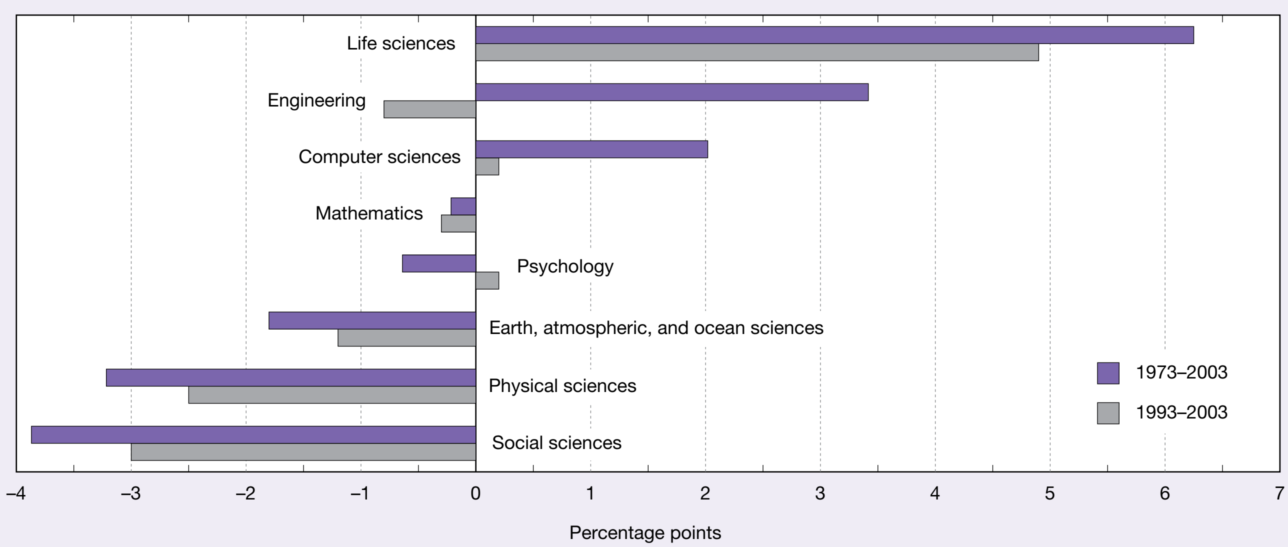
The federally financed fraction of support for *each* of the broad S&E fields, except for computer sciences, was lower in 2003 than in 1980 (appendix table 5-4).[7] The most dramatic decline occurred in the social sciences, down from 54% in 1980 to 40% in 2003. The overall decline in federal share also holds for all the reported S&E subfields. However, most of the declines occurred in the 1980s, and many fields did not experience declining federal shares after that. In some fields, the federal share of support has increased since 1990.

Although total expenditures for academic R&D in constant 2000 dollars increased in every field between 1973 and 2003 (figure 5-6; appendix table 5-5), the R&D emphasis of the academic sector, as measured by its S&E field shares, changed during this period (figure 5-7). Relative shares of academic R&D:

- Increased for the life sciences, engineering, and computer sciences
- Remained roughly constant for mathematics
- Declined for psychology; the earth, atmospheric, and ocean sciences; the physical sciences; and the social sciences

Although the proportion of the total academic R&D funds going to the life sciences increased by about 6 percentage points between 1973 and 2003, from 53% to 59% of academic R&D, the medical sciences' share increased by 10 percentage points during this period, from 22% to 32%, and the shares for the agricultural sciences and biological sciences both declined (appendix table 5-5). The largest declines in the proportion of total academic R&D funds were

Figure 5-7
Changes in share of academic R&D in selected S&E fields: 1973–2003 and 1993–2003



NOTE: Fields ranked by change in share during 1973–2003, in descending order.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures: Fiscal Year 2003;* and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-5.

Science and Engineering Indicators 2006

in the social sciences and physical sciences, which declined by about 4 and 3 percentage points, respectively. When this analysis was limited to the period 1993–2003, similar trends in share changes were seen, with two exceptions: the engineering share declined by almost 1 percentage point, and the psychology share increased slightly.

Federal Support of Academic R&D

The federal government continues to provide the majority of the funding for academic R&D. Its overall contribution is the combined result of discrete funding decisions for several key R&D-supporting agencies with differing missions. Most of the funding provided by the federal government to academia reflects decisions arrived at through a competitive peer review process. Some of the funds are from long-established programs, such as those of the U.S. Department of Agriculture (USDA), that support academic research through formula funding rather than peer review, and other funds are the result of appropriations that Congress directs federal agencies to award to projects that involve specific institutions. These latter funds are known as *congressional earmarks.* (See sidebar, "A Brief Look at Congressional Earmarking.") Examining and documenting the funding patterns of the key funding agencies is key to understanding both their roles and that of the federal government overall.

Top Agency Supporters

Six agencies are responsible for most of the federal obligations for academic R&D, providing an estimated 96% of such obligations in FY 2005 (appendix table 5-6). NIH provided an estimated 66% of total federal financing of academic R&D in 2005. An additional 13% was provided by NSF; 7% by the Department of Defense (DOD); 5% by the National Aeronautics and Space Administration (NASA); 3% by the Department of Energy (DOE); and 2% by the USDA.[8] Federal obligations for academic research (i.e., without the development component) are concentrated similarly to those for R&D (appendix table 5-7). Some differences exist, however, because some agencies place greater emphasis on development (e.g., DOD), whereas others place greater emphasis on research (e.g., NIH).

Between 1990 and 2005, NIH's funding of academic R&D increased most rapidly, with an estimated average annual growth rate of 6.1% per year in constant 2000 dollars, increasing its share of federal funding from just above 50% to an estimated 66%. NSF and NASA experienced the next highest annual rates of growth: 3.9% and 3.6%, respectively.

Agency Support by Field

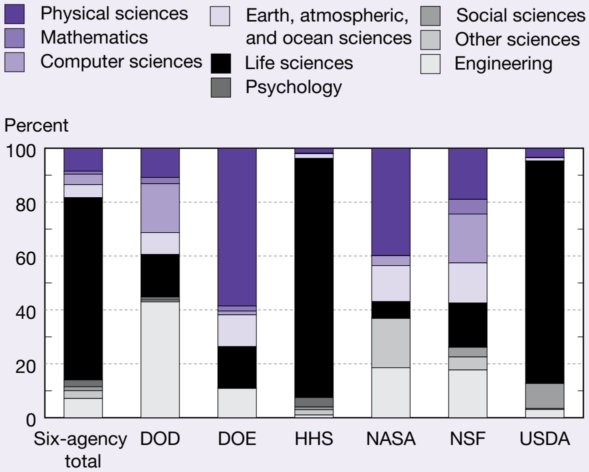
Federal agencies emphasize different S&E fields in their funding of academic research. Several agencies concentrate their funding in one field (e.g., the Department of Health and Human Services [HHS] and USDA in the life sciences and DOE in the physical sciences), whereas NSF, NASA, and DOD have more diversified funding patterns (figure 5-8; appendix table 5-8). Even though an agency may place a large share of its funds in one field, it may not be a leading contributor to that field, particularly if it does not spend much on academic research (figure 5-9).

In FY 2003, NSF was the lead federal funding agency for academic research in the physical sciences (31% of total funding); mathematics (69%); the computer sciences (66%); and the earth, atmospheric, and ocean sciences (43%) (appendix table 5-9). DOD and NSF were the lead funding agencies in engineering (37% and 35%, respectively). HHS was the lead funding agency in the life sciences (90%), psychology (96%), and the social sciences (46%). Within the S&E subfields, other agencies took the leading role: DOE in physics (46%), the USDA in the agricultural sciences (99%), and NASA in astronomy (78%) and astronautical engineering (73%). If the analysis is confined to basic academic research, which constituted 62% of federal obligations for academic research in 2003, the lead funding agencies by field differ slightly (table 5-1).

A Brief Look at Congressional Earmarking

Obtaining exact figures for either the amount of funds or the number of projects specifically earmarked for universities and colleges, either overall or for research, is often difficult because of the lack of an accepted definition of academic earmarking and because the funding legislation is often obscure in its description of the earmarked projects. However, a number of efforts have been undertaken to attempt to measure the extent of this activity. According to a recent analysis by the American Association for the Advancement of Science, R&D earmarks in the FY 2005 congressional appropriations bills were $2.1 billion, up 9% from FY 2004. These estimates include earmarks to all types of R&D performers. *The Chronicle of Higher Education* formerly estimated trends in academic earmarking through an annual survey of federal spending laws and the congressional reports that accompanied them. *The Chronicle's* latest analysis was for 2003, and its series shows steady increases in academic earmarks between 1996 and 2003, from $296 million to just over $2 billion. Not all of these funds, however, go to projects that involve research. Because the federal government provided about $23 billion for academic R&D expenditures in FY 2003, these estimates suggest less than 10% of federal academic R&D support is accounted for by earmarks. (For a more detailed historical discussion of earmarks, see sidebar "Congressional Earmarking to Universities and Colleges" in *Science and Engineering Indicators – 2004*.)

Figure 5-8
Federal agency academic research obligations, by field: FY 2003



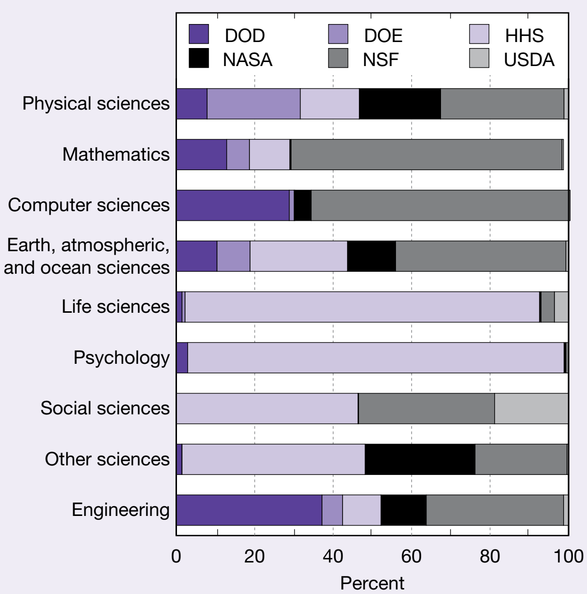
DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

NOTE: Agencies reported represent approximately 97% of federal academic research obligations.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming). See appendix table 5-8.

Science and Engineering Indicators 2006

Figure 5-9
Major agency field shares of federal academic research obligations: FY 2003



DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

NOTE: Agencies reported represent approximately 97% of federal academic research obligations.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming). See appendix table 5-9.

Science and Engineering Indicators 2006

Table 5-1
Lead funding agency for academic basic research, by selected field: 2003

Field	Agency	Funded (%)
Physical sciences	NSF	40
Mathematics	NSF	76
Computer sciences	NSF	85
Earth, atmospheric, and ocean sciences	NSF	54
Life sciences	HHS	88
Psychology	HHS	95
Social sciences	NSF	52
Other sciences	NASA	35
Engineering	NSF	46

HHS = U.S. Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (forthcoming).

Science and Engineering Indicators 2006

An Institutional Look at Academic R&D

The previous sections examined R&D for the entire academic sector. This section looks at some of the differences across institution types.

Funding for Public and Private Universities and Colleges

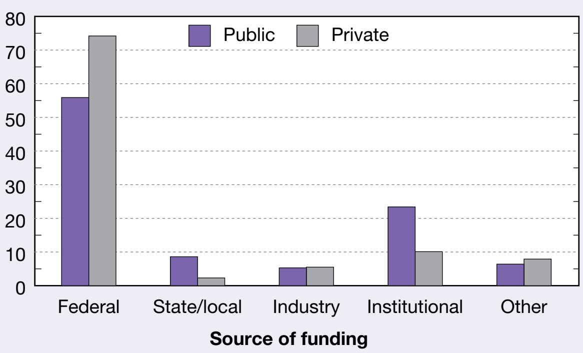
Although public and private universities rely on the same funding sources for their academic R&D, the relative importance of those sources differs substantially for these two types of institutions (figure 5-10; appendix table 5-10). For all *public* academic institutions combined, about 9% of R&D funding in 2003, the most recent year for which data are available, came from state and local funds; about 23% from institutional funds; and about 56% from the federal government. *Private* academic institutions received a much smaller portion of their funds from state and local governments (2%) and institutional sources (10%), and a much larger share from the federal government (74%). The difference in the role of institutional funds at public institutions may largely reflect the substantial amounts of general-purpose state and local government funds that public institutions receive and can decide to use for R&D (although data on such breakdowns are not collected).[9] (For a more detailed discussion of the composition of institutional funds for public and private academic institutions, see sidebar "The Composition of Institutional Academic R&D Funds.")

Both public and private institutions received approximately 5% of their R&D support from industry in 2003. The industry share of support for both public and private institutions decreased between 1993 and 2003, whereas both the federal and institutional shares of support increased.

Distribution of R&D Funds Across Academic Institutions

The distribution of R&D funds across academic institutions has been and continues to be a matter of interest both to those concerned with the academic R&D enterprise and those concerned with local and regional economic development. Most academic R&D is now, and has been historically, concentrated in relatively few of the 3,600 U.S. institutions of higher education.[10] If institutions are ranked by their 2003 R&D expenditures, the top 200 institutions account for about 95% of R&D expenditures that year. (See appendix table 5-11 for a more detailed breakdown of the distribution among the top 100 institutions.)

Figure 5-10
Sources of academic R&D funding for public and private institutions: 2003



SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures: Fiscal Year 2003* (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-10.

Science and Engineering Indicators 2006

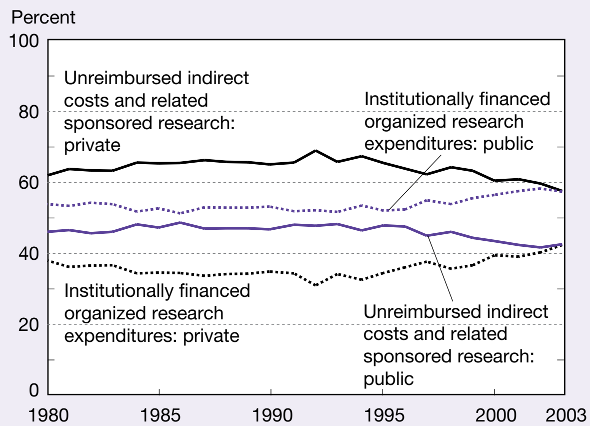
The historic concentration of academic R&D funds diminished slightly between the mid-1980s and mid-1990s but has remained relatively steady since then (figure 5-12). In 1983, the top 10 institutions received about 20% of the nation's total academic R&D expenditures, compared with 17% in 2003. There was almost no change in the shares of the group of institutions ranked 11–20 and 21–100 during this period. Consequently, the decline in the top 20 institutions' share was offset by an increase in the share of those institutions outside the top 100. This group's share increased from 17% to 20% of total academic R&D funds, signifying a broadening of the base of institutional performers.

It should be noted that the composition of the universities in any particular group is not necessarily the same over time, because mobility occurs within groups. For example, only 5 of the top 10 institutions in 1983 were still in the top 10 in 2003. The discussion later in this chapter

The Composition of Institutional Academic R&D Funds

During the past three decades, institutional funds for academic R&D grew faster than funds from any other sources except industry and faster than any other source in the past two decades (appendix table 5-2). In 2003, academic institutions committed a substantial amount of their own resources to R&D: roughly $7.7 billion, or 19% of total academic R&D. In 2003, the share of institutional support for academic R&D at public institutions (23%) was greater than that at private institutions (10%) (appendix table 5-10). One possible reason for this large difference in relative support is that public universities and colleges' own funds may include considerable state and local funds not specifically designated for R&D but used for that purpose by the institutions. Throughout the 1980s and most of the 1990s, institutional R&D funds were divided roughly equally between two components: (1) institutionally financed organized research expenditures and (2) unreimbursed indirect costs and related sponsored research. The balance shifted toward the former after 1998 as the latter share began to decline for both types of institutions. Institutional funds at public and private universities and colleges differ not only in their importance to the institution but also in their composition. Since 1980, from 58% to 69% of private institutions' own funds were designated for unreimbursed indirect costs plus cost sharing, compared with 42% to 49% of public institutions' own funds (figure 5-11).

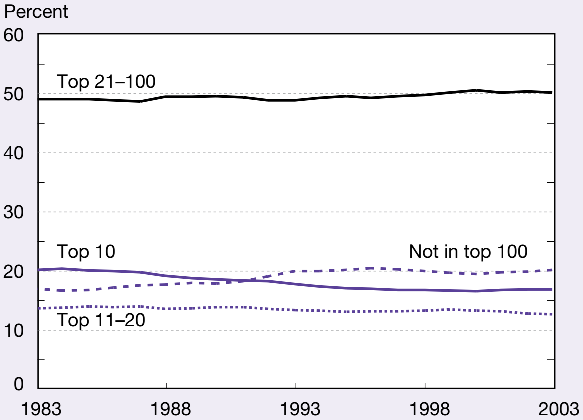
Figure 5-11
Components of institutional R&D expenditures for public and private academic institutions: 1980–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations.

Science and Engineering Indicators 2006

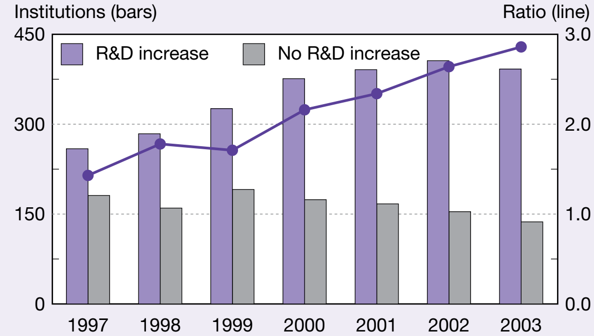
Figure 5-12
Share of academic R&D, by rank of university and college academic R&D expenditures: 1983–2003



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-11.

Science and Engineering Indicators 2006

Figure 5-13
University and college R&D trends: 1997–2003



NOTE: Ratio is number of institutions reporting increased total R&D expenditures from prior year divided by number of institutions reporting either unchanged or decreased R&D expenditures from prior year.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations; and *U.S. Academic R&D Continues to Grow as More Universities and Colleges Expand Their R&D Activities,* NSF 04-319 (2004).

Science and Engineering Indicators 2006

in "Spreading Institutional Base of Federally Funded Academic R&D" points to an increasing number of academic institutions receiving federal support for their R&D activities between 1972 and 2002. Many of the newer institutions receiving support are not the traditional Carnegie research and doctorate-granting institutions.

One program with the objective of improving the geographical distribution of federal academic R&D funds is the Experimental Program to Stimulate Competitive Research (EPSCoR). Several federal agencies have established EPSCoR or EPSCoR-like programs. EPSCoR attempts to increase the R&D competitiveness of eligible states through developing and using the science and technology resources resident in a state's major research universities. Eligibility for EPSCoR participation is limited to jurisdictions that have historically received lesser amounts of federal R&D funding and have demonstrated a commitment to develop their research bases and improve the quality of the S&E research conducted at their universities and colleges.

Changes in R&D Expenditures Across Academic Institutions

As academic R&D expenditures grew between 1997 and 2003, more institutions expanded their R&D activities. In FY 2003, as in the 6 preceding years, a greater number of institutions reported increased R&D expenditures than reported decreased R&D expenditures (figure 5-13). In fact, an examination of the ratio of the number of institutions increasing their expenditures from one year to the next to the number that did not increase their expenditures shows a fairly steady rise in this ratio during this period (figure 5-13). In FY 1997, approximately 1.4 institutions reported increased expenditures over FY 1996 for each institution that reported either unchanged or decreased R&D expenditures. In FY 2003, 2.9 institutions, more than twice as many as in 1997, increased their R&D expenditures for each institution that did not.[11]

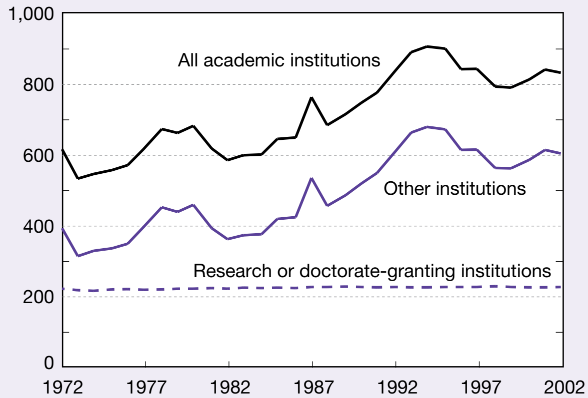
Spreading Institutional Base of Federally Funded Academic R&D

The number of academic institutions receiving federal support for their R&D activities increased fairly steadily between 1972 and 1994, when it reached a peak of 907 institutions. Between 1995 and 2002, the number of institutions receiving federal support fluctuated between 791 and 901 (figure 5-14).[12] These fluctuations almost exclusively affected institutions of higher education with Carnegie classifications of comprehensive; liberal arts; 2-year community, junior, and technical; and professional and other specialized schools. The number of such institutions receiving federal support more than doubled between 1973 and 1994, rising from 315 to 680. It then dropped to 563 by 1999 before beginning to rise again in the past several years (appendix table 5-12). These institutions' share of federal support also increased between 1972 and 2002, from 9% to just above 14%. The number of Carnegie research and doctorate-granting institutions receiving federal support remained relatively constant during this period.

Academic R&D Equipment

Research equipment is an integral component of the academic R&D enterprise. This section examines expenditures on research equipment, the federal role in funding these expenditures, and the relation of equipment expenditures to overall R&D expenditures.

Figure 5-14
Academic institutions receiving federal R&D support, by selected Carnegie classification: 1972–2002

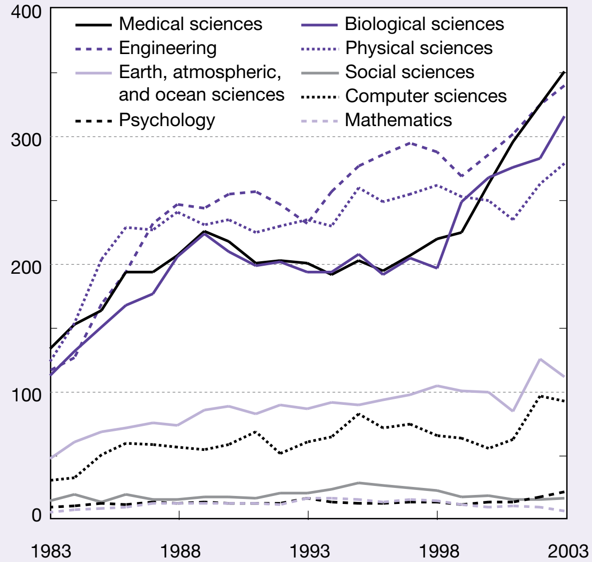


NOTES: Other institutions include all institutions except Carnegie research and doctorate-granting institutions. Institutions designated by 1994 Carnegie classification code. For information on these institutional categories, see chapter 2 sidebar, "Carnegie Classification of Academic Institutions."

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions: FY 2002,* NSF 05-309 (2005); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-12.

Science and Engineering Indicators 2006

Figure 5-15
Current fund expenditures for research equipment at academic institutions, by field: 1983–2003



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 2000 dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures: Fiscal Year 2003* (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-13.

Science and Engineering Indicators 2006

Expenditures

In 2003, about $1.8 billion in current funds was spent for academic research equipment. About 81% of these expenditures were concentrated in three fields: the life sciences (45%), engineering (20%), and the physical sciences (16%) (figure 5-15; appendix table 5-13).

Current fund expenditures for academic research equipment grew at an average annual rate of 4.6% (in constant 2000 dollars) between 1983 and 2003. However, recent annual growth (since 2000) was almost 6%, compared with less than 1% during the 1990s. The growth patterns in S&E fields varied during this period. For example, equipment expenditures for engineering (5.5%) and the biological sciences (5.2%) grew more rapidly during the 1983–2003 period than did those for the social sciences (0.7%) and agricultural sciences (0.5%).

Federal Funding

Federal funds for research equipment are generally received either as part of research grants or as separate equipment grants, depending on the funding policies of the particular federal agencies involved. The importance of federal funding for research equipment varies by field. In 2003, the social sciences received about 45% of their research equipment funds from the federal government; in contrast, federal support accounted for more than 70% of equipment funding in the physical sciences, mathematics, the computer sciences, psychology, and the earth, atmospheric, and ocean sciences (appendix table 5-14). The share of research equipment expenditures funded by the federal government declined from 62% to 55% between 1983 and 2001, but thereafter rose to 63% in 2003. This overall pattern masks different trends in individual S&E fields.

R&D Equipment Intensity

R&D equipment intensity is the percentage of total annual R&D expenditures from current funds devoted to research equipment. This proportion has been declining fairly steadily since reaching its peak in 1986 (7%). By 2003, it had declined to 5% (appendix table 5-15). R&D equipment intensity varies across S&E fields, tending to be higher in the physical sciences (about 9% in 2003) and lower in the social sciences (1%) and psychology (3%).

Several years ago, Congress requested that an NSF National Survey of Academic Research Instrumentation, last conducted in 1994, be reinstated to determine the extent to which a lack of equipment and instrumentation prevents the academic research community from undertaking cutting-edge, world-class science. NSF is investigating the feasibility of obtaining such information.

Academic R&D Infrastructure

The physical infrastructure of academic institutions is critical to supporting R&D activities. Traditional indicators of the status of the research infrastructure are the amount of research space currently available and the amount of investment in future facilities. Furthermore, the quality of research space is a key factor in the types of research that can be undertaken.

In addition to the traditional "bricks and mortar" research infrastructure, "cyberinfrastructure" is playing an increasingly important role in the conduct of S&E research. Technological advances are significantly changing S&E research methods. In some cases, advanced technology is already changing the role of traditional bricks and mortar facilities. According to the NSF Advisory Panel on Cyberinfrastructure, these advances are not simply changing the conduct of science but are revolutionizing it (NSF 2003). The panel defined *cyberinfrastructure* as the "infrastructure based upon distributed computer, information and communication technology" (NSF 2003, p 1.2). The report discusses the current and potential future importance of cyberinfrastructure, stating that "digital computation, data, information and networks are now being used to replace and extend traditional efforts in science and engineering research" (NSF 2003, p 1.1).

At this time, how the relationship between cyberinfrastructure and traditional bricks and mortar infrastructure will play out is unknown. Access to high-quality research facilities may become available to researchers located at institutions where traditional research space has not been available. Some institutions now indicate they need less physical space as they begin to conduct research not in their own laboratories or research facilities but through networking and/or high-performance computing, communicating with research facilities thousands of miles away or accessing very large databases generated by advanced data collection technologies.

Bricks and Mortar

Research Space. Research-performing colleges and universities[13] continued to expand their stock of research space in FY 2003 with the largest increase in total research space since 1988. By the end of FY 2003, total research space increased 11% from FY 2001 to approximately 173 million net assignable square feet (NASF)[14] (table 5-2). This increase was substantially greater than any previous 2-year increase since FY 1988 and continued a trend of increases in the amount of academic research space. During this 15-year period, the amount of research space increased biennially at a rate of at least 4%.

Except for the agricultural sciences, all S&E fields experienced increases in research space between FY 2001 and FY 2003. Two fields, the computer sciences and mathematics, experienced the largest increases (but their total space was the smallest among all S&E fields). Social science space increased by 27%. Growth in medical sciences research space, 26%, was the fourth highest, reaching 35 million NASF. Only the biological sciences had more research space (36 million NASF). These two fields, combined with engineering, accounted for 57% of all research space at the end of FY 2003.

Little change occurred in the distribution of research space across S&E fields during this 15-year period. The largest increase in the share of total research space occurred in the medical sciences. However, this share only changed 3 percentage points between 1988 and 2003. The engineering

Table 5-2
S&E research space in academic institutions, by field: FY 1988–2003
(Millions of net assignable square feet)

Field	1988	1990	1992	1994	1996	1998	1999	2001	2003
All fields	112	116	121	127	136	143	148	155.1	172.6
Physical sciences	16	16	17	17	18	18	19	19.2	20.4
Mathematics	1	1	1	1	1	1	1	1.0	1.5
Computer sciences	1	1	2	2	2	2	2	2.4	3.1
Earth, atmospheric, and ocean sciences	6	6	7	7	7	8	8	8.1	8.9
Agricultural sciences	18	21	20	20	22	25	24	27.8	26.4
Biological sciences	24	27	28	28	30	31	31	33.4	36.0
Medical sciences	19	20	23	23	25	25	26	27.8	34.9
Psychology	3	3	NA	3	3	3	4	4.5	4.4
Social sciences	3	3	NA	3	4	5	3	4.5	5.7
Other sciences	4	2	2.0	2	2	3	3	3.0	3.8
Engineering	16	17	21	21	22	23	24	25.5	27.4
Animal research space	NA	NA	NA	11	12	12	13	NA	16.7

NA = not available

NOTES: Animal research space listed separately and also included in individual field totals. Detail may not add to total because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Years 1988–2003.

Science and Engineering Indicators 2006

share of total research space increased 2 percentage points. The largest decrease, only 2 percentage points, occurred in the physical sciences.

Construction of Research Space. Universities invested $7.6 billion in FY 2002–03 in the construction of 16 million NASF of research space (appendix tables 5-16 and 5-17).[15] Almost half of all universities began construction projects (NSF/SRS forthcoming).

Although universities began construction of research space in all S&E fields in FY 2002–03, the largest share of space under construction (56%) was for research in the medical sciences and biological sciences (appendix table 5-17). Fifty-six percent of research space construction started in FY 2002 or FY 2003 is to be used for research in these two fields. If engineering research space is included, these three fields account for about 70% of the new construction started. Even if some newly constructed space replaces existing space, the share of newly constructed space in the medical sciences (31%) was substantially greater than that of any other field, and therefore would not likely change the overall field distribution. The biological sciences, which had the second largest share, accounted for 25% of newly constructed research space.

If the universities were able to follow through on planned construction for FY 2004 and FY 2005, the medical sciences and biological sciences will likely continue to dominate the share of total research space (appendix table 5-17). Universities plan to construct 19 million NASF of research space during this period at an estimated cost of $9.1 billion. The biological sciences and medical sciences will account for 53% of the planned space and 61% of estimated construction costs (appendix tables 5-16 and 5-17).

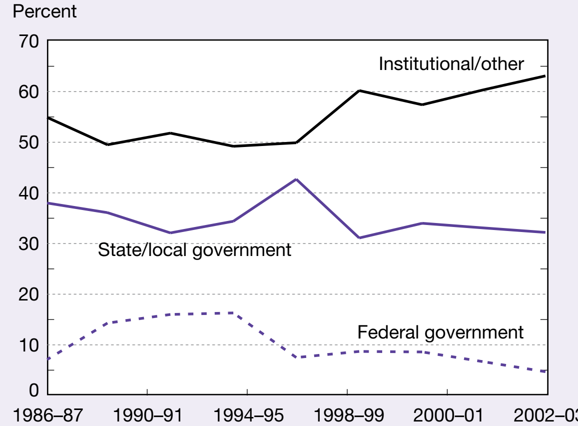
Funds for Construction. Institutions use one or more sources to fund their capital projects, including the federal government, state or local governments, and the institutions' own funds.[16] The federal government's share of total construction funding has been declining and reached its smallest proportion (5%) since 1986–87 in FY 2002–03 (figure 5-16; appendix table 5-18). During the same period, the institutional share of construction funds increased overall and reached its highest share, 63%, in FY 2002–03.

Over time, the share of institutional funds universities and colleges have allocated for repair/renovation of research space has been consistently greater than the share they have allocated for construction. However, even for repair/renovation, the institutional share of total funds reached its highest level since 1988, 71%, in FY 2002–03 (NSF/SRS forthcoming).

Unmet Needs. Determining the capital infrastructure needs of universities has at least several dimensions. Two indicators of need are the dollar value of deferred projects and the quality of existing space.

Deferred projects are projects in a university's institutional plans that are needed for current program commitments but that have not yet been funded and therefore are not scheduled to begin. Institutions reported approximately $8.4 billion in deferred construction projects in FY 2003 (appendix table 5-16). More than half of this deferred construction was in the biological sciences and medical sciences.

Figure 5-16
Source of funds for construction: 1986–87 to 2002–03



NOTE: Data extrapolated for 2000–01 period because data not collected.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Years 1986–2003. See appendix table 5-18.

Science and Engineering Indicators 2006

There are no objective criteria to determine how much of a field's research actually requires state-of-the-art space. However, space rated as needing replacement *can* be seen as an indicator of need. In FY 2003, institutions rated 30% of their existing space as state of the art and 79% as either state of the art or suitable for most levels of research and reported that 5% should be discontinued as research space within the next 2 years (appendix table 5-19).[17] The amount of space needing replacement varied little by field, ranging from 7% in the social sciences and earth, atmospheric, and ocean sciences to 2% in mathematics.

Perhaps not surprisingly, the computer sciences, the field that had the greatest amount of relative growth in research space between FY 2001 and FY 2003, rated the largest percentage of its space as state of the art. The medical sciences, another field that experienced a large increase in the amount of new space during this period, had the second highest amount of space rated as state of the art.

Cyberinfrastructure: Networking

Networking resources are a key component of cyberinfrastructure. Networks allow users and researchers to communicate and transfer data both within a specific institution's boundaries and with others around the world. At many institutions, the same networks are used for multiple academic functions such as instruction, research, and administration.[18]

All academic institutions today have network connections to the *commodity Internet,* or *Internet1,* the network commonly known as the Internet. Although Internet connections are used for many purposes (e.g., e-mail, buying books from the campus bookstore), conducting research can require higher capabilities of network connections than other activities.

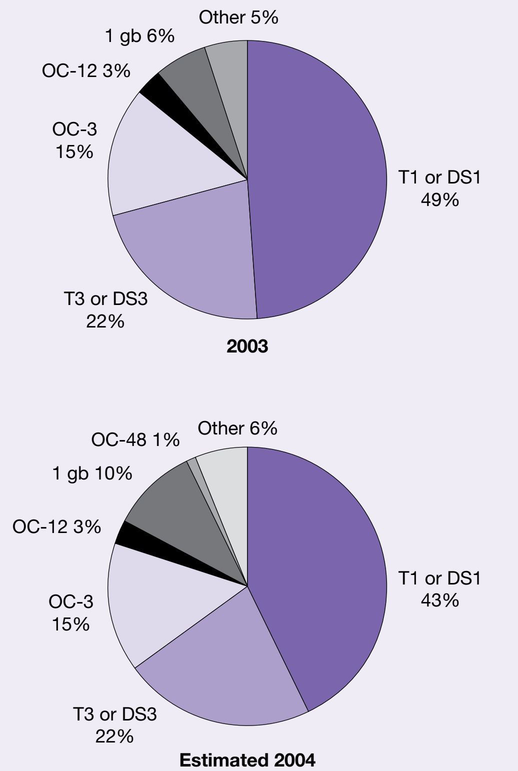
There are numerous indicators of network capability. One common indicator is bandwidth, or speed. A network's bandwidth can affect the amount and type of research activity accomplished through the network. The faster the network speed, the more capable the network is in handling both large amounts of data and communication traffic and more demanding or sophisticated communications. Whereas a slow network connection might well be able to transmit scientific articles, transmitting scientific instruments located thousands of miles away or accessing large databases demands (among other requirements) high bandwidth or fast speed.

Desktop Connection Speed. The speed of the desktop computer's connection to the campus network will likely differ from that of the campus network's connection to the Internet. Generally, researchers access the Internet from their desktop computers. Therefore, the speed of the desktop connection to the institution's campus network is one useful indicator of an institution's network capability. Desktop connection speeds will vary across an institution. Almost 75% of academic institutions reported the highest operating speed of the majority of their desktop connections (ports) as 100 megabits/second in FY 2003, and 1% reported it as 1 gigabit/second (NSF/SRS forthcoming).

In FY 2003, 76% of non-doctorate-granting institutions had the majority of their desktop connections at 100 megabits/second or faster, compared with 71% of doctorate-granting institutions (appendix table 5-20). However, only 19% of non-doctorate-granting institutions estimated their *highest* speed as 1 gigabit/second, compared with 46% of doctorate-granting institutions. Most institutions planned to obtain faster connection speeds in FY 2004, and 52% of all institutions estimated that their highest connection speed would be 1 gigabit/second at the end of FY 2004.

Internet Connection Speed. Another critical point is the connection between the institution's campus network and the Internet. At the end of FY 2003, most universities had multiple connections to the Internet at a variety of speeds. The majority (49%) were at the lowest speed, 1.5 megabits/second (i.e., T1 or DS1 lines). The second largest share of connections (22%) was at the next lowest speed, 45 megabits/second (i.e., T3 or DS3 lines). Together, these two speeds accounted for 71% of connections (figure 5-17; appendix table 5-21). However, at least 6% of connections were at 1 gigabit/second or faster. Doctorate-granting institutions had the largest number of high-speed connections. Although the greatest *number* of connections was at 1.5 or 45 megabits/second, the *highest connection speed* was 155 megabits/second or faster at 45% of all institutions and 1 gigabit/second or faster at 12% (table 5-3).

Figure 5-17
Internet connection speed: 2003 and 2004



gb = gigabits/second

NOTE: 2004 data estimated.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Year 2003. See appendix table 5-21.

Science and Engineering Indicators 2006

Overall, institutions did not anticipate a large increase in the total number of Internet connections between FY 2003 and FY 2004. However, institutional plans overall called for fewer connections at slower speeds and a larger number at faster speeds, estimating a 4% increase in the number of connections at speeds of 1 gigabit or higher by the end of FY 2004. Both doctorate-granting and non-doctorate-granting institutions anticipated increases in connection speeds. In fact, non-doctorate-granting institutions estimated fewer total connections overall but more at higher speeds. Furthermore, both doctorate- and non-doctorate-granting institutions expected to increase the speed of their highest speed connections by the end of FY 2004.

Wireless and High-Performance Network Connections. In addition to their hardwire network connections, many universities have wireless Internet connections as well as connections to advanced or high-performance networks. High-performance networks are not only faster than the Internet but also have other characteristics important to conducting research. At the end of FY 2003, 65% of academic institutions had connections to Abilene (often called *Internet2*) (NSF/SRS

Table 5-3
Highest institutional connection speed to commodity Internet (Internet1), by type of institution: FY 2003 and 2004
(Percent distribution)

Type of institution	Number of connections	T1/DS1 (1.5 mb)	T3/DS3 (45 mb)	OC-3 (155 mb)	OC-12 (622 mb)	1 gb	OC-48 (2.4 gb)	Other
FY 2003								
All academic	424	9	36	29	4	11	1	10
Doctorate granting	301	6	29	32	6	14	1	12
Nondoctorate granting	123	15	54	20	2	2	1	7
FY 2004 (estimated)								
All academic	420	5	33	26	6	16	1	13
Doctorate granting	299	5	25	28	7	20	1	14
Nondoctorate granting	121	7	51	22	3	7	1	9

mb = megabits/second; gb = gigabits/second

NOTES: Some institutions reported connection speeds in category "other." Detail may not add to total because of rounding or absence of commodity Internet (Internet1) connection.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Year 2003.

Science and Engineering Indicators 2006

forthcoming), a high-performance network dedicated to research led by a consortium of universities, governments, and private industry. A substantially larger proportion (79%) of doctorate-granting institutions had Abilene connections as compared with non-doctorate-granting institutions (28%).

Although wireless networking is used less frequently for research, universities are moving toward greater institutional coverage by wireless networking. At the end of FY 2003, 67% of institutions had 20% or less of their building areas covered by wireless network connections (NSF/SRS forthcoming). However, less than 30% estimated that their coverage would be 20% or less by the end of FY 2004.

Doctoral Scientists and Engineers in Academia

The pursuit of new knowledge, the training of the people in whom that knowledge is embodied, and its use in generating innovation make academia a national resource whose vitality rests in the scientists and engineers who study and work there. Especially important are those with doctorates who do the research, teach and train the students, and stimulate or help to produce innovation.[19]

Employment and research activity at the leading research-performing universities in the United States merit special attention.[20] These institutions have a disproportionate influence on the nation's academic science, engineering, and R&D enterprise. Although they enroll only 22% of full-time undergraduates and award 32% of all bachelor's degrees, they award 39% of bachelor's degrees in S&E fields. Of U.S. S&E doctorate holders with a U.S. baccalaureate degree, research universities are the source of 55% of all of them and the source of more than 60% of those who are employed in academia and report R&D as their primary work activity. Moreover, these institutions conduct more than 80% of academic R&D (as measured by expenditures) and produce the bulk of both academic articles and patents. (See "Outputs of S&E Research: Articles and Patents" later in this chapter.)

Growth in academic employment over the past half century reflected both the need for teachers, driven by increasing enrollments, and an expanding research function, largely supported by federal funds. Trends in indicators related to research funding are presented earlier in this chapter. This section presents indicators about academic personnel. Unless otherwise indicated, the discussion is limited to those who received their S&E doctorate at a U.S. institution. Because of the complex interrelationship between academic teaching and research, much of the discussion deals with the overall academic employment of S&E doctorate holders, specifically, the relative balance between faculty and nonfaculty positions, demographic composition, faculty age structure, hiring of new doctorate holders, trends in work activities, and trends in federal support. The section also examines the academic research workforce: its definition and size; its deployment across institutions, positions, and fields; and the extent to which it is receiving federal support. Finally, a previously mentioned sidebar, "Has Academic R&D Shifted Toward More Applied Work?," briefly discusses whether a shift away from basic research toward more applied R&D activities has been occurring.

The main findings are a relative shift in the employment of S&E doctorate holders away from the academic sector toward other sectors; a slower increase in full-time faculty positions than in postdoc and other full- and part-time positions; a relative shift in hiring away from white males toward women and minorities; an increasing proportion of foreign-born faculty and postdocs; an aging academic doctoral labor force; a decline in the share of academic researchers who report receiving federal support; and growth of an academic researcher pool outside the regular faculty ranks.

Trends in Academic Employment of Doctoral Scientists and Engineers

Academic employment of S&E doctorate holders reached a record high of 258,300 in 2003.[21] However, long-term growth in the number of these positions between 1973 and 2003 was slower than in either business or government. Growth in the academic sector was also much slower between 1983 and 2003 than it was between 1973 and 1983 (table 5-4). As a result, the share of all S&E doctorate holders employed in academia dropped from about 55% to 45% during the 1973–2003 period (table 5-5). Beginning in the 1990s, the share of those with recently awarded degrees (that is, a degree awarded within 3 years of the survey year) employed in academia was generally substantially higher than the overall academic employment share for S&E doctorate holders, possibly reflecting the relatively large number of young doctorate holders in postdoc positions. In 2003, more than half of recent doctorate holders were employed in academia.

Academic Hiring

Employment growth over the past decade was much slower at the research universities than at other academic institutions. Appendix table 5-22 breaks down academic employment by type of institution. From 1993 to 2003, doctoral S&E employment at research universities grew by 1.2% annually, whereas employment at other institutions increased by 2.6% annually. During the same period, employment increased slightly less rapidly at public universities and colleges than at their private counterparts (1.2% versus 1.4% a year) and employment at both public and private research universities grew much more slowly than overall employment (figure 5-18; table 5-4; appendix table 5-23).

All Academic S&E Doctoral Employment

Trends in academic employment of S&E doctorate holders suggest continual movement away from the full-time faculty position as the academic norm. Overall academic employment of S&E doctorate holders grew from 118,000 in 1973 to 258,300 in 2003 (appendix table 5-24). However, during this period, full-time faculty positions increased more slowly than postdoc and other full- and part-time positions. This trend accelerated between 1993 and 2003, with the full-time faculty growth rate at less than two-thirds the overall growth rate (table 5-6).

Figure 5-19 shows the resulting distribution of academic employment of S&E doctorate holders. The overall faculty share was 75% of all academic employment in 2003, down from 87% in the early 1970s. The share of full-time senior faculty fell from just over 60% of total employment in 1993 to less than 55% in 2003. The share of junior faculty fluctuated between 18% and 21% between 1983 and 2003. These employment trends, particularly during the 1993–2003 period, occurred as real spending for academic R&D rose by two-thirds, retirement of faculty who were hired during the 1960s increased, academic hiring of young doctorate holders showed a modest rebound, and universities displayed greater

Table 5-4
Average annual growth rate for employment of S&E doctorate holders in U.S. economy: 1973–2003
(Percent)

Sector	1973–2003	1973–83	1983–93	1993–2003
All sectors	3.3	5.4	2.5	2.0
Academia	2.6	4.1	2.0	1.9
Research universities	2.2	3.2	2.3	1.2
Other	3.2	5.0	1.6	2.6
Business	4.9	7.9	4.1	2.7
Government	3.7	5.5	2.5	3.1
Other	1.4	5.3	0.5	–1.6

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

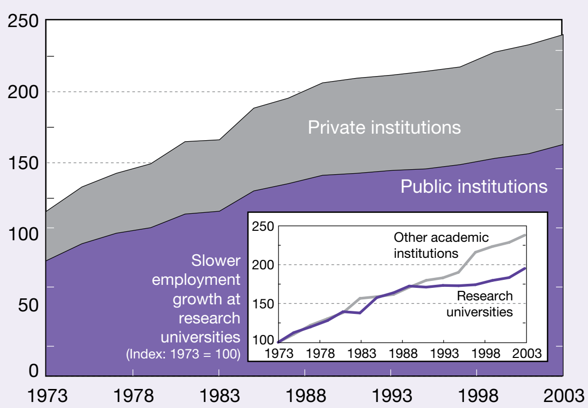
Table 5-5
S&E doctorate holders employed in academia, by years since doctorate: Selected years, 1973–2003
(Percent)

Years since doctorate	1973	1983	1993	2003
Employed doctorate holders	54.8	48.4	45.9	45.5
≤3	55.2	48.0	50.5	53.5
4–7	55.8	44.9	47.0	46.2
>7	54.2	49.4	45.0	44.2

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

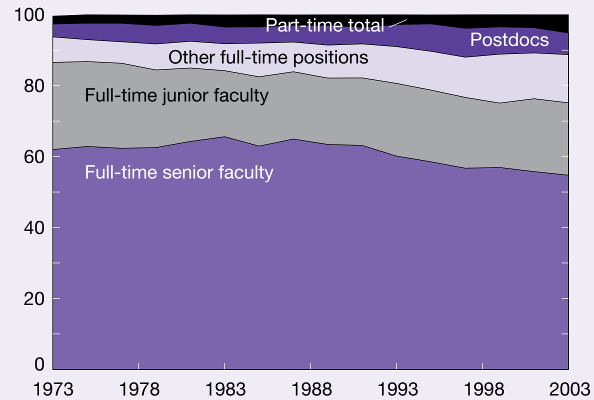
Figure 5-18
S&E doctorate holders employed in public and private universities and colleges: 1973–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-23.

Science and Engineering Indicators 2006

Figure 5-19
S&E doctorate holders, by type of academic appointment: 1973–2003



NOTES: Junior faculty includes assistant professors and instructors. Senior faculty includes full and associate professors. Other full-time positions include nonfaculty positions such as research associates, adjunct appointments, lecturers, and administrative positions.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-23.

Science and Engineering Indicators 2006

interest in the practical application of academic research results (discussed later in this chapter).[22]

Nonfaculty ranks, that is, full- and part-time adjunct faculty, lecturers, research and teaching associates, administrators, and postdocs, increased from 41,400 in 1993 to 64,200 in 2003. This 55% increase stood in sharp contrast to the 13% rise in the number of full-time faculty. Both the full-time nonfaculty and part-time components grew rapidly between 1993 and 2003. Postdocs rose more slowly during this period and, in fact, actually declined after 1997 after quite substantial growth up to that year.[23] Part-time employees accounted for only a small share (between 2% and 4%) of all academic S&E doctoral employment throughout most of the period before rising to just above 5% in 2003 (appendix table 5-24).

Recent S&E Doctorate Holders

The trends discussed above reflect the entire academic workforce of S&E doctorate holders. Another picture of current trends can be found by looking at the academic employment patterns of those with recently awarded S&E doctorates (degrees earned at U.S. universities within 3 years of the survey year).

Table 5-6
Average annual growth rate for S&E doctorate holders, by academic position: 1973–2003
(Percent)

Academic position	1973–2003	1973–83	1983–93	1993–2003
All positions	2.6	4.1	2.0	1.9
Full-time faculty	2.1	3.7	1.5	1.2
Professors	2.4	5.1	1.4	0.9
Associate professors	1.8	3.8	0.6	1.1
Junior faculty	2.0	1.1	2.9	1.9
Full-time nonfaculty	5.3	5.9	5.2	4.7
Postdocs	4.5	7.2	4.8	1.7
Part-time positions	5.2	7.4	–0.2	8.4

NOTES: Junior faculty includes assistant professors or instructors. Nonfaculty includes positions such as research associates, adjunct appointments, lecturers, and administrative positions.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-23.

Science and Engineering Indicators 2006

Recent S&E doctorate holders who entered academic employment at research universities were more likely to be in postdoc than in faculty positions (figure 5-20; appendix table 5-25). Between 1973 and 2003, the share of recent doctorate holders hired into full-time faculty positions fell by more than 40%, from 74% to 44%. The decline in such employment at research universities was slightly steeper, from 60% to 31%. Conversely, the overall share of recent S&E doctorate holders who reported being in postdoc positions rose from 13% to 34% (from 22% to 48% at research universities). However, after increasing throughout the 1990s, the share of recent S&E doctorate holders in postdoc positions reached its peak level in 1999, after which it declined overall and at research universities.

Young Doctorate Holders With a Track Record

For those employed in academia 4–7 years after earning their doctorates, the picture looks quite similar: about 65% had faculty rank in 2003, compared with about 89% in 1973. Before increasing slightly between 2001 and 2003, the trend had been continuing downward since 1991. A little more than half of these doctorate holders were in tenure-track positions in 2003, with about 13% already tenured. The shares of both those in tenure-track positions and those with tenure declined between 1991 and 2001 and increased in 2003. Whether or not the 2003 figures mark the beginning of a trend remains to be seen (figure 5-21). Trends at research universities were similar. However, at the research universities, the share of those in faculty, tenured, or tenure-track positions was much smaller than at other academic institutions (appendix table 5-25).

Shift in Employment

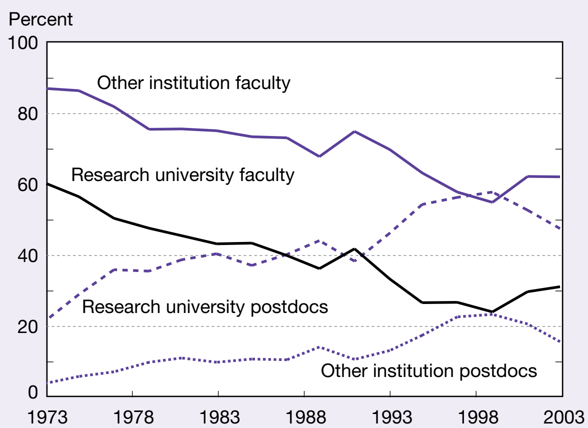
The relative shift toward nonfaculty employment affected almost every major S&E degree field. The share of all doctoral employment held by full-time faculty was lower in 2003 than in 1993 in every broad S&E field. However, in many of these fields, the relative shift toward nonfaculty positions appears to have slowed or leveled off toward the end of this period (appendix table 5-24).

Retirement of S&E Doctoral Workforce

The trend toward relatively fewer full-time faculty and relatively more full-time nonfaculty and postdoc positions is especially noteworthy because academia is approaching a period of increasing retirements. In the 1960s, the number of institutions, students, and faculty in the United States expanded rapidly, bringing many young doctorate holders into academic faculty positions. This growth slowed sharply in the 1970s, and faculty hiring has since continued at a more modest pace. The result is that an increasing number and proportion of faculty are today reaching or nearing retirement age.[24]

The Age Discrimination in Employment Act of 1967 became fully applicable to universities and colleges in 1994.[25] It prohibits the forced retirement of faculty at any age, raising concerns about the potential ramifications of an aging professoriate. Sufficient data have now accumulated to allow examination of some of these concerns. Figure 5-22 shows the age distribution of academic S&E doctorate holders, and figure 5-23 displays the percentage that are age 60 or older.

Figure 5-20
S&E doctorate holders with recent degrees employed at research universities and other academic institutions, by type of position: 1973–2003

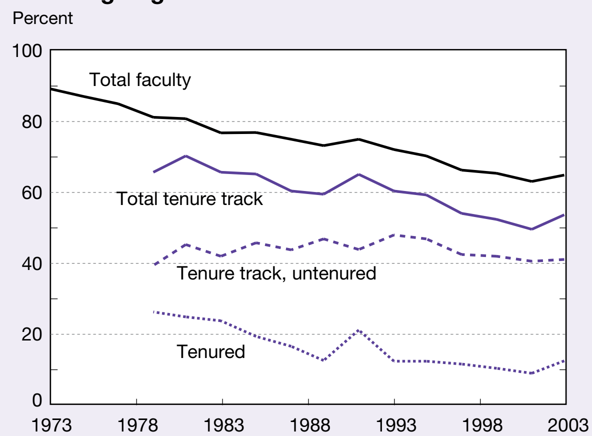


NOTES: Recent doctorate holders earned degrees within 3 years of survey. Faculty employed full time as full, associate, and assistant professors and instructors. Not all positions are shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-25.

Science and Engineering Indicators 2006

Figure 5-21
Faculty and tenure-track status of S&E doctorate holders employed in academia 4–7 years after receiving degree: 1973–2003

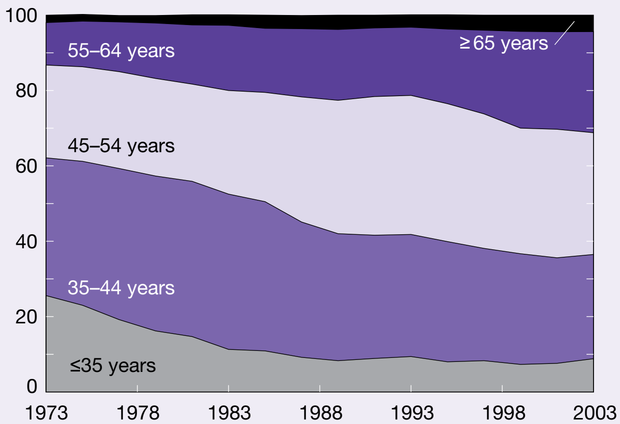


NOTES: Faculty positions include full, associate, and assistant professors and instructors. Tenure-track data not available for 1973–77.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-25.

Science and Engineering Indicators 2006

Figure 5-22
Age distribution of academic S&E doctorate holders employed in faculty positions: 1973–2003

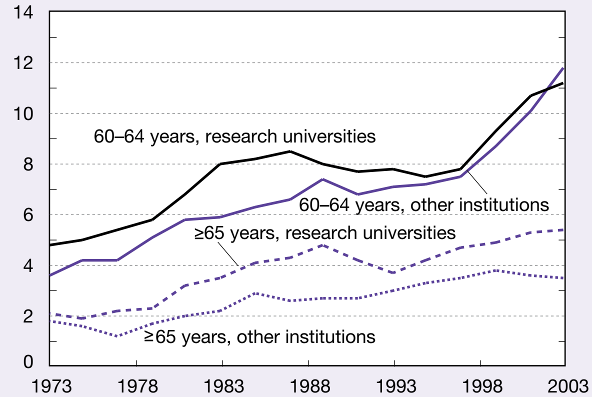


NOTE: Faculty employed full time as full, associate, and assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-26.

Science and Engineering Indicators 2006

Figure 5-23
Full-time faculty age 60 years and over at research universities and other higher education institutions: 1973–2003



NOTE: Faculty positions include full, associate, and assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-27.

Science and Engineering Indicators 2006

The data indicate that until recently, individuals age 65 or older (and 70 years or older) constituted a growing share of the S&E doctorate holders employed in academia, suggesting that the Age Discrimination in Employment Act may in fact have had some impact on the age distribution of the professoriate. The data also show that the share of those ages 60–64 was rising well before the act became mandatory, leveled off in the early 1990s, and began to rise again after 1995, reaching just below 12% in 2003. A similar progression can be seen for those age 65 or older, who in 2003 made up over 5% of the research universities' full-time faculty and less than 4% of other institutions' full-time faculty. The employment share of those older than 70 also rose during most of the past three decades, reaching more than 1% of all S&E doctorate holders and all full-time faculty employed in academia in 2001 before dropping to just below 1% for both groups in 2003 (figure 5-23; appendix tables 5-26 and 5-27).

Increasing Role of Women and Minority Groups

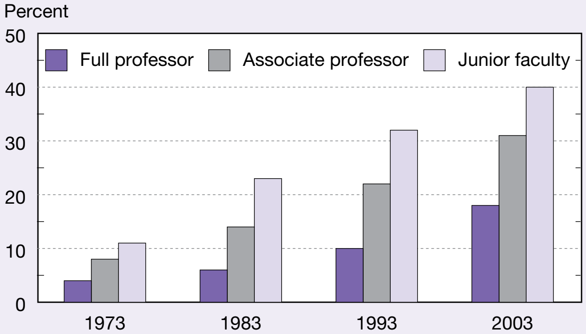
Women and underrepresented minority groups constitute a pool of potential scientists and engineers that has not been fully tapped and that, in the case of underrepresented minorities, represents a growing share of U.S. youth, estimated to reach 36% of the college-age population by 2020 (see appendix table 2-4). An accumulating body of research points to the importance of role models and mentoring to student success in mathematics, science, and engineering, especially for women and underrepresented minorities.[26] Thus, the presence of women and underrepresented minorities among faculty on college campuses may be a factor in the recruitment of students from both groups to the S&E fields.

Women

The academic employment of women with S&E doctorates rose sharply between 1973 and 2003, reflecting the increase in the proportion of women among recent S&E doctorate holders. The number of women with S&E doctorates in academia increased more than sevenfold during this period, from 10,700 in 1973 to an estimated 78,500 in 2003 (appendix table 5-28), as compared with about a 70% increase for men. This increase is reflected in the rising share of women among S&E doctorate holders in academic positions. In 2003, women constituted 30% of all academic S&E doctoral employment and just below 28% of full-time faculty, up from 9% and 7%, respectively, in 1973. Women made up a smaller share of total employment at research universities than at other academic institutions at both the beginning and end of this period, with the differential diminishing marginally throughout the period (table 5-7). Compared with male faculty, female faculty remained relatively more heavily concentrated in the life sciences, social sciences, and psychology, with correspondingly lower shares in engineering, the physical sciences, and mathematics.

Women hold a larger share of junior faculty positions than positions at either the associate or full professor rank. However, their share of all three positions rose substantially between 1973 and 2003. In 2003, women constituted 18% of full professors, 31% of associate professors, and 40% of junior faculty, the latter roughly in line with their share of recently earned S&E doctorates[27] (figure 5-24; appendix table 5-28). These trends reflect the recent arrival of significant numbers of women doctorate holders in full-time academic faculty positions.

Figure 5-24
Share of doctoral S&E faculty positions held by women, by rank: Selected years, 1973–2003



NOTE: Junior faculty includes assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

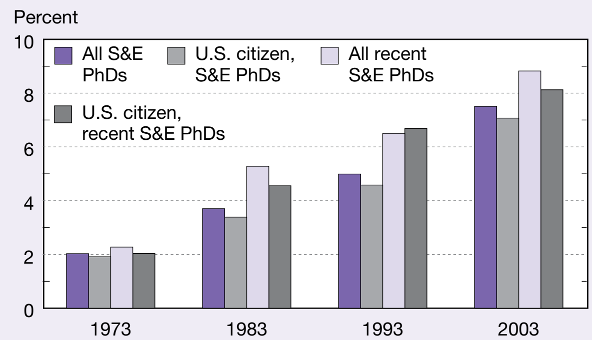
Underrepresented Minority Groups

The U.S. Census Bureau's demographic projections have long indicated an increasing prominence of minority groups among future college- and working-age populations. With the exception of Asians/Pacific Islanders, these groups tended to be less likely than whites to earn S&E degrees or work in S&E occupations.[28] Private and governmental groups have sought to broaden the participation of blacks, Hispanics, and American Indians/Alaska Natives in these fields, with many programs targeting their advanced training through the doctorate level.

The absolute rate of conferral of S&E doctorates on members of underrepresented minority groups has increased, as has academic employment; but taken together, blacks, Hispanics, and American Indians/Alaska Natives remain a small percentage of the S&E doctorate holders employed in academia (appendix table 5-29). Because the increases in hiring come from a very small base, these groups constituted only about 8% of both total academic employment and full-time faculty positions in 2003, up from about 2% in 1973. Underrepresented minorities constituted a smaller share of total employment at research universities than at other academic institutions throughout this period (table 5-7). However, among recent doctorate holders, they represented almost 9% of total academic employment and nearly 12% of full-time faculty positions.

These trends are similar for all underrepresented minorities and for those who are U.S. citizens (figure 5-25). Compared with whites, blacks tended to be relatively concentrated in the social sciences and psychology and relatively less

Figure 5-25
Share of underrepresented minorities among S&E doctorate holders employed in academia, by citizenship status and years since degree: Selected years, 1973–2003



NOTES: Denominator always refers to set of individuals defined in legend. Underrepresented minorities include blacks, Hispanics, and American Indians/Alaska Natives. Recent doctorate holders earned degrees within 3 years of survey.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

Table 5-7
Female and minority S&E doctorate holders employed in academia, by Carnegie institution type: Selected years, 1973–2003
(Percent)

Group and institution type	1973	1983	1993	2003
Female				
Research universities	7.4	13.7	20.2	29.1
Other academic institutions	11.2	16.4	23.8	31.6
Underrepresented minority				
Research universities	1.3	3.0	4.1	6.8
Other academic institutions	2.9	4.5	6.0	8.9
Asian/Pacific Islander				
Research universities	4.7	7.4	11.3	15.1
Other academic institutions	3.8	6.0	8.0	11.7

NOTES: Institutions designated by 1994 Carnegie classification code. For more information on these institutional categories, see Carnegie Foundation for the Advancement of Teaching, *A Classification of Institutions of Higher Education*, Princeton University Press (1994), and chapter 2 sidebar, "Carnegie Classification of Academic Institutions." Underrepresented minority includes blacks, Hispanics, and American Indians/Alaska Natives.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

represented in the physical sciences; the earth, atmospheric, and ocean sciences; mathematics; and the life sciences. The field distribution of Hispanic degree holders is similar to that of white degree holders.

Asians/Pacific Islanders

Asians/Pacific Islanders more than tripled their employment share in the S&E academic doctoral workforce between 1973 and 2003, increasing from 4% to 13% (appendix table 5-29). However, a distinction needs to be made between those who are U.S. citizens and those who are not because the latter group constituted close to 40% of this group's doctorate holders in the academic S&E workforce in 2003.[29] The employment share of Asians/Pacific Islanders who are U.S. citizens grew from about 2% of the total academic S&E doctoral workforce in 1973 to just above 9% in 2003, a magnitude of growth similar to that of underrepresented minorities (figure 5-26). Asians/Pacific Islanders, whether or not they are U.S. citizens, represent a larger percentage of total employment at research universities than at other academic institutions (table 5-7). Limiting the analysis to recent S&E doctorate holders leads to even more dramatic differences between Asians/Pacific Islanders who are U.S. citizens and those who are not. Whereas the Asian/Pacific Islander share of all recent S&E doctorate holders employed in academia rose from 5% in 1973 to almost 22% in 2003, the share of those who are U.S. citizens increased from 1% to 8% (figure 5-26).

Compared with whites, Asians/Pacific Islanders as a whole are more heavily represented in engineering and computer sciences and represented at very low levels in psychology and social sciences. This finding holds both for U.S. citizens and for all Asians/Pacific Islanders. In 2003, Asians/Pacific Islanders constituted 29% of academic doctoral computer scientists and more than 23% of engineers (appendix table 5-29)

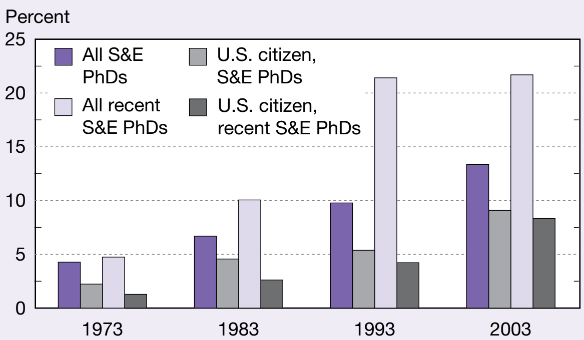
Whites

The relative prominence of whites, particularly white males, in the academic S&E doctoral workforce diminished between 1973 and 2003 (figure 5-27). In 2003, whites constituted 79% of the academic doctoral S&E workforce, compared with 91% in 1973 (table 5-8; appendix table 5-29). The share of white males declined from about 83% to about 55% during this period. The decline in the shares of whites and white males who recently received their doctorates was even greater, from 91% to 68% and from 80% to 38%, respectively. Part of the decline is due to the increasing roles played by women, underrepresented minorities, and Asians/Pacific Islanders. However, the decline in share is not the whole story. During the 1990s, the absolute number of white males in the academic doctoral S&E workforce who recently received their doctorates was virtually unchanged.

Foreign-Born S&E Doctorate Holders

An increasing number and share (23%) of S&E doctorate holders who earned U.S. degrees and are employed at U.S. universities and colleges are foreign born (appendix table 5-30). Like other sectors of the economy, academia has long relied extensively on foreign talent among its faculty, students, and other professional employees. This reliance increased fairly steadily between 1973 and 2003. Figure 5-28 divides holders of U.S. S&E doctorates employed in

Figure 5-26
Share of Asians/Pacific Islanders among S&E doctorate holders employed in academia, by citizenship status and years since degree: Selected years, 1973–2003

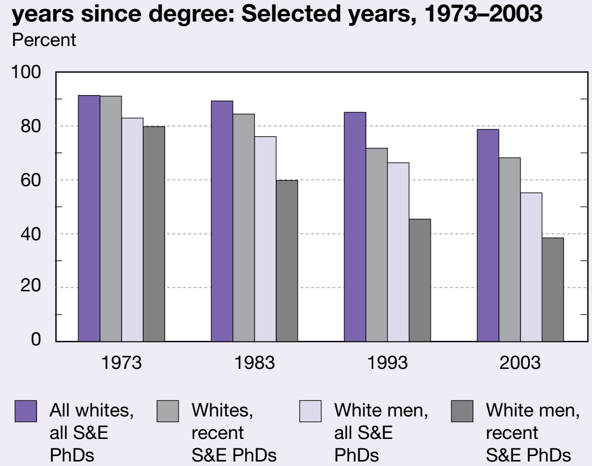


NOTES: Denominator always refers to set of individuals defined in legend. Recent doctorate holders earned degrees within 3 years of survey.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

Figure 5-27
Share of all whites and white men among S&E doctorate holders employed in academia, by years since degree: Selected years, 1973–2003



NOTE: Recent doctorate holders earned degrees within 3 years of survey.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

Table 5-8
White and white male S&E doctorate holders employed in academia, by years since degree: Selected years, 1973–2003

Group	1973 Thousands	1973 Percent	1983 Thousands	1983 Percent	1993 Thousands	1993 Percent	2003 Thousands	2003 Percent
All S&E doctorate holders	118.0	100	176.3	100	213.8	100	258.3	100
White	107.7	91	157.4	89	181.8	85	203.3	79
Male	97.8	83	134.1	76	141.8	66	142.5	55
Recent S&E doctorate holders	25.0	100	20.5	100	25.1	100	30.3	100
White	22.8	91	17.3	84	18.0	72	20.7	68
Male	20.0	80	12.3	60	11.4	45	11.7	39

NOTE: Recent doctorate holders earned their degrees within 3 years of survey year.

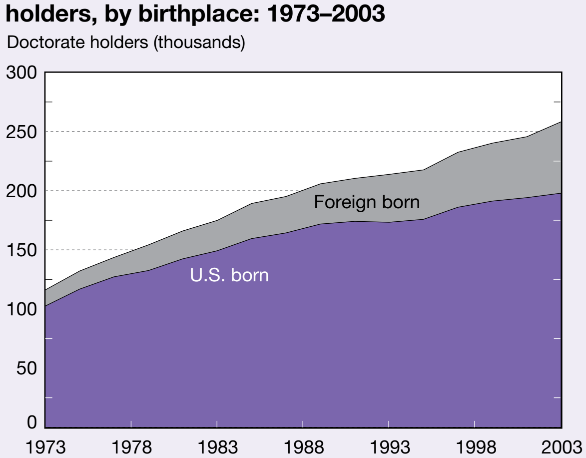
SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

academic institutions into native-born and foreign-born individuals.[30] However, in addition to foreign-born individuals who hold S&E doctorates from U.S. institutions, U.S. universities and colleges also employ a substantial number of foreign-born holders of S&E doctorates awarded by foreign universities. Preliminary estimates from the 2003 National Survey of College Graduates indicate there are approximately 36,000 in the latter group, which would increase the share of foreign-born doctoral-level scientists and engineers employed at U.S. universities and colleges to closer to 33%. The following discussion is based on holders of U.S. doctorates only unless otherwise noted. More information on foreign-born doctorate holders working in the United States can be found in chapter 3.

Employment in higher education of foreign-born S&E doctorate holders has increased continuously, both in number and share, since the late 1970s. Academic employment of foreign-born S&E doctorate holders rose from an average of about 11% of the total in 1973 to 23% in 2003, with some fields, especially computer sciences (44%) and engineering (40%), reaching considerably higher proportions. In 2003, the overall percentage of foreign-born postdocs with S&E doctorates was 43%. The percentage in the physical sciences was 57% and in engineering, 63% (appendix table 5-30).[31]

Figure 5-28
Academically employed U.S. S&E doctorate holders, by birthplace: 1973–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-30.

Science and Engineering Indicators 2006

Size of Academic Research Workforce

The interconnectedness of research, teaching, and public service in academia makes it difficult to measure the size of the academic research workforce precisely.[32] For example, a researcher may be doing full-time research in a lab and report research as his or her only activity but mentor several graduate students, which many consider a form of teaching even though no classroom instruction is involved. Two estimates of the number of academic doctoral researchers are presented here: (1) a count of those who report that research is their primary work activity and (2) a higher count of those who report that research is either their primary or secondary work activity.[33]

Postdocs and those in nonfaculty positions are included in both estimates.[34] To provide a more complete measure of the number of individuals involved in research at academic institutions, a lower bound estimate of the number of full-time graduate students who support the academic research enterprise is included, based on those whose primary mechanism of support is a research assistantship (RA). This estimate excludes graduate students who rely on fellowships, traineeships, or teaching assistantships for their primary means of support as well as the nearly 40% who are primarily self-supporting. Many of these students are also likely to be involved in research activities during the course of their graduate education.[35]

Research as Primary Work Activity

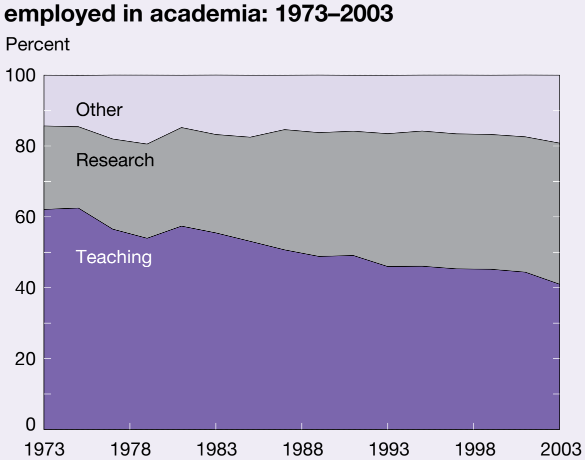
The growth of academic researchers with S&E doctorates who report research as their primary work activity has been substantial, from 27,800 in 1973 to 102,900 in 2003 (appendix table 5-31). During this period, the number of those with teaching as their primary activity increased much less rapidly, from 73,300 to 105,900. Figure 5-29 displays the resulting shifting proportions in the academic workforce. After many years of increase, the proportion of those reporting research as their primary activity began to level off in the mid-1990s, although it increased again in 2003. The drop in the proportion of those reporting teaching as their primary activity has been fairly continuous since the early 1990s.

The different disciplines have distinct patterns of relative emphasis on research, but the shapes of the overall trends are roughly the same. The life sciences stand out, with a much higher share identifying research as their primary activity and, correspondingly, a much lower share reporting teaching as their primary activity. Conversely, mathematics and the social sciences had the largest shares identifying teaching as their primary activity and the lowest shares reporting research as their primary activity (figure 5-30).

Research as Either Primary or Secondary Work Activity

The number of academic S&E doctorate holders reporting research as their primary or secondary work activity also showed greater growth than the number reporting teaching as their primary or secondary activity. The former group increased from 82,300 in 1973 to 178,700 in 2003, whereas the latter group increased from 94,900 to 160,000 (appendix table 5-32).[36]

Figure 5-29
Primary work activity of S&E doctorate holders employed in academia: 1973–2003

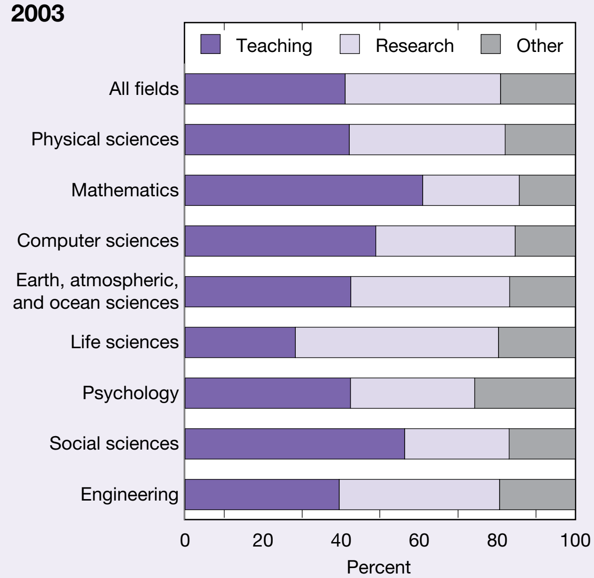


NOTE: Research includes basic or applied research, development, or design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-31.

Science and Engineering Indicators 2006

Figure 5-30
Primary work activity of academic S&E doctorate holders employed in academia, by degree field: 2003



NOTE: Research includes basic or applied research, development, or design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-31.

Science and Engineering Indicators 2006

The life sciences accounted for much of this trend, with researchers growing from 26,000 to 65,100 and teachers from about the same base (25,300) to 43,500. The other fields generally included fewer researchers than teachers in the 1970s and early 1980s, but this pattern reversed after that time in the physical sciences; the earth, atmospheric, and ocean sciences; and engineering.

Graduate Research Assistants

The close coupling of advanced training with hands-on research experience is a key strength of U.S. graduate education. To the count of S&E doctoral researchers for whom research is a primary or secondary work activity can be added an estimate of the number of S&E graduate students who are active in research. Among the almost 400,000 full-time S&E graduate students in 2003, many contributed significantly to the conduct of academic research.

Graduate RAs were the primary means of support for more than one-fourth of these students. Table 5-9, which shows the distribution of all full-time S&E graduate students and graduate research assistants (full-time graduate students whose primary mechanism of support is an RA) by field between 1973 and 2003, demonstrates that the number of research assistants has grown considerably faster than graduate enrollment, both overall and in most fields. In both graduate enrollment and the distribution of RAs, there was a shift away from the physical sciences and social sciences and into the life sciences, computer sciences, and engineering. In engineering and the

Table 5-9
Full-time S&E graduate students and graduate research assistants at universities and colleges, by degree field: Selected years, 1973–2003

	1973		1983		1993		2003	
Group and degree field	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
Graduate students	161.6	100	252.0	100	329.6	100	398.0	100
Physical sciences	21.1	13	25.2	10	30.6	9	30.4	8
Mathematics	10.3	6	11.0	4	14.5	4	14.6	4
Computer sciences	2.9	2	10.6	4	17.4	5	30.9	8
Earth, atmospheric, and ocean sciences	7.8	5	12.0	5	11.3	3	11.5	3
Life sciences	40.6	25	69.2	28	91.6	28	123.2	31
Psychology	15.2	9	26.6	11	34.8	11	35.8	9
Social sciences	32.4	20	43.5	17	55.6	17	61.3	15
Engineering	31.3	19	53.9	21	73.8	22	90.4	23
Graduate research assistants	35.9	100	54.9	100	90.2	100	114.3	100
Physical sciences	6.3	18	9.1	17	12.3	14	13.5	12
Mathematics	0.7	2	0.8	2	1.4	2	1.8	2
Computer sciences	0.7	2	1.4	3	3.8	4	7.5	7
Earth, atmospheric, and ocean sciences	2.6	7	3.5	6	4.7	5	4.6	4
Life sciences	9.4	26	16.5	30	28.0	31	35.5	31
Psychology	1.9	5	3.0	5	4.6	5	5.6	5
Social sciences	4.0	11	5.0	9	7.4	8	8.4	7
Engineering	10.4	29	15.6	28	28.0	31	37.4	33

NOTES: Graduate research assistants are full-time graduate students with research assistantships as primary mechanism of support. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering.

Science and Engineering Indicators 2006

physical sciences, the proportion of RAs was high relative to graduate enrollment. In the life sciences, the proportion of RAs relative to enrollment was more balanced, possibly reflecting the heavier reliance of these fields on postdoctoral researchers.

Adding graduate research assistants to the count of S&E doctoral researchers for whom research is either the primary or secondary activity yields a more complete lower bound measure of the number of individuals involved in academic research. As noted above, many more graduate students than those with an RA as their primary mechanism of support are carrying out research activities. In addition, more departments are involving undergraduate students in research. With these caveats, the estimated number of academic researchers in 2003 was approximately 293,000 (figure 5-31; appendix table 5-33). It is worth noting that in both computer sciences and engineering, the number of graduate research assistants exceeded the number of doctoral researchers.

Deployment of Academic Research Workforce

This section discusses the distribution of the academic research workforce across types of institutions, positions, and fields. It also examines differences in research intensity by looking at S&E doctorate holders involved in research activities relative to all S&E doctorate holders employed in academia.

Distribution Across Types of Academic Institutions

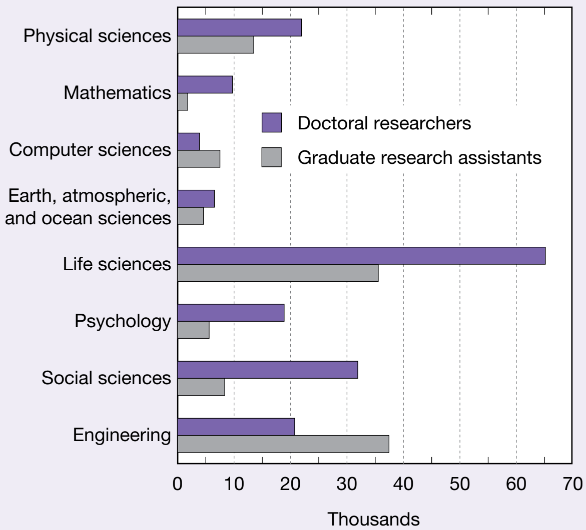
The majority of the research workforce is concentrated in the research universities. In 2003, the research universities employed 49% of all S&E doctorate holders in academic positions, 57% of those reporting research as their primary or secondary activity, and 71% of those reporting research as their primary activity, as well as 80% of S&E graduate students for whom an RA was the primary means of support (appendix table 5-34).

Over the years, however, the research universities' shares of both S&E doctorate holders reporting research as their primary or secondary activity and of graduate research assistants have declined. Table 5-10 provides a long-term overview of the changes in these institutional distributions. These changes are occurring at the same time that research universities' shares of total and federal expenditures for academic research are decreasing. Both trends indicate a growing research presence at institutions not traditionally classified as research universities.

Distribution Across Academic Positions

A pool of academic researchers outside the regular faculty ranks has grown over the years, as shown by the distribution of S&E doctorate holders reporting research as their primary or secondary activity across different types of academic positions:

Figure 5-31
Estimated number of doctoral researchers and graduate research assistants in academia, by degree field: 2003



NOTES: Doctoral researchers are those whose primary or secondary work activity is basic or applied research, development, or design. Graduate research assistants are full-time graduate students with research assistantships as primary mechanism of support.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and Survey of Graduate Students and Postdoctorates in Science and Engineering, special tabulations. See appendix table 5-33.

Science and Engineering Indicators 2006

faculty, postdoctoral fellows, and all other types of appointments (table 5-11; appendix table 5-35). The faculty share of researchers declined from about 88% in 1973 to about 77% in 2003 (approximately the same as the faculty share of all academic employment). For those reporting research as their primary activity, however, the faculty share changed little during this period. The overall decline in faculty share was offset by increases in the shares for both postdocs and those in other nonfaculty positions. Although there have been shifts in the shares of both postdocs and those in other nonfaculty positions during the 30-year period, their respective shares show little difference at the beginning and end of the period. For both those who report research as their primary or secondary activity and those who report it as their primary activity, most of the distributional change across types of academic positions occurred by the mid-1990s.

Distribution Across S&E Fields

Table 5-12 indicates that the distribution across fields of total academic S&E doctoral employment and those who report research as their primary or secondary activity are quite similar. However, the distribution of those who report research as their primary activity differs considerably from the other two distributions in several fields. Notably, it is greater in the life sciences and smaller in mathematics and the social sciences.

Table 5-10
S&E doctorate holders and graduate research assistants employed in academia, by Carnegie institution type: 1973–2003
(Percent distribution)

Group and institution type	1973–83	1983–93	1993–2003
All employed S&E doctorate holders	100.0	100.0	100.0
Research universities	53.7	53.4	50.0
Doctorate-granting institutions	11.5	11.4	11.0
Comprehensive institutions	18.0	18.5	18.3
Other	16.8	16.8	20.7
Researchers	100.0	100.0	100.0
Research universities	64.8	62.2	57.8
Doctorate-granting institutions	10.9	11.2	11.3
Comprehensive institutions	12.4	13.9	14.5
Other	11.9	12.8	16.4
Graduate research assistants	100.0	100.0	100.0
Research universities	87.5	84.0	80.4
Doctorate-granting institutions	9.3	10.1	11.8
Comprehensive institutions	2.2	3.5	4.9
Other	1.0	2.4	2.9

NOTES: Researchers are those reporting research as primary or secondary work activity. Graduate research assistants are full-time graduate students with research assistantships as primary mechanism of support. Institutions designated by 1994 Carnegie classification code. For information on these institutional categories, see chapter 2 sidebar, "Carnegie Classification of Academic Institutions." Freestanding schools of engineering and technology included under comprehensive institutions. "Other" includes freestanding medical schools, 4-year colleges, specialized institutions, and institutions without Carnegie code. Detail may not add to total because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations; and Survey of Graduate Students and Postdoctorates in Science and Engineering, special tabulations. See appendix table 5-34.

Science and Engineering Indicators 2006

Table 5-11
S&E doctorate holders employed in academia, by involvement in research and position: Selected years, 1973–2003

Involvement in research and position	1973	1983	1993	2003
	Thousands			
All academic employment	118.0	176.1	213.8	258.3
Research as primary or secondary activity	82.3	104.7	150.1	178.7
Research as primary activity	27.8	48.9	80.2	102.9
	Percent distribution			
All academic employment	100.0	100.0	100.0	100.0
Full-time faculty	87.6	84.3	80.6	75.2
Postdocs	3.5	4.7	6.2	6.1
Other full- and part-time positions	8.9	11.0	13.1	18.7
Research as primary or secondary activity	100.0	100.0	100.0	100.0
Full-time faculty	87.5	83.0	81.1	76.5
Postdocs	4.9	7.1	8.9	8.6
Other full- and part-time positions	7.6	9.9	10.0	14.9
Research as primary activity	100.0	100.0	100.0	100.0
Full-time faculty	71.3	68.7	70.9	69.5
Postdocs	13.8	14.5	15.8	13.7
Other full- and part-time positions	14.9	16.6	13.3	16.8

NOTES: Research includes basic or applied research, development, and design. Full-time faculty includes full, associate, and assistant professors plus instructors. Other full- and part-time positions include full-time nonfaculty such as research associates, adjunct positions, lecturers, administrative positions, and part-time positions of all kinds. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-35.

Science and Engineering Indicators 2006

Table 5-12
S&E doctorate holders employed in academia, by degree field and involvement in research: 2003
(Percent distribution)

	Involvement in research		
Degree field	All academic employment	Primary/ secondary activity	Primary activity
All fields	100.0	100.0	100.0
Physical sciences	12.2	12.3	12.2
Mathematics	6.0	5.4	3.7
Computer sciences	2.0	2.2	1.8
Earth, atmospheric, and ocean sciences	3.4	3.7	3.5
Life sciences	34.5	36.4	45.1
Psychology	12.1	10.6	9.7
Social sciences	18.8	17.9	12.7
Engineering	10.9	11.6	11.3

NOTES: Research includes basic or applied research, development, and design. Detail may not add to total because of rounding.

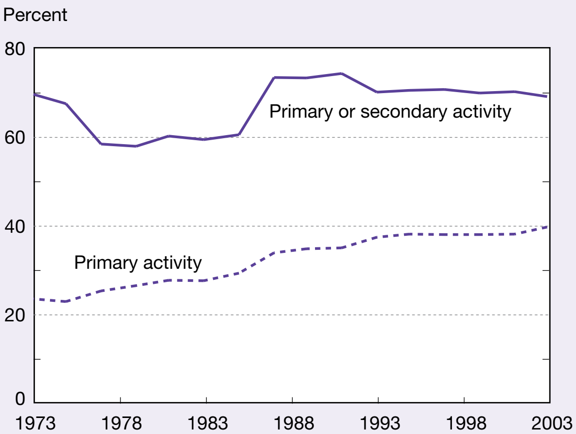
SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-36.

Science and Engineering Indicators 2006

Research Intensity of Academic Institutions

The number of academic S&E doctorate holders reporting research as their primary or secondary activity relative to all S&E doctoral employment declined between 1975 and 1977; was relatively constant at about 60% from the mid-1970s to the mid-1980s, when R&D funds grew relatively slowly; then rose again in 1987 to about 74%; dropped to about 70% in 1993; and remained relatively constant at that level until 2003 (figure 5-32; appendix table 5-36). On the other hand, the corresponding proportion of S&E doctorate holders in academia who reported research as their primary activity experienced a long-term upward trend from the mid-1970s through 2003, increasing from about 23% of total employment to about 40%. The latter trend is fairly similar for each of the broad S&E fields except the computer sciences, which is a new field relative to the others (table 5-13). These data may indicate a growing emphasis on the research function in academia. However, since the two researcher measures

Figure 5-32
S&E doctorate holders employed in academia, by involvement in research: 1973–2003



NOTE: Percent refers to S&E doctorate holders involved in basic or applied research, development, or design as percentage of all S&E doctorate holders.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-35.

Science and Engineering Indicators 2006

tell somewhat different stories, the reader is cautioned that they are suggestive rather than definitive.

Government Support of Academic Doctoral Researchers

Academic researchers rely on the federal government for a significant share (about 60%) of their overall research support. The institutional and field distributions of these funds are well documented, but little is known about their distribution among researchers. This section presents data from reports by S&E doctorate holders in academia about the presence or absence of federal support for their work. However, nothing is known about the magnitude of these funds to individual researchers. (See sidebar, "Interpreting Federal Support Data.")

Appendix table 5-37 shows the percentage of academic S&E doctorate holders who received federal support for their work during the period 1973–2003, broken out by field. The analysis examines the overall pool of doctoral S&E researchers as well as young doctorate holders, for whom support may be especially critical in establishing a productive research career.

Academic Scientists and Engineers Who Receive Federal Support

In 2003, 46% of all S&E doctorate holders in academia, 72% of those for whom research was the primary activity, and 36% of those for whom research was a secondary activity reported federal government support (appendix table 5-37). As table 5-14 shows, for S&E as a whole and for each of the broad fields, the likelihood of receiving federal support in 2003 was either the same as in 1991 or lower.

The percentage of S&E doctorate holders in academia who received federal support differed greatly across the S&E fields. In 2003, this percentage ranged from about 63% in the earth, atmospheric, and ocean sciences to about 22% in the social sciences (table 5-14; appendix table 5-37).

Full-time faculty received federal funding less frequently than other full-time doctoral employees, who, in turn, were supported less frequently than postdocs. In 2003, about 45% of full-time faculty, 48% of other full-time employees, and 78% of postdocs received federal support. As indicated earlier, these proportions were lower than those in 1991, but dropped less for full-time faculty than for postdocs or other full-time positions (appendix table 5-37). (See sidebar, "Has Academic R&D Shifted Toward More Applied Work?)

Table 5-13
S&E doctorate holders employed in academia who reported research as primary activity, by degree field: Selected years, 1973–2003
(Percent)

Degree field	1973	1983	1993	2003
All fields	23.6	27.8	37.5	39.8
Physical sciences	26.8	30.7	42.0	40.0
Mathematics	15.5	15.5	21.9	24.8
Computer sciences	NA	40.0	36.0	35.7
Earth, atmospheric, and ocean sciences	20.1	31.2	42.2	40.7
Life sciences	36.7	44.3	52.8	52.0
Psychology	16.7	21.0	26.8	31.8
Social sciences	12.1	12.6	24.1	26.8
Engineering	16.6	21.5	34.2	41.1

NA = not available

NOTE: Research includes basic or applied research, development, and design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-36.

Science and Engineering Indicators 2006

Table 5-14
S&E doctorate holders employed in academia who reported receiving federal support in previous year, by degree field: Selected years, 1973–2003
(Percent)

Degree field	1973	1983	1991[a]	2003
All fields	44.5	44.3	50.3	46.0
Physical sciences	47.7	50.9	56.6	54.8
Mathematics	26.9	30.1	34.5	30.6
Computer sciences	NA	44.6	49.4	48.9
Earth, atmospheric, and ocean sciences	45.0	54.5	66.2	62.6
Life sciences	59.3	60.0	65.5	57.3
Psychology	37.5	30.1	34.7	34.6
Social sciences	25.5	23.7	28.4	21.9
Engineering	53.5	54.7	63.2	57.3

NA = not available

[a]1991 used because 1993 not comparable with other years and understates degree of federal support by asking whether work performed during week of April 15 was supported by government. In other years, question pertains to work conducted over course of year.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-37.

Science and Engineering Indicators 2006

Interpreting Federal Support Data

Interpretation of the data on federal support of academic researchers is complicated by a technical difficulty. Between 1993 and 1997, respondents to the Survey of Doctorate Recipients were asked whether work performed during the week of April 15 was supported by the federal government; in most other survey years, the reference was to the entire preceding year; in 1985, it was to 1 month. However, as these data series clearly illustrate, the volume of academic research activity is not uniform over the entire academic year. A 1-week (or 1-month) reference period seriously understates the number of researchers supported over an entire year. Thus, the numbers for 1985 and 1993–97 cannot be compared directly with results for the earlier years or those from the 1999 through 2003 surveys, which again used an entire reference year.

The discussion here compares data for 1999 through 2003 with the earlier series. All calculations express the proportion of those with federal support relative to the number responding to this question. The reader is cautioned that, given the nature of these data, the trends discussed are broadly suggestive rather than definitive. The reader also is reminded that the trends in the proportion of all academic researchers supported by federal funds occurred against a background of rising overall numbers of academic researchers.

Federal Support of Young S&E Doctorate Holders in Academia

Early receipt of federal support is viewed as critical to launching a promising academic research career. The pattern of support for young researchers is similar to that of the overall academic S&E doctoral workforce: those in full-time faculty positions were less likely to receive federal support than those in postdoc or other full-time positions. However, for each of these three positions, the percentage reporting federal support in 2003 was higher for the overall academic S&E doctoral workforce than for those with recently earned doctorates (i.e., within 3 years of the survey) (appendix tables 5-37 and 5-38).

In 2003, about 49% of those with recently earned doctorates received federal support, with 30% of those in full-time faculty positions and 45% of those in other full-time positions receiving support, compared with about 78% of those in postdoc positions (appendix table 5-38). As with all academic doctoral holders, younger researchers were less likely to report federal support in 2003 than in 1991. The share of postdocs receiving federal support was relatively low (below 70%) in some fields (e.g., the social sciences, psychology, and mathematics) and high (80% or more) in others (e.g., computer sciences; the life sciences; and the earth, atmospheric, and ocean sciences).

In 2003, young academics who had gained some experience (i.e., those who had received their doctorate 4–7 years earlier) were considerably more likely to receive federal support than those with recently earned doctorates. However, this group also was less likely to receive support in 2003 than in 1991 (table 5-15; appendix tables 5-37 and 5-38). It should be pointed out that the data provide no information about whether an individual reporting federal support is being supported as a principal investigator on a research project or is participating in a more dependent status rather than as an independent researcher.

Table 5-15
S&E doctorate holders employed in academia 4–7 years after receiving degree who reported receiving federal support in previous year, by degree field: Selected years, 1973–2003
(Percent)

Degree field	1973	1983	1991[a]	2003
All fields	44.6	50.1	57.4	47.6
Physical sciences	44.8	66.2	67.2	51.1
Mathematics	29.0	39.8	28.3	33.9
Computer sciences	NA	43.5	66.2	43.6
Earth, atmospheric, and ocean sciences	53.4	64.5	76.6	67.9
Life sciences	59.7	67.1	70.6	57.2
Psychology	37.8	32.3	38.8	37.5
Social sciences	29.0	28.1	36.6	22.7
Engineering	50.7	64.3	73.2	64.3

NA = not available

[a]1991 used because 1993 not comparable with other years and understates degree of federal support by asking whether work performed during week of April 15 was supported by government. In other years, question pertains to work conducted over course of year.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-38.

Science and Engineering Indicators 2006

Has Academic R&D Shifted Toward More Applied Work?

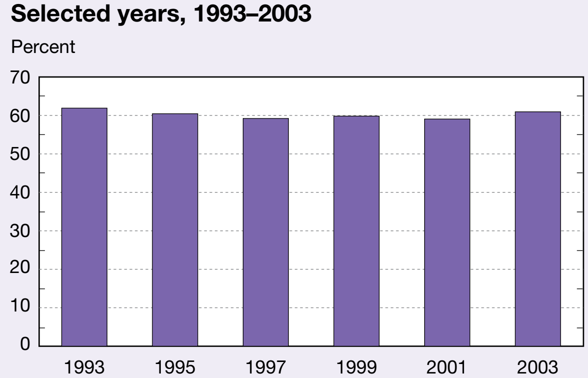
Emphasis on exploiting the intellectual property that results from the conduct of academic research is growing. (See section "Outputs of S&E Research: Articles and Patents.") Some observers believe that emphasis has been accompanied by a shift away from basic research and toward the pursuit of more utilitarian, problem-oriented questions.

We lack definitive data to address this issue. As indicated earlier in the chapter, it is often difficult to make clear distinctions among basic research, applied research, and development. Sometimes basic and applied research can be complementary to each other and embodied in the same research. Some academic researchers may obtain ideas for basic research from their applied research activities.

Two indicators, however, bear on this issue. One is the share of all academic R&D expenditures directed to basic research. Appendix table 5-1 does not show any decline in the basic research share since the late 1980s. The second indicator is the response to a question S&E doctorate holders in academia were asked about their primary or secondary work activities, including four R&D functions: basic research, applied research, design, and development.

As figure 5-33 shows, for those employed in academia who reported research as their primary activity, involvement in basic research declined slightly between 1993 and 2003, from 62% to 61%—probably not statistically significant. The available data, although limited, provide little evidence to date of a shift toward more applied work.

Figure 5-33
S&E doctorate holders with primary activity research whose primary activity is basic research: Selected years, 1993–2003



NOTE: S&E doctorate holders involved in research include those whose primary work activity is basic or applied research, development, or design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2006

Outputs of S&E Research: Articles and Patents

The products of academic research include trained personnel and advances in knowledge. Trained personnel are discussed earlier in this chapter and also in chapter 2. This section presents data on two knowledge-related additional indicators of scientific research output: scientific articles authored worldwide and patents received by U.S. academic institutions. In addition, it presents data on citations to previous scientific work contained in articles and patents.

Articles, patents, and citations provide indicators, albeit imprecise ones, of scientific output, the content and priorities of scientific research, the institutional and intellectual linkages within the research community, and the ties between scientific research and practical application. Data on articles, patents, and citations, used judiciously, enable meaningful comparisons across institutional sectors, scientific disciplines, and nations in terms of scientific output and research capacity.

Articles are one key measure of output for scientific research because publication has been the norm for disseminating and validating research results and is crucial for career advancement in most scientific fields.[37] Data on the authorship of articles also provide information on the extent of research collaboration and on patterns and trends in collaboration across institutional, disciplinary, and national boundaries.

Citations provide another measure of scientific productivity by indicating how influential previous research has been. Patterns in citations can show links within and across institutional boundaries. Citations to scientific articles in U.S. patents provide indications of the degree to which technological innovations rely on scientific research.

The number of patents issued to U.S. universities is another indicator of the output of academic science. In addition, it is an indicator of the relationship between academic research and commercial application of new technologies.

For a discussion of the nature of the data used in this section, see sidebar, "Data and Terminology."

Data and Terminology

The article counts, coauthorship data, and citations discussed in this section are based on S&E articles, notes, and reviews published in a slowly expanding set of the world's most influential scientific and technical journals tracked by Thompson ISI, formerly the Institute for Scientific Information, in the *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI)* (http://www.isinet.com/products/citation/). These data are not strictly comparable to those presented in editions prior to the 2004 edition of *Science and Engineering Indicators,* which were based on a fixed *SCI/SSCI* journal set. The advantage of the "expanding" set of journals is that it better reflects the current mix of influential journals and articles. However, changes over time in journal coverage can inflate article counts. The number of journals covered by *SCI/SSCI* was 4,458 in 1988, 4,601 in 1993, 5,084 in 1998, and 5,315 in 2003.

Field designations for articles in the journals tracked by *SCI/SSCI* are determined by the classification of the journal in which an article appears. Journals are assigned to 1 of 134 fine fields, which are grouped into 12 broad fields, on the basis of the patterns of a journal's citations (appendix table 5-39).

SCI and *SSCI* give good coverage of a core set of internationally recognized peer-reviewed scientific journals, albeit with some English-language bias. The coverage extends to electronic journals, including print journals with electronic versions and electronic-only journals. Journals of regional or local importance may not be covered, which may be salient for the categories of engineering and technology, psychology, the social sciences, the health sciences, and the professional fields, as well as for nations with a small or applied science base.

Author as used here means *departmental or institutional author.* Articles are attributed to countries and sectors by the author's institutional affiliation at the time of publication. If the institutional affiliation of an article's author is not listed, the article would not be attributed to an institutional author and would not be included in the article counts in this chapter. Likewise, *coauthorship* refers to institutional coauthorship: a paper is considered coauthored only if its authors have different institutional affiliations or are from separate departments of the same institution. Multiple authors from the same department of an institution are considered as one institutional author. The same logic applies to cross-sectoral and international collaboration.

Two methods of counting articles based on attribution are used: fractional and whole counts. In *fractional counting*, credit for an article with authors from more than one institution or country is divided among the collaborating institutions or countries based on the proportion of their participating departments or institutions. In *whole counting*, each collaborating institution or country receives one credit for its participation in the article. Fractional counting is generally used for article and citation counts, and whole counting for coauthorship data.

All data presented here derive from the Science Indicators database prepared for the National Science Foundation by ipIQ, Inc., formerly CHI Research, Inc. The database excludes all letters to the editor, news pieces, editorials, and other content whose central purpose is not the presentation or discussion of scientific data, theory, methods, apparatus, or experiments.

Worldwide Trends in Article Output

The number of scientific articles cataloged in the internationally recognized peer-reviewed set of S&E journals covered by the *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI)* grew from approximately 466,000 in 1988 to nearly 700,000 in 2003, an increase of 50% (figure 5-34). The growth of publications reflects both an expansion in the number of journals covered by the *SCI* and *SSCI* databases and an increase in the number of articles per journal during this period. The number of articles in a fixed set of journals that have been tracked by *SCI/SSCI* since 1985 has also risen, indicating that the number of articles per issue and/or issues per journal grew during this period. Other S&E journal databases that have broader and/or more specialized coverage of scientific fields in general show an increasing number of publications (appendix table 5-40).

Data on article authorship by country provide an indication of the knowledge and research capacity of regions and countries. Data by scientific discipline provide a comparative measure of national research priorities.

Trends in Three Major Publishing Regions

Strong increases in S&E articles published in the European Union (EU)-15,[38] Japan, and the East Asia-4 countries and economies (China, including Hong Kong, Singapore, South Korea, and Taiwan) accounted for 69% of the increase in world output between 1988 and 2003 (figure 5-35; appendix table 5-41).

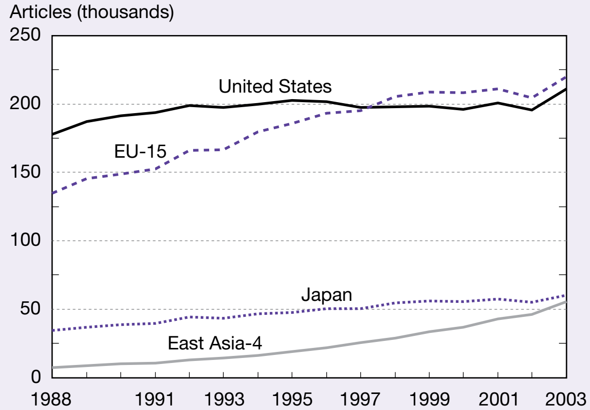
The article output of the EU-15 grew by more than 60% between 1988 and 2003, surpassing that of the United States in 1998 (figure 5-35; appendix table 5-41). This rate of growth slowed, however, starting in the mid-1990s (figure 5-36). Japan's article output rose at a slightly faster pace than that of the EU-15 (figure 5-36), resulting in gain in output of nearly 75% between 1988 and 2003. Japan's growth rate, however, slowed in the latter half of the 1990s in a pattern similar to that of the EU-15.

The article output of the East Asia-4 rose more than sevenfold, pushing its share of the world's S&E articles from below 2% in 1988 to 8% in 2003 (figure 5-35; table 5-16). By country, the increase in output was 6-fold in China and the Taiwan economy, 7-fold in Singapore, and nearly 18-fold in South Korea, up from only 771 articles in 1988 to more than 13,000 15 years later (appendix table 5-41). S&E article growth in China and South Korea resulted in these two countries becoming the 6th- and 12th-ranked countries by share of world article output in 2003 (appendix table 5-42). On a per capita basis, the article output levels of Singapore, South Korea, and Taiwan were comparable to those of other advanced countries (appendix table 5-43). China's per capita article output, however, was far below this level.

Trends in U.S. Article Output

In the United States, growth in article output was markedly slower than in the other major S&E publishing regions and remained essentially flat between 1992 and 2003, despite continued growth of research inputs.[39] Neither the full dimensions of this trend, a reversal of three prior decades of consistent growth, nor the reasons for it are clear (See sidebar, "Exploring Recent Trends in U.S. Publications Output.") As a result

Figure 5-35
S&E article output, by major S&E publishing region or country/economy: 1988–2003



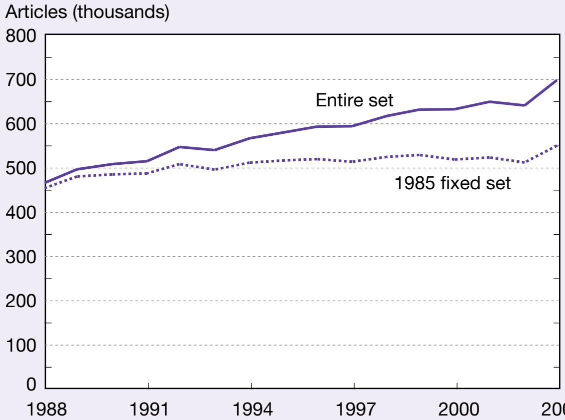
EU = European Union

NOTES: Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-41.

Science and Engineering Indicators 2006

Figure 5-34
Worldwide S&E article output of selected journal sets: 1988–2003

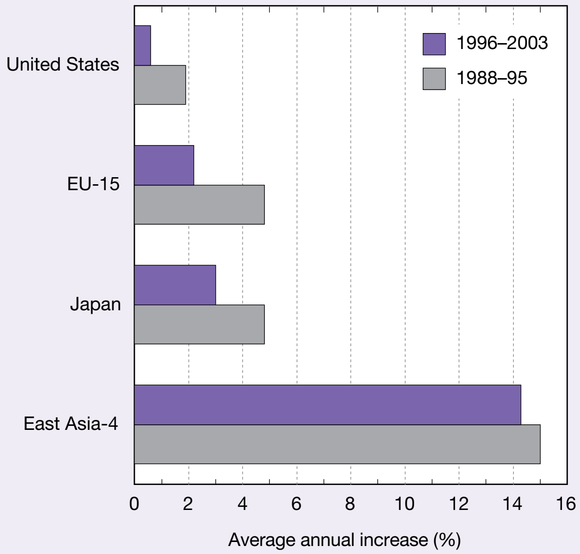


NOTES: Entire journal set consists of journals tracked by *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI)* that increase over time. 1985 fixed journal set is fixed number of journals reflecting *SCI* and *SSCI* journal coverage in 1985.

SOURCES: Thomson ISI, *SCI* and *SSCI,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Figure 5-36
Growth in S&E article output, by major S&E publishing region or country/economy: 1988–2003



EU = European Union

NOTES: Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each publishing country/economy receives fractional credit on basis of proportion of its participating institutions. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-41.

Science and Engineering Indicators 2006

of nearly stagnant U.S. output and continued growth in other parts of the world, the U.S. share of all articles fell from 38% to 30% between 1988 and 2003 (table 5-16).

This phenomenon of stagnant output is not limited to the United States. Five mature industrial countries with significant article outputs (Canada, the United Kingdom, France, the Netherlands, and Sweden) experienced a similar flattening starting in the latter half of the 1990s (figure 5-37).

The U.S. growth trend varied by field (table 5-17). Biomedical research and physics, which together accounted for one-quarter of U.S. article output in 2003, declined between 1996 and 2003. During the same period, articles in clinical medicine, which accounted for 31% of all output in 2003, increased at the same average rate (0.6%) as overall annual output. The six remaining fields that constituted 44% of U.S. articles in 2003—biology, chemistry, the earth and space sciences, engineering and technology, mathematics, and the social and behavioral sciences[40]—had higher than average growth during 1996–2003.

Trends in Other Regions and Countries

Output increased sharply in many regions and countries between 1988 and 2003, but there were notable exceptions (appendix table 5-41):

Exploring Recent Trends in U.S. Publications Output

Publication of research results in the form of articles in peer-reviewed journals is the norm for contributing to the knowledge base in nearly all scientific disciplines. It has become customary to track the number of peer-reviewed articles as one, albeit imperfect, indicator of research output. In recent years, international use of this and related indicators has become widespread, as countries seek to assess their relative performance.

The recent flattening in the output of U.S. S&E publications contrasts with continued increases in real R&D expenditures and number of researchers. The reasons for these divergent trends remain unclear. To explore what factors may be implicated in this development, the National Science Foundation (NSF) undertook a special study that addresses the following questions:

- What key trends affected the scientific publishing industry in the 1990s?
- Is the apparent change in output trends real or an artifact of the indicators used?
- What are the characteristics of the change in the trend?
- What factors may contribute to it, and what evidence exists about whether and how these factors are involved?

The project analyzes key developments in scientific publishing, with particular focus on the 1990s, to establish the broad outlines of the environment in which scientific publishing in the United States is taking place. In addition to an in-depth look at indicators of U.S. output trends, it includes methodological research that focuses directly on measurement approaches, journal coverage, and other technical considerations that affect indicators of publications output.

Work is underway to determine where in the U.S. research system these trend changes are found; what institutional, demographic, funding, or other factors may be contributing to them; in what fields these changes are occurring; and how different changes relate to one another.

A primary focus of the study is the U.S. academic system, which publishes the majority of U.S. articles and conducts most U.S. research. NSF's Science Resources Statistics (SRS) division has been conducting a multivariate study to examine quantifiable relationships among publication outputs, resource inputs, and institutional characteristics of the top 200 academic R&D institutions. Selected data from this study are presented in this chapter. SRS staff have also conducted interviews with faculty and administrators at nine top-tier research universities to better understand how the publishing and research environment may be changing and help put quantifiable data in context. The results of the study are expected to be published in a series of special reports.

Table 5-16
Share of world S&E article output, by major publishing region or country/economy: 1988, 1996, and 2003
(Percent distribution)

Region or country/economy	1988	1996	2003
Worldwide	100.0	100.0	100.0
EU-15	28.8	32.6	31.5
United States	38.1	34.0	30.3
Japan	7.4	8.5	8.6
East Asia-4	1.5	3.7	7.9
Other OECD	10.9	11.1	11.2
All other countries	13.2	10.2	10.5

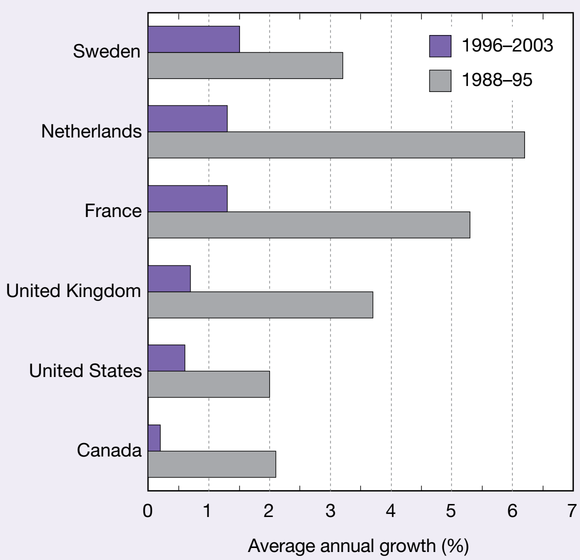
EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTES: Region/country/economy ranked by share in 2003. Shares based on articles credited to institutional address of region/country/economy. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong. Other OECD excludes United States, Japan, and South Korea.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Figure 5-37
Growth of S&E article output, by selected country: 1988–2003



NOTES: Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries, each country receives fractional credit on basis of proportion of its participating institutions.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-41.

Science and Engineering Indicators 2006

- The S&E article output of Latin America more than tripled.
- The combined output of the Southeast Asian countries of Indonesia, Malaysia, the Philippines, Thailand, and Vietnam nearly tripled.
- The output of the Near East and North Africa more than doubled, albeit from a low base.
- The output of India, the Asian country with the largest S&E article output after Japan and the East Asia-4, began increasing in the mid-1990s after years of stagnation, resulting in a 44% gain during this period.
- The combined output of the Eastern European countries of Bulgaria, the Czech Republic, Hungary, Poland, and Romania followed a similar trend to that of India. Output began increasing in the late 1990s, resulting in a 41% gain during this period.
- In contrast to the Eastern European countries listed above, Russia's output decreased 27% between 1994 and 2003.
- The S&E article output of Sub-Saharan Africa, which accounted for less than 1% of world output in 2003, fell 7% between 1988 and 2003.

Field Distribution of Articles

The publications of the United States, the EU-15, and Japan are dominated by the life sciences (figure 5-38). Other Organisation for Economic Co-operation and Development (OECD) countries also have a similar portfolio (appendix tables 5-44 and 5-45). In the portfolios of the East Asia-4, however, the physical sciences and engineering and technology are more dominant. Among developing countries, the portfolios of countries in the Near East and North Africa (excluding Israel) and Eastern Europe and the former Union of Soviet Socialist Republics (USSR) are similar to those of the East Asia-4. Like the United States, the EU-15, and Japan,

Latin America and Sub-Saharan Africa have portfolios dominated by the life sciences (appendix tables 5-44 and 5-45).

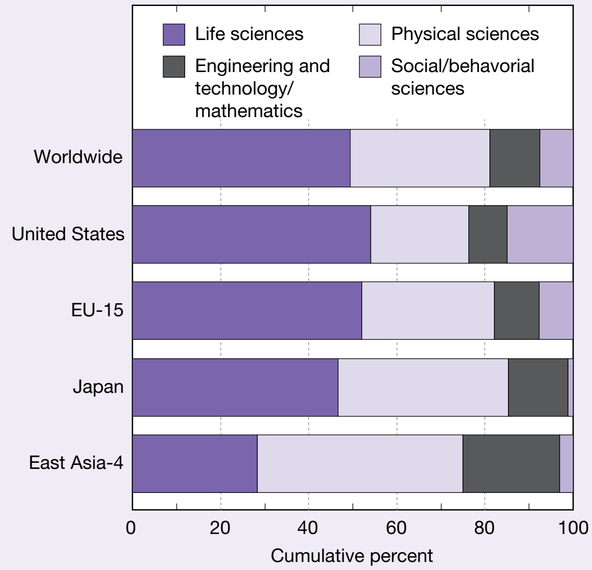
Worldwide Trends in Scientific Collaboration

Patterns in coauthorship of S&E articles are an indicator of how research is organized. Trends toward more frequent coauthorship spanning national, sectoral, and institutional boundaries indicate greater globalization and interdependence in the science community. The rise in scientific collaboration has been driven by several factors:

- ♦ The scientific advantages of combining knowledge, perspectives, techniques, and resources that extend beyond a single institution or discipline to advance scientific research
- ♦ Lower costs of air travel and telephone calls, which have facilitated collaborative research and conference attendance, which can lead to coauthorship
- ♦ The widespread use of new kinds of information technology, including the Internet, e-mail, and high-capacity computer networks that allow researchers to locate collaborators, exchange information, share data files, and even conduct experiments from a distance
- ♦ National policies in many countries that encourage institutional or international collaboration and the end of Cold War barriers to collaboration
- ♦ The participation of graduate students in study abroad programs

The rise in international collaboration has been driven by intensified collaboration among the major S&E publishing regions: the United States, the EU-15, Japan, and the East Asia-4. Other contributing factors are collaboration between these major publishing regions and the developing world

Figure 5-38
Field distribution of S&E articles, by major S&E publishing region or country/economy: 2003



EU = European Union

NOTES: Regions/countries/economies ranked by share of life sciences. Life sciences consist of clinical medicine, biomedical research, and biology. Biology includes agricultural sciences. Physical sciences consist of chemistry, physics, and earth and space sciences. Social/behavioral sciences consist of social sciences, psychology, health sciences, and professional fields. Engineering/technology includes computer sciences. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-45.

Science and Engineering Indicators 2006

Table 5-17
U.S. S&E article output, by field: 1988–2003
(Percent)

Field	Average annual growth 1988–95	Average annual growth 1996–2003	2003 share of article output
All fields	1.9	0.6	100.0
Mathematics	–2.5	2.3	1.8
Earth/space sciences	4.4	2.1	5.9
Biology	–0.2	1.3	6.6
Social/behavioral sciences	1.1	1.3	14.9
Engineering/technology	2.4	1.0	7.0
Chemistry	1.8	0.8	7.5
Clinical medicine	2.1	0.6	31.2
Biomedical research	3.6	–0.2	16.3
Physics	1.4	–0.6	8.8

NOTES: Articles on fractional-count basis, i.e., for articles with collaborating U.S. and foreign institutions, United States receives fractional credit on basis of proportion of its participating institutions. Fields ranked by 1996–2003 growth rate. Social/behavioral sciences consist of psychology, social sciences, health sciences, and professional fields. Engineering/technology includes computer sciences. Biology includes agricultural sciences.

SOURCES: Thomson ISI, *Science Citation Index and Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

and the development of an East Asian area of collaboration centered on Japan and, increasingly, China.

One indicator of increasing collaboration, the average number of author names and addresses on an article, rose between 1988 and 2003 (table 5-18). A second indicator is the distribution of articles by type of authorship: articles authored by a single national institution, articles authored by multiple departments or institutions within a single country, and international articles, which are those with authors from at least two different countries (figure 5-39). Between 1988 and 2003, international articles doubled in share from 8% to 20%, and articles authored by multiple departments or institutions within a single country increased their share from 32% to 39%.

The number of countries collaborating on an article also expanded. In 2003, more than 60 countries had joint authorship with at least 60 nations, compared with 32 in 1996 (figure 5-40; appendix table 5-46). Although international ties have greatly expanded, many countries, particularly in the developing world or those with smaller scientific establishments, tend to concentrate much of their collaboration with a relatively small number of developed countries.

International Collaboration by the United States

U.S. researchers collaborate with counterparts in more countries than do the researchers of any other country. In 2003, U.S. authors collaborated with authors in 172 of the 192 countries that had any internationally coauthored articles in 2003 (appendix table 5-46). Scientific collaboration in the United States increased between 1988 and 2003, particularly international collaboration. The average number of foreign addresses on U.S. scientific articles more than tripled during this period (table 5-18). The share of U.S. articles with international authorship (articles with at least one U.S. address and one address outside the United States)[41] grew the fastest, rising from 10% of all U.S. S&E articles in 1988 to 25% in 2003 (figure 5-41). Such articles became more prevalent in all fields. By field, international collaboration in 2003 was highest in the earth and space sciences, physics, and mathematics, at a rate of more than 35% (figure 5-42). International collaboration rates were much lower in the social sciences, psychology, the health sciences, and the professional fields at 10%–14%.

The U.S. share of the world's internationally coauthored articles fell between 1988 and 2003, however, from 51% to 44% (figure 5-43). Its share of coauthorship on the international articles of the EU-15 and Japan fell from almost 50% in 1988 to below 40% in 2003 (figures 5-44 and 5-45; appendix tables 5-47, 5-48, and 5-49). In turn, the East Asia-4 and the countries of Eastern Europe and the former USSR increased their share with these two regions (appendix tables 5-47 through 5-52). The United States also lost coauthorship share on the international articles of the East Asia-4 as these economies expanded their collaboration with the EU and other countries (figure 5-46). Finally, the U.S. coauthorship share fell in many developing countries (appendix tables 5-50 through 5-55). In India, both the U.S. and the EU-15 shares fell as India increased coauthorship with Japan and the East Asia-4 (appendix tables 5-47 through 5-49). In Latin America, the U.S. share declined from 45% to 37% between 1988 and 2003, and the EU-15 became the largest collaborating region (appendix tables 5-47 through 5-49).

Two regions increased their coauthorship share on U.S. articles: the East Asia-4 and Eastern Europe and the former

Table 5-18
Author names and addresses on S&E articles, by major publishing region or country/economy: 1988, 1996, and 2003
(Average number)

Author names and addresses	Worldwide	United States	EU-15	Japan	East Asia-4
1988					
Names	3.06	2.98	3.33	3.96	3.37
All addresses	1.75	1.78	1.70	1.63	1.63
Foreign addresses	na	0.15	0.19	0.14	0.34
1996					
Names	3.68	3.75	4.17	4.82	4.75
All addresses	2.19	2.11	2.05	1.99	2.07
Foreign addresses	na	0.32	0.35	0.31	0.56
2003					
Names	4.22	4.42	4.81	5.58	5.61
All addresses	2.68	2.44	2.42	2.39	2.30
Foreign addresses	na	0.51	0.52	0.49	0.55

na = not applicable
EU = European Union

NOTES: East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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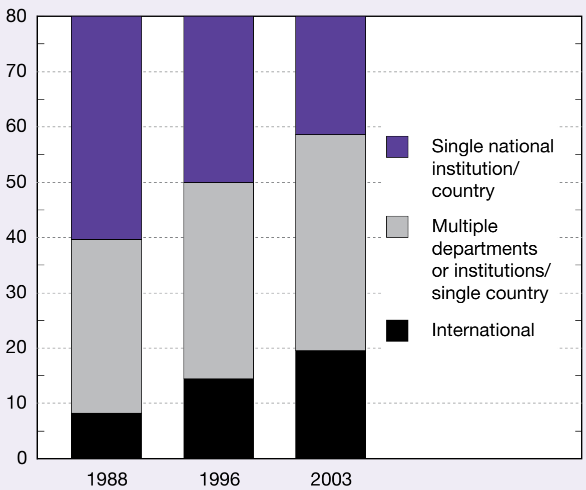
Figure 5-39
Distribution of S&E articles by type of authorship: 1988–2003



NOTES: Single national institution/country articles have one institutional address. Multiple department or institution/single country articles have multiple addresses from a single country, either from a single institution or multiple institutions. International articles have authors from at least two different countries listed on article. Counts of S&E articles worldwide were 466,419 in 1988, 593,568 in 1996, and 698,726 in 2003.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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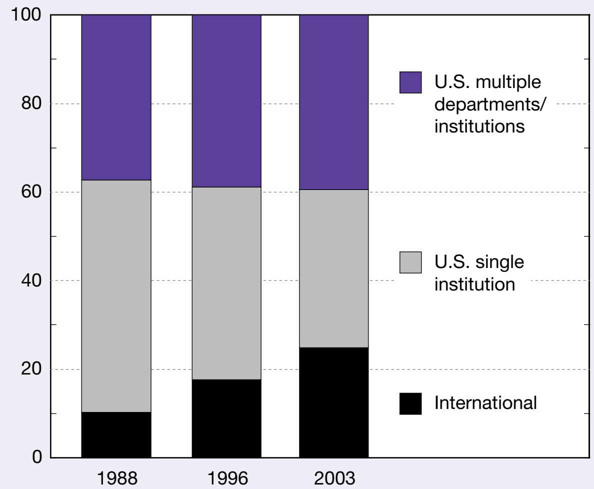
Figure 5-41
U.S. S&E articles, by type of authorship: 1988, 1996, and 2003



NOTES: Domestic multiple department/institution articles are those with more than one listed institutional address from the same institution or multiple U.S. institutions. International articles have at least one collaborating U.S. and foreign institution. Articles on whole count basis, i.e., for article with collaborating U.S. and foreign institutions, the United States is credited one count for its participation (187,225 in 1988, 221,414 in 1996, and 242,397 in 2003).

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-59 and 5-60.

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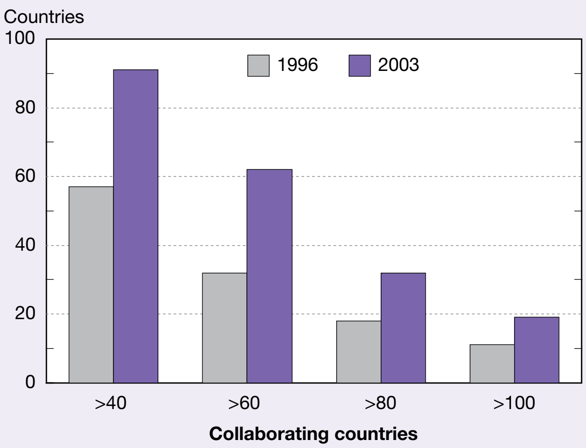
Figure 5-40
Collaborating countries/economies on S&E articles: 1996 and 2003



NOTE: Data are number of countries/economies that have jointly authored articles (based on institutional address) with indicated number of countries/economies.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-46.

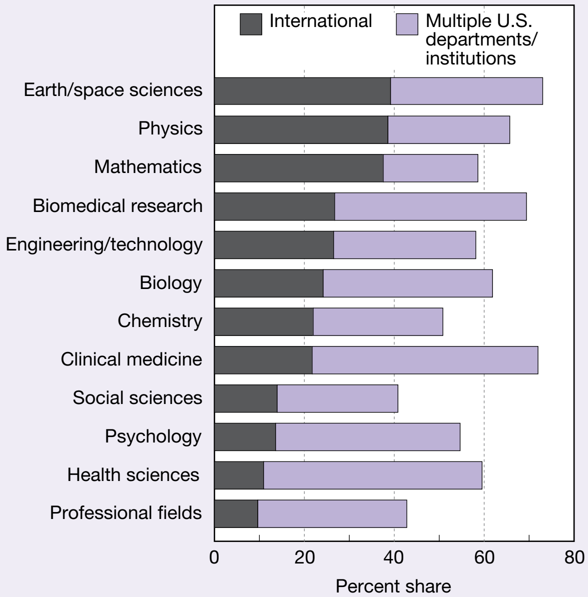
Science and Engineering Indicators 2006

USSR (figure 5-47). The increases were primarily due to China and South Korea in the former group and Russia in the latter. The patterns of international collaboration with the United States also appear to reflect the relationship between the number of U.S. foreign-born doctorate recipients and publications jointly authored by their country of origin and the United States (figure 5-48).[42]

International Collaboration by the EU-15

In the EU-15, articles with at least one coauthor from a non-EU-15 country accounted for 36% of all articles in 2003, up from 17% in 1988 (figure 5-49). The EU-15 countries, many of which had extensive ties during the previous decade, continued to expand their partnerships. There were 10 EU-15 member countries with ties to 100 or more nations in 2003, a clear indicator of this region's extensive scientific collaboration with other nations (appendix table 5-46). Much of the high degree of international collaboration within the EU (as measured by the share of member countries' articles coauthored with other EU-15 countries) reflects the extensive intraregional collaboration centered on France, Germany, Italy, the Netherlands, and the United Kingdom (appendix tables 5-47 through 5-49). The extent of intra-European collaboration reflects proximity, historical ties, and EU programs that encourage collaboration.

Figure 5-42
Extent of multiple authorship on U.S. S&E articles, by field: 2003

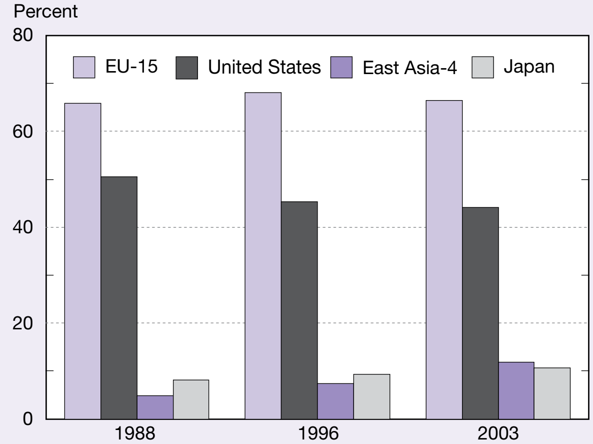


NOTES: Number of S&E articles with authors from multiple departments/institutions, including foreign, as share of total S&E articles. Fields ranked by international share. Field volume on whole-count basis, i.e., for articles with collaborating U.S. and foreign institutions, the United States is credited one count. International articles are those with at least one collaborating U.S. and foreign institution. Multiple U.S. department/institution articles are those with multiple U.S. addresses from the same institution or multiple U.S. institutions. Engineering/technology includes computer sciences. Biology includes agricultural sciences.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-59 and 5-60.

Science and Engineering Indicators 2006

Figure 5-43
Share of international S&E articles, by major S&E publishing region or country/economy: 1988, 1996, and 2003



EU = European Union

NOTES: Articles on whole-count basis, i.e., for articles with collaborating institutions from more than one country/economy, each country/economy is credited one count. International articles are those with at least one collaborating institution from indicated region/country/economy and an institution from outside the region/ country/economy (38,190 in 1988, 85,968 in 1996, and 136,577 in 2003). Shares exceed 100% because each selected region/ country/economy receives one count for its participation on articles with other selected countries/regions. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

International Collaboration by Japan

In Japan, the share of articles with international coauthors increased from 9% to 22% between 1988 and 2003, as Japan broadened its collaboration with more countries (figure 5-49; appendix table 5-46). Japan's collaboration with the East Asia-4 increased considerably during this period, particularly with China (figure 5-50).

International Collaboration by the East Asia-4

In the economies comprising the East Asia-4, the share of articles with a coauthor outside the region increased slightly during the period 1988–2003 (figure 5-49).[43] The change in collaborative patterns was similar to that in Japan, with a decline in U.S. involvement, as measured by share of articles, an expansion in the number of collaborative partners, and a growing intraregional collaborative network centered in Japan and, increasingly, China (figure 5-50).

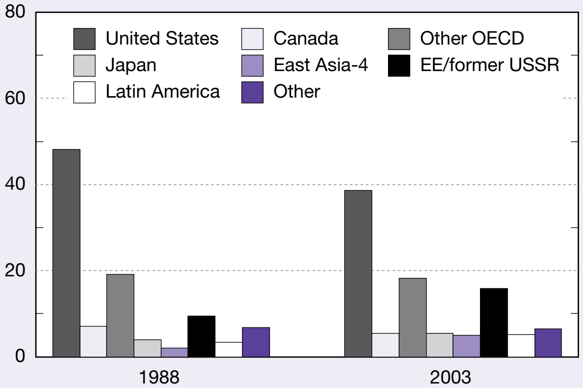
Trends in Output and Collaboration Among U.S. Sectors

The volume and share of article production by various U.S. institutional sectors (academic, federal and state government, private for profit, and nonprofit) offer a measure of the relative role of these sectors in U.S. research. Coauthorship among these sectors provides an indicator of the integration of U.S. sectors in the U.S. S&E community. Government policies have reinforced collaboration among U.S. sectors by funding research programs that require or encourage collaboration. International collaboration of U.S. sectors is an indicator of the globalization of U.S. sectors in the international S&E community.

Output Trends of U.S. Sectors

The growth in the academic sector, which generates most U.S. publications (74% in 2003), mirrored the overall pattern of U.S. S&E article output (table 5-19). Growth trends did vary, however, among a subset of top 200 academic R&D institutions grouped on the basis of their R&D growth and 1994 Carnegie classification. At institutions that registered higher-than-average R&D growth between 1988 and 2003, the growth in article output was correspondingly

Figure 5-44
Region/country/economy coauthorship share on EU-15 international S&E articles, by selected region/grouping: 1988 and 2003



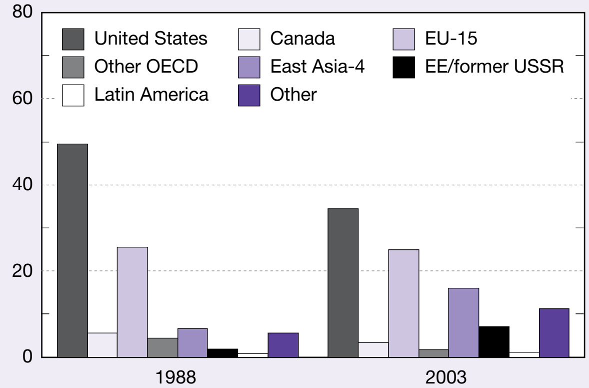
EE = Eastern Europe; EU = European Union; OECD = Organisation for Economic Co-operation and Development; USSR = Union of Soviet Socialist Republics

NOTES: Coauthorship share is fractional share of region/country/economy on EU-15 international articles (25,179 in 1988, 58,576 in 1996, and 90,779 in 2003). International articles are those with at least one collaborating EU-15 institution and one non-EU-15 institution. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-47, 5-48, and 5-49.

Science and Engineering Indicators 2006

Figure 5-45
Region/country/economy coauthorship share on Japan's international S&E articles, by selected region/grouping: 1988 and 2003



EE = Eastern Europe; EU = European Union; OECD = Organisation for Economic Co-operation and Development; USSR = Union of Soviet Socialist Republics

NOTES: Coauthorship share is fractional share of region/country/economy on Japan's international articles (3,097 in 1988, 7,973 in 1996, and 14,534 in 2003). Japan's international articles are those with at least one collaborating Japanese institution and one non-Japanese institution. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-47, 5-48, and 5-49.

Science and Engineering Indicators 2006

greater than that of other institutions (table 5-20; appendix table 5-56). By Carnegie class, the S&E article output of private academic institutions, which produce approximately one-third of the articles attributed to the top 200 academic R&D institutions, grew faster than that of public academic institutions between 1988 and 2001 (table 5-21).

The combined article output of nonacademic sectors, which accounted for slightly more than one-quarter of overall U.S. output in 2003, also followed the pattern of overall U.S. S&E article output (table 5-19). The growth trend, however, varied by sector. In the federal government, output declined after 1994, primarily because of a decrease in articles in the life sciences and physics (figure 5-51). The output of the private for-profit sector fell during the 1990s, with significant declines in the fields of chemistry, physics, and engineering and technology. The article output of the nonprofit sector grew nearly 30% between 1988 and 2003 due to an increase in articles in clinical medicine.

Collaboration Among U.S Sectors

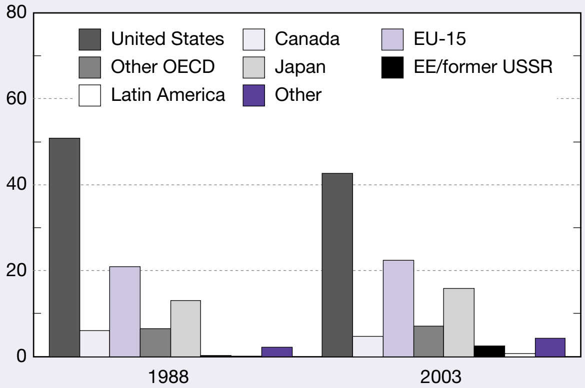
Collaboration of the academic sector with other U.S. sectors increased between 1988 and 2003, as measured by the share of coauthored articles (figure 5-52; appendix tables 5-57 and 5-58). Twenty-eight percent of academic articles in 2003 were coauthored with nonacademic authors, up from 22% in 1988. Collaboration among nonacademic sectors also rose during this period (table 5-22; appendix tables 5-57 and 5-58). The federal government and the private for-profit sector each nearly doubled their share of papers coauthored with other U.S. nonacademic sectors, from about 15% in 1988 to nearly 30% in 2003, realizing the highest gains in share of all nonacademic sectors.

The international collaboration of the U.S. academic sector increased significantly between 1988 and 2003. The share of academic articles with a foreign author increased from 11% to 24% during this period, a change in magnitude similar to the increase in the share of all U.S. articles with a foreign coauthor (figure 5-52; appendix tables 5-59 and 5-60). As measured by the share of articles with coauthors from non-U.S. institutions, the international collaboration of nonacademic sectors more than doubled during this period (table 5-22).

Worldwide Trends in Citation of S&E Articles

Citations in S&E articles generally credit the contribution and influence of previous research to a scientist's own research. Trends in citation patterns by region, country, scientific field, and institutional sector are indicators of the influence of scientific literature across institutional and

Figure 5-46
Region/country/economy coauthorship share on East Asia-4 international S&E articles, by selected region/grouping: 1988 and 2003



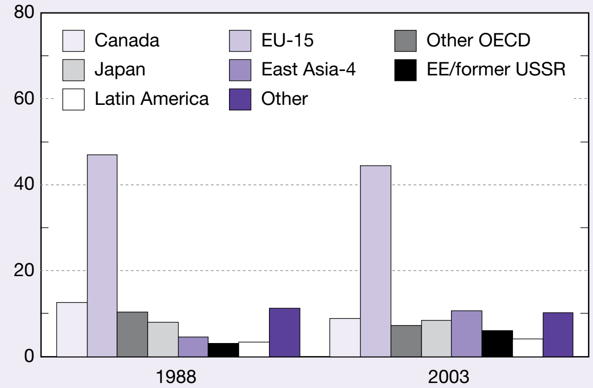
EE = Eastern Europe; EU = European Union; OECD = Organisation for Economic Co-operation and Development; USSR = Union of Soviet Socialist Republics

NOTES: Coauthorship share is fractional share of region/country/economy on East Asia-4 international articles (1,824 in 1988, 6,085 in 1996, and 15,110 in 2003). East Asia-4 international articles are those with at least one collaborating East Asia-4 institution and one non-East Asia-4 institution. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-47, 5-48, and 5-49.

Science and Engineering Indicators 2006

Figure 5-47
Foreign coauthorship on U.S. international S&E articles, by selected region/grouping: 1988 and 2003



EE = Eastern Europe; EU = European Union; OECD = Organisation for Economic Co-operation and Development; USSR = Union of Soviet Socialist Republics

NOTES: Coauthorship share is fractional share of region/country/economy on U.S. international articles (19,294 in 1988, 39,046 in 1996, and 60,180 in 2003). U.S. international articles are those with at least one U.S. author and one non-U.S. author. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-47, 5-48, and 5-49.

Science and Engineering Indicators 2006

national boundaries.[44] Citations may also indicate the accessibility of scientific research across national boundaries.

The volume of citations worldwide increased from 2.69 million in 1992 to 4.34 million in 2003, an increase of 61% (figure 5-53). During this period, the share of cross-national citations grew from 42% to 48%, another sign of the increasing globalization of science. With widespread use of the Internet and electronic databases, researchers increasingly are accessing scientific literature from around the world. The rate of foreign research citation varied by field in 2003, with higher-than-average shares in biomedical research, physics, and chemistry, and the lowest shares in psychology, the social sciences, the health sciences, and the professional fields (figure 5-54). The fields with the lowest shares of foreign research citation also have lower than average shares of internationally authored articles.

Citation Trends for Three Major Publishing Regions

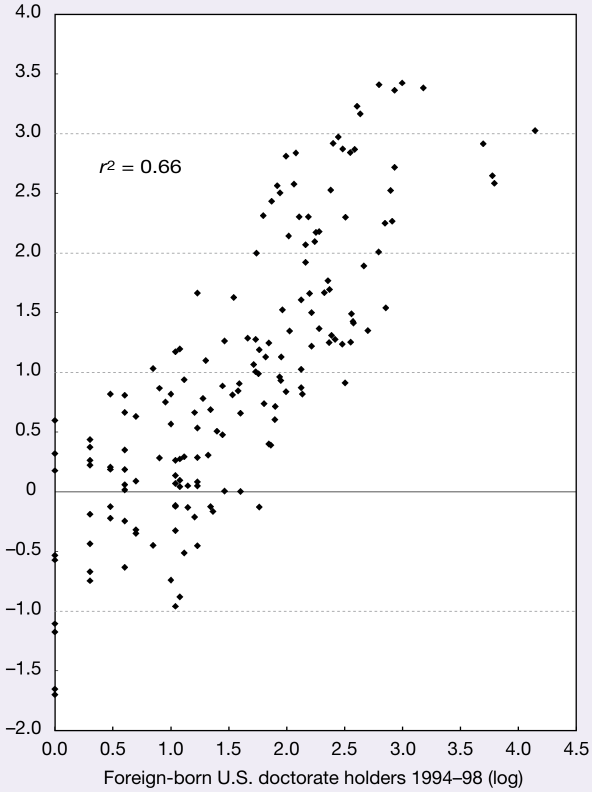
The EU-15, Japan, and the East Asia-4, the same regions that drove the increase in S&E article output, also drove the increase in volume of citation of scientific literature between 1988 and 2003 (figure 5-55; appendix table 5-61). Citation of EU-15 literature grew by 87% between 1992 and 2003, pushing this region's share of the world's cited literature from 28% to 33% (table 5-23). Citation of Japanese literature also rose substantially, increasing at roughly the same rate as the citation of EU-15 literature. Citation of literature from East Asia-4 authors in China, Singapore, South Korea, and Taiwan rose nearly sevenfold in volume during this period, with the collective share of these countries rising from less than 1% of the world's cited literature in 1992 to 3% in 2003.

Citation Trends for the United States

The volume of cited U.S. scientific literature grew 32% between 1988 and 2003, less than half the rate of the EU-15 and Japan, and flattened during the late 1990s. This resulted in the U.S. share falling from 52% in 1992 to 42% in 2003 (figure 5-55; table 5-23; appendix table 5-61). This flattening in citation of U.S. literature occurred across almost all fields and mirrored the trend of flat U.S. output of S&E articles during this period (table 5-24). Two fields diverged from this overall trend: Between 1992 and 2003, citations of physics literature fell 19%, paralleling the drop in publications, whereas citations of articles in the earth and space sciences rose more than 80%. Nevertheless, U.S. literature remained the most cited source of foreign S&E literature for the EU-15, Japan, and the East Asia-4.

S&E literature originating in the United States represents a much larger share of the literature cited by U.S. authors than the S&E literature of the three other major publishing

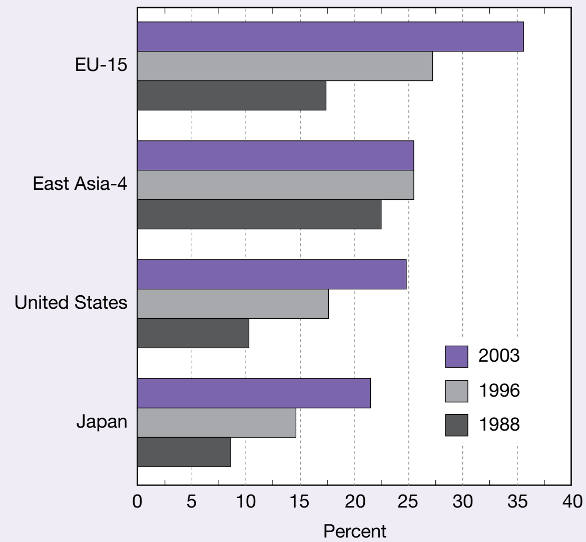
Figure 5-48
Relation of foreign-born U.S. doctorate holders to their country's scientific collaboration with United States: 1994–98 and 1999–2003



SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tablulations.

Science and Engineering Indicators 2006

Figure 5-49
Share of international S&E articles, by major S&E publishing region or country/economy: 1988, 1996, and 2003



EU = European Union

NOTES: Region/country/economy ranked by 2003 share. International articles are those with at least one collaborating institution from indicated region/country/economy and one institution from outside the region/country/economy. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

regions represents for each of those regions. In 2003, U.S. literature accounted for 61% of the literature cited by U.S. authors, whereas Japanese literature accounted for only 36% of the literature cited by Japanese authors, the second highest share of domestic citation among the four major publishing regions (figure 5-56). The foreign literature cited the most by the United States in 2003 was that of the EU-15, accounting for a 23% share.

Relative Citation of S&E Literature

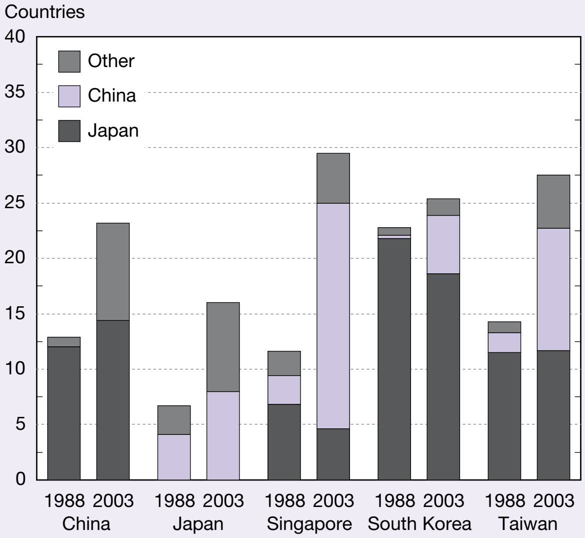
An alternative measure, the *relative citation index*, shows the comparative citation intensity of a country or region's research by scientists from the rest of the world.[45] This indicator showed less change in the citation patterns of the four major S&E publishing regions between 1992 and 2003 than simple citation volume. The U.S. relative citation index was considerably higher than that of the other three publishing regions between 1992 and 2003 and remained constant during this period (table 5-25). U.S. relative citation indexes by field also remained stable (appendix table 5-62). The relative citation index of the EU-15 was the second highest, increasing slightly between 1992 and 2003. The relative citation index of the East Asia-4, which was considerably lower than that of the EU-15, also increased slightly during this period. The relative citation index of Japan was considerably lower than those of the United States and the EU-15 and showed little change.

Trends in Highly Cited S&E Literature

A country or region's share of highly cited S&E articles, as ranked by frequency of citation, provides an indicator of its position in highly influential research. Between 1992 and 2003, the U.S. share of the top 5% of cited S&E articles fell from 59% to 50%, whereas the shares of the other three publishing regions, particularly the EU-15, rose (figure 5-57; appendix table 5-63). The decline in the U.S. share of all cited S&E articles during this period, which occurred at roughly the same magnitude as the decline in highly cited articles, suggests that the erosion of the U.S. citation share was not confined to less influential research.

The trend during this period for the United States and the other three major publishing regions was similar when measured by share of citations in highly cited journals (the

Figure 5-50
Intraregional collaboration on international S&E articles of selected East Asian countries/ economies: 1988 and 2003



NOTES: International S&E articles are those with at least one collaborating institution from an indicated East Asian country/ economy. Share of country authorship is fractional share of a given East Asian country/economy on designated East Asian country/ economy's international S&E articles. Other consists of Singapore, South Korea, and Taiwan.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-47, 5-48, and 5-49.

Science and Engineering Indicators 2006

journals being ranked by the average number of citations to articles published in each journal) (appendix table 5-64). Despite the declining U.S. share of influential research, U.S. shares of highly cited articles and journals continued to be high relative to the United States' overall share of citations. In comparison, the other three publishing regions' shares of

Table 5-20
Growth of S&E article output of top 200 academic R&D institutions, by R&D growth quartile: 1988–2003
(Percent)

	Average annual growth rate		
Quartile	1988–2003	1988–95	1996–2003
Total	1.5	2.1	1.0
Quartile 1	2.5	3.5	1.3
Quartile 2	2.0	2.5	1.5
Quartile 3	0.9	1.1	0.6
Quartile 4	1.0	1.8	0.4

NOTES: Top 200 academic R&D institutions assigned to four quartiles, ranging from quartile 1, consisting of institutions with highest growth rate, to quartile 4, consisting of those with lowest growth rate. Four institutions excluded because of incomplete R&D data. Articles on fractional-count basis, i.e., for articles with multiple collaborating top-200 institutions and/or other institutions, each top 200 institution receives fractional credit on basis of proportion of its participating institutions.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-56.

Science and Engineering Indicators 2006

highly cited articles and journals were equal to or less than their overall citation shares.

Citations in U.S. Patents to S&E Literature

U.S. patents cite previous source material to help meet the application criteria of the U.S. Patent and Trademark Office (U.S. PTO).[46] Although existing patents are cited the most often, U.S. patents have increasingly cited scientific articles. This growth in citation of S&E literature, referenced by scientific field, technology class of the patent, and the nationality of the inventor and cited literature, provides an indicator of the link between research and practical application.[47]

Table 5-19
S&E article output, by academic and nonacademic sector: Selected years, 1988–2003
(Thousands)

Sector	1988	1991	1993	1995	1997	1999	2001	2003
All sectors	177.7	194.0	197.4	202.9	197.5	198.5	200.9	211.2
Academic	127.3	139.3	142.3	146.5	144.6	145.5	147.8	156.6
Top 200 academic R&D institutions	116.9	127.8	130.4	134.6	132.4	133.3	135.7	143.6
Other	10.4	11.5	11.9	11.9	12.2	12.1	12.1	13.1
Nonacademic	50.4	54.7	55.1	56.4	52.9	53.1	53.1	54.6

NOTES: Top 200 U.S. academic R&D institutions determined by total R&D expenditures between 1988 and 2001. Articles on fractional-count basis, i.e., for articles with collaborating institutions from more than one sector, each sector receives fractional credit on basis of proportion of its participating institutions. Nonacademic consists of private for profit, private nonprofit, federal government, state and local government, federally funded research and development centers, and other.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-56.

Science and Engineering Indicators 2006

Table 5-21
Growth in S&E article output of top 200 academic R&D institutions, by type of control and Carnegie classification: 1988–2001
(Percent)

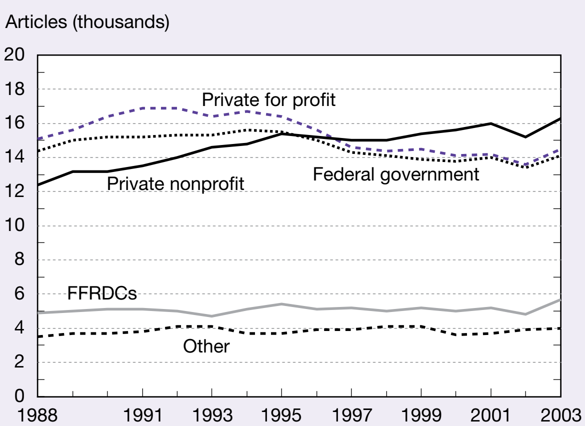
Type of control and Carnegie classification	Average annual growth rate 1988–2001	1988–95	1996–2001
All 200	1.5	2.5	0.2
Public	1.3	2.3	–0.0
Research 1	1.1	2.2	–0.2
Research 2	1.4	2.1	0.7
Medical	2.6	3.8	0.1
All others	2.6	2.8	1.1
Private	2.0	2.7	0.7
Research 1	2.0	2.5	0.8
Research 2	0.7	0.8	0.9
Medical	2.9	4.3	0.8
All others	2.0	2.7	0.7

NOTES: Top 200 academic R&D institutions assigned according to 1994 Carnegie classification. Articles on fractional-count basis, i.e., for articles with multiple collaborating top-200 institutions and/or other institutions, each top 200 institution receives fractional credit on basis of proportion of its participating institutions.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Figure 5-51
S&E article output of U.S. nonacademic sectors: 1988–2003



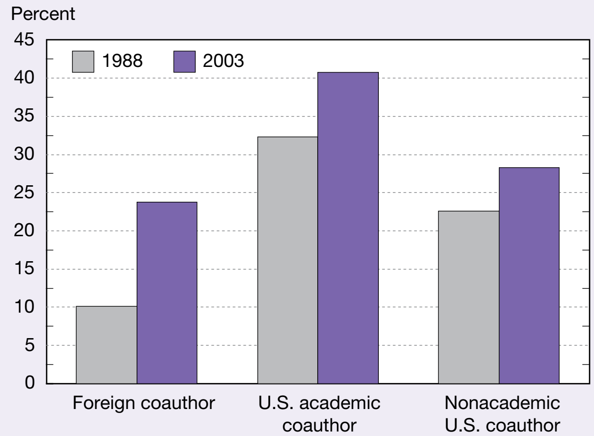
FFRDC = federally funded research and development center

NOTES: Articles on fractional-count basis, i.e., for articles with collaborating institutions from more than one sector, each sector receives fractional credit on basis of proportion of its participating institutions. Other consists of state and local government and unknown.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Figure 5-52
U.S. sector and foreign coauthorship share of U.S. academic S&E articles: 1988 and 2003



NOTE: Articles on whole-count basis, i.e., for articles with collaborating institutions from multiple sectors and/or foreign institutions, each sector and/or foreign country receives one count for participation by its institution(s).

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-57, 5-58, 5-59, and 5-60.

Science and Engineering Indicators 2006

U.S. patent citations to S&E articles on an average per patent and volume basis rose rapidly between 1987 and 1998, when growth slowed (figure 5-58; appendix table 5-65).[48] The growth in citations through much of the period 1987–2002 was driven, in part, by increased patenting of research-driven products and processes, primarily in the life sciences, and changes in the practices and procedures of the U.S. PTO. (See next section, "Patents Awarded to U.S. Universities.")

The rapid growth in the volume of citations throughout much of the period 1995–2004 was centered in articles authored by the academic sector (61% share of total citations in 2004), primarily in the fields of biomedical research and clinical medicine (appendix table 5-66). Academic-authored articles in these two fields accounted for 41% of the increase in total citations across all fields between 1995 and 2004. Citations to academic articles in physics and engineering and technology also increased during this period and became a larger share (40% to 61% in physics and 44% to 53% in engineering and technology). This increase coincided with a decline in the share of patent citations of articles authored by the industrial (private for-profit) sector in these fields and the stagnating publications output in that sector.

Industry was the next most widely cited sector (21% share in 2004), with articles in the fields of physics and engineering and technology prominently represented. Industry, however, lost share in these two fields between 1995 and 2004 (appendix table 5-66).

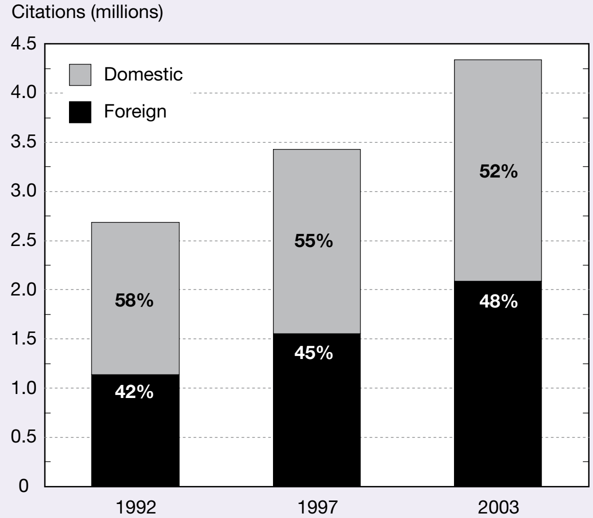
The bulk of U.S. patents citing scientific literature were issued to U.S. inventors, who accounted for 65% of these patents in 2003, a share disproportionately higher than the 51% of all U.S. patents issued to U.S. inventors (table 5-26). The three other major S&E publishing regions accounted for most of the patents citing S&E literature issued to non-U.S. inventors. These regions' shares of patents citing S&E literature, however, were equal to or less than their shares of all U.S. patents.

Examination of the share of cited literature of each of the four major publishing regions, adjusted for their respective share of the world output of scientific literature (relative citation index) and excluding citation of the literature of the inventor's country or region suggests that, relative to its share of publications, U.S. scientific literature is cited in U.S. patents more frequently than that of the EU-15, Japan, or the East Asia-4 (table 5-27). Thus, in both patents and scientific articles, U.S. literature is cited more frequently than would be expected based on the U.S. share of world article output.

Patents Awarded to U.S. Universities

The results of academic S&E research increasingly extend beyond articles in S&E journals to patent protection of research-derived inventions.[49] Patents are an indicator of the efforts of academic institutions to protect the intellectual property derived from their inventions, technology transfer,[50] and industry-university collaboration. The rise of patents received by U.S. universities attests to the increasingly important role of academic institutions in creating and

Figure 5-53
Worldwide citations of S&E literature: 1992, 1997, and 2003



NOTES: Citations are references to articles, notes, and reviews in journals covered by *Science Citation Index* (SCI) and *Social Sciences Citation Index* (SSCI). Citation counts based on a 3-year window with 2-year lag; e.g., citations for 2001 are references made in articles published in 2001 to articles published in 1997–99. Numbers refer to share of citations to foreign S&E literature. Foreign citations are references originating outside author's country. Domestic citations are references that originate from same country as article author.

SOURCES: Thomson ISI, SCI and SSCI, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-61.

Science and Engineering Indicators 2006

Table 5-22
Coauthorship share of nonacademic sectors: 1988 and 2003
(Percent)

Sector and year	Total articles	U.S. sector: Academic	U.S. sector: Nonacademic	Non-U.S. Institutions
FFRDCs				
1988	7,171	39.2	14.6	16.3
2003	10,975	51.9	21.6	37.0
Federal government				
1988	22,044	48.2	16.2	9.9
2003	27,020	57.3	27.5	24.4
State/local government				
1988	3,670	60.4	30.3	5.4
2003	4,112	68.1	50.5	12.7
Private for profit				
1988	20,221	31.1	15.2	8.2
2003	25,584	47.3	27.4	24.1
Private nonprofit				
1988	19,473	54.0	15.5	9.1
2003	29,957	59.0	24.5	22.3

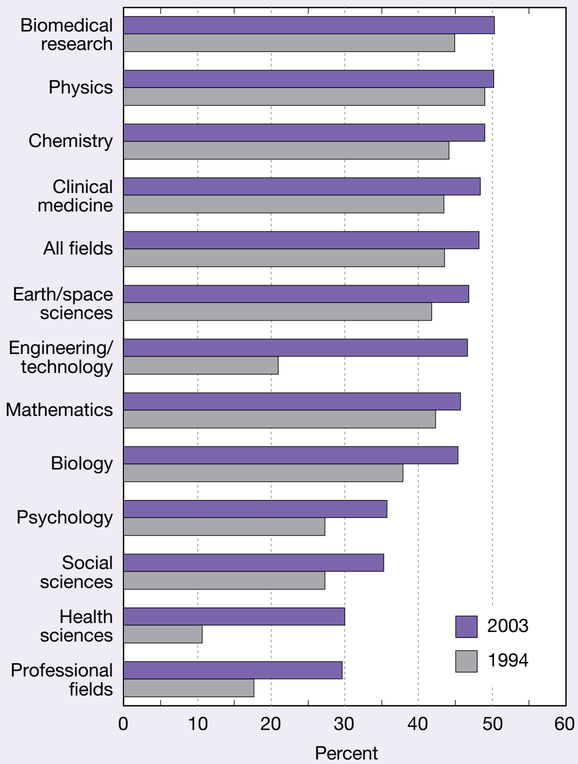
FFRDC = federally funded research and development center

NOTE: Articles on whole-count basis, i.e., for articles with collaborating institutions from more than one U.S. sector and/or non-U.S. sector, each sector with at least one participating institution is credited one count.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-57, 5-58, 5-59, and 5-60.

Science and Engineering Indicators 2006

Figure 5-54
Foreign scientific literature cited in worldwide scientific articles: 1994 and 2003



NOTES: Citations are references to scientific articles in journals covered by *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI).* Citation counts based on a 3-year period with 2-year lag (e.g., citations for 2000 are references made in articles published in 1996–98). Fields ranked by 2001 share. Engineering/technology includes computer sciences. Biology includes agricultural sciences.

SOURCES: Thomson ISI, *SCI* and *SSCI,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-62.

Science and Engineering Indicators 2006

supporting knowledge-based industries closely linked to scientific research.

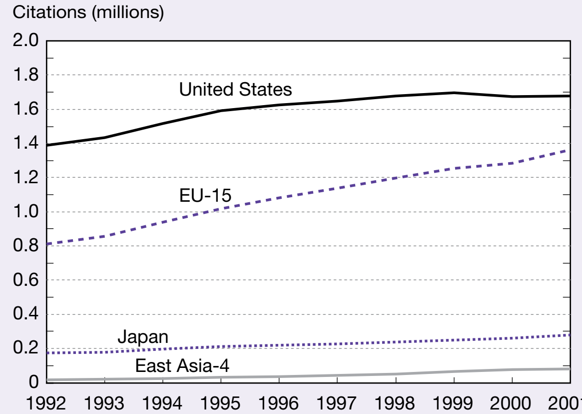
Growth in Patenting by Academic Institutions

Patenting by academic institutions increased markedly between 1988 and 2003, quadrupling from about 800 to more than 3,200 patents (appendix tables 5-67 and 5-68). (See also NSB 1996, appendix table 5-42.) The academic share of patents also rose slightly during this period, even as growth in all U.S. patents increased rapidly (figure 5-59).

Several factors appear to have supported the rapid rise in academic patenting:

♦ **The Bayh-Dole University and Small Business Patent Act.** This 1980 law (Public Law 96-517) established a uniform government-wide policy and process for government grantees and contractors to retain title to inventions resulting from federally supported R&D (whether fully

Figure 5-55
Citations of S&E literature, by region or country/economy: 1988–2003



EU = European Union

NOTES: Citations on fractional-count basis, i.e., for cited articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-61.

Science and Engineering Indicators 2006

Table 5-23
Share of world scientific literature cited in S&E articles, by major S&E publishing region or country/economy: 1992, 1997, and 2003
(Percent distribution)

Region or country/economy	1992	1997	2003
Worldwide	100.0	100.0	100.0
United States	51.7	48.1	42.4
EU-15	28.1	30.8	32.5
Other OECD	9.2	9.5	9.8
Japan	6.5	6.6	7.3
East Asia-4	0.7	1.3	3.3
All other countries	3.8	3.8	4.6

EU = European Union; OECD = Organisation for Economic Co-operation and Development.

NOTES: Region/country/economy ranked by share in 2001. Share based on publication counts from set of journals classified and covered by *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI)* and on institutional address of article. Citations on fractional-count basis, i.e., for cited articles with collaborating institutions from more than one country/economy, each country/economy receives fractional credit on basis of proportion of its participating institutions. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong. Other OECD excludes United States, Japan, and South Korea. Detail may not add to total because of rounding.

SOURCES: Thomson ISI, *SCI* and *SSCI*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-61.

Science and Engineering Indicators 2006

Table 5-24
Worldwide citations of U.S. scientific articles, by field: Selected years, 1992–2003

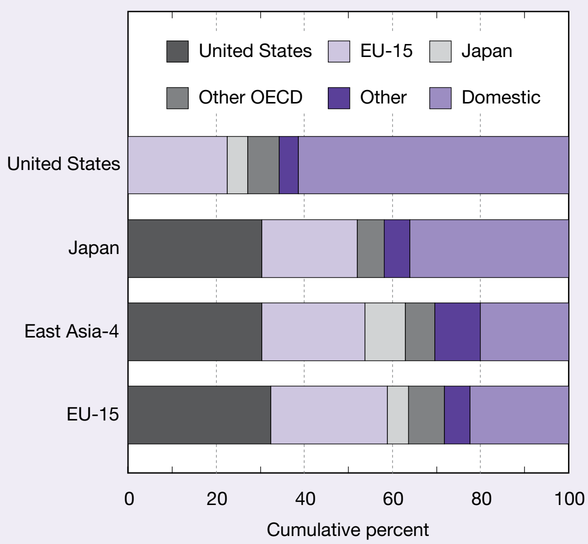
Field	1992	1995	1997	1999	2001	2003
All fields	1,389,314	1,593,418	1,648,899	1,696,859	1,678,294	1,839,481
Clinical medicine	475,793	538,931	574,859	584,330	589,762	649,522
Biomedical research	460,148	553,775	572,122	594,596	568,328	596,642
Biology	52,535	58,998	58,130	56,981	57,899	71,664
Chemistry	88,010	105,770	105,762	110,927	109,703	136,724
Physics	137,922	139,810	131,958	125,968	120,593	112,046
Earth/space sciences	55,086	69,487	73,507	83,053	82,614	100,282
Engineering/technology	32,680	34,631	32,958	34,001	36,809	45,178
Mathematics	6,858	6,492	6,418	7,520	7,794	9,504
Social/behavioral sciences	80,282	85,524	93,187	99,481	104,793	117,919

NOTES: Citations on fractional-count basis, i.e., for cited articles with collaborating institutions from outside the United States, the United States receives fractional credit on basis of proportion of its participating institutions. Social/behavioral sciences consist of psychology, social sciences, health sciences, and professional fields. Engineering/technology includes computer sciences. Biology includes agricultural sciences. Detail may not add to total because of rounding.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-61.

Science and Engineering Indicators 2006

Figure 5-56
Citation of S&E literature, by major S&E publishing region or country/economy: 2003



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTES: Citations on fractional-count basis, i.e., for cited articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. EU citation of EU literature consists of citation of EU member countries outside of each member country. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong. Other OECD excludes United States, Japan, and South Korea.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Table 5-25
Relative prominence of citations of scientific literature, by major S&E publishing region or country/economy: 1992, 1997, and 2003
(Relative citation index)

Region or country/economy	1992	1997	2003
United States	1.000	1.016	1.026
EU-15	0.659	0.689	0.737
Japan	0.566	0.539	0.575
East Asia-4	0.255	0.275	0.335

EU = European Union

NOTES: Relative citation index is major publishing region/country/economy's share of cited literature adjusted for its share of published literature. Citations of country/economy's own literature are excluded. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

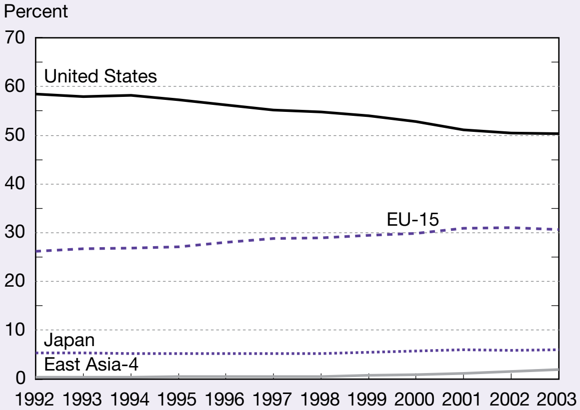
SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-62.

Science and Engineering Indicators 2006

or partially funded) and encouraged the licensing of such inventions to industry.

- **Emerging and maturing research-based industries.** During the 1990s, industries emerged and matured that used commercial applications derived from "use-oriented" basic research in life sciences fields such as molecular biology and genomics (Stokes 1997).
- **Strengthening of patent protection.** Changes in the U.S. patent regime strengthened overall patent and copyright protection and encouraged the patenting of biomedical and life sciences technology. The creation of the Court of Appeals of the Federal Circuit to handle patent infringement cases was one factor in the strengthening of overall patent protection. The Supreme Court's landmark 1980

Figure 5-57
Share of top 5% of cited S&E articles, by major S&E publishing region or country/economy: 1992–2003



EU = European Union

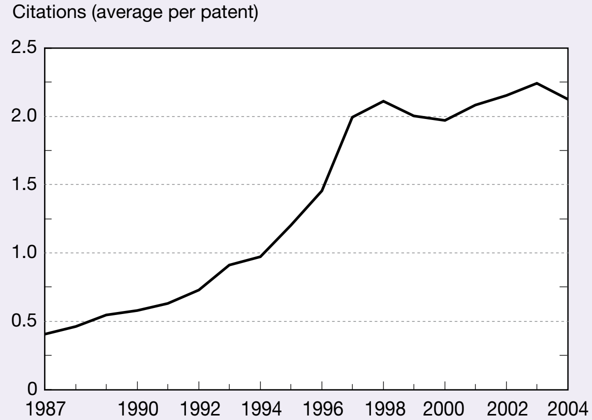
NOTES: Citations are references to scientific articles in journals covered by *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI).* Citation counts based on a 3-year period with 2-year lag (e.g., citations for 2003 are references made in articles published in 2003 to top 5% of articles published in 1999–2001). Citations on fractional-count basis, i.e., for cited articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *SCI* and *SSCI,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-63.

Science and Engineering Indicators 2006

ruling in *Diamond* v. *Chakrabarty,* which allowed patentability of genetically modified life forms, also may have been a major stimulus behind the recent rapid increases.

Figure 5-58
Citations of S&E material in U.S. patents: 1987–2004



NOTE: S&E material constitutes references to articles in S&E journals and nonarticle materials such as reports, technical notes, and conference proceedings.

SOURCES: ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-65.

Science and Engineering Indicators 2006

The rise in U.S. academic patenting has been accompanied by a growing number of patents awarded to institutions. The number of institutions awarded patents increased by more than 60% between the late 1980s and 2003 to 198 (appendix tables 5-67 and 5-68).[51] Both public and private institutions participated in this rise. Despite the increase in institutions receiving patents, the distribution of patenting activity has remained highly concentrated among a few major research universities. Among the top 100 R&D institutions, the top 25 recipients between 1994 and 2003 accounted for 55% of all academic patents in 2003, a share that has remained

Table 5-26
Share of U.S. patents citing S&E literature, by nationality of inventor: 1990, 1997, and 2003
(Percent distribution)

Nationality of inventor	1990 Total (90,379)	1990 Citing literature (6,367)	1997 Total (112,030)	1997 Citing literature (15,423)	2003 Total (164,450)	2003 Citing literature (20,111)
Worldwide	100.0	100.0	100.0	100.0	100.0	100.0
United States	52.4	63.1	54.9	66.8	51.1	64.5
EU-15	19.5	16.5	15.7	14.8	15.1	15.0
Japan	21.6	15.2	20.7	12.0	21.6	11.2
East Asia-4	1.2	0.3	3.8	1.2	7.0	2.4
All other countries	5.3	4.9	4.9	5.2	5.2	6.9

EU = European Union

NOTES: Number of U.S. patents (in parentheses) and nationality of inventor based on U.S. patents referencing S&E articles in journals classified and tracked by *Science Citation Index (SCI)*. East Asia-4 consists of China, Singapore, South Korea, and Taiwan. China includes Hong Kong.

SOURCES: Thomson ISI, *SCI*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Table 5-27
Citation of S&E literature in U.S. patents relative to share of scientific literature, by selected major publishing region or country/economy and field: 2004
(Relative citation index)

Field	United States	European Union-15	Japan	East Asia-4
All fields	1.208	0.784	0.851	0.578
Clinical medicine	1.102	0.816	0.716	0.424
Biomedical research	1.242	0.744	0.590	0.363
Chemistry	2.128	1.619	1.326	0.906
Physics	1.249	0.603	1.333	0.873
Engineering/technology	1.158	0.791	0.993	0.590

NOTES: Relative citation index is frequency of citation of major publishing region/country/economy's scientific literature by U.S. patents, adjusted for its world share of published S&E literature. Citations of country/economy's own literature are excluded. Index of 1.00 indicates region/country/economy's share of cited literature equals its world share of scientific literature. Index >1.00 or <1.00 indicates region cited relatively more/less frequently than indicated by its share of world S&E literature. Citations are references to U.S. S&E articles in journals indexed and tracked by *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI)*. Citation counts based on 6-year window with 2-year lag, (e.g., citations for 2002 are references in U.S. patents issued in 2002 to articles published in 1995–2000). Scientific field determined by ipIQ's classification of journal. Engineering/technology includes computer sciences.

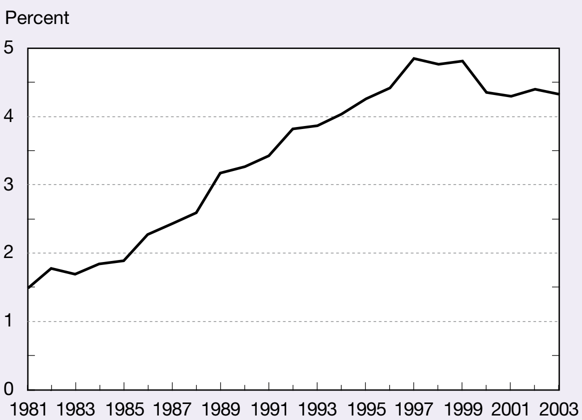
SOURCES: Thomson ISI, *SCI* and *SSCI*, http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

constant for two decades. Including the next 75 largest recipients increases the share to more than 80% of patents granted to all institutions since 1987 (appendix tables 5-67 and 5-68).

The growth in academic patents occurred primarily in the life sciences and biotechnology (Huttner 1999). Patents in two technology areas or *utility classes,* both with presumed biomedical relevance, accounted for a third of the academic total in 2003, up from less than a fourth in the early 1980s. The class that experienced the fastest growth, class 435 (chemistry, molecular biology, and microbiology), doubled its share during this period (figure 5-60). Its share, however, fell from a peak of 21% in 1998 to 15% in 2003.

Figure 5-59
U.S. academic share of patenting by U.S. private and nonprofit sectors: 1981–2003



NOTES: Patents issued by U.S. Patent and Trademark Office (U.S. PTO) to U.S. universities and corporations. U.S. private and nonprofit sectors include U.S. corporations (issued bulk of patents in this category), nonprofits, small businesses, and educational institutions.

SOURCES: U.S. PTO, *Technology Assessment and Forecast Report: U.S. Colleges and Universities, Utility Patent Grants, 1969–2003* (2004); and special tabulations.

Science and Engineering Indicators 2006

A survey by the Association of University Technology Managers (AUTM), which tracks several indicators of academic patenting, licensing, and related practices, shows the expansion of patenting and related activities by universities (table 5-28; appendix table 5-69). The number of new patent applications more than quintupled between FY 1991 and FY 2003,[52] indicating the growing effort and increasing success of universities obtaining patent protection for their technology.

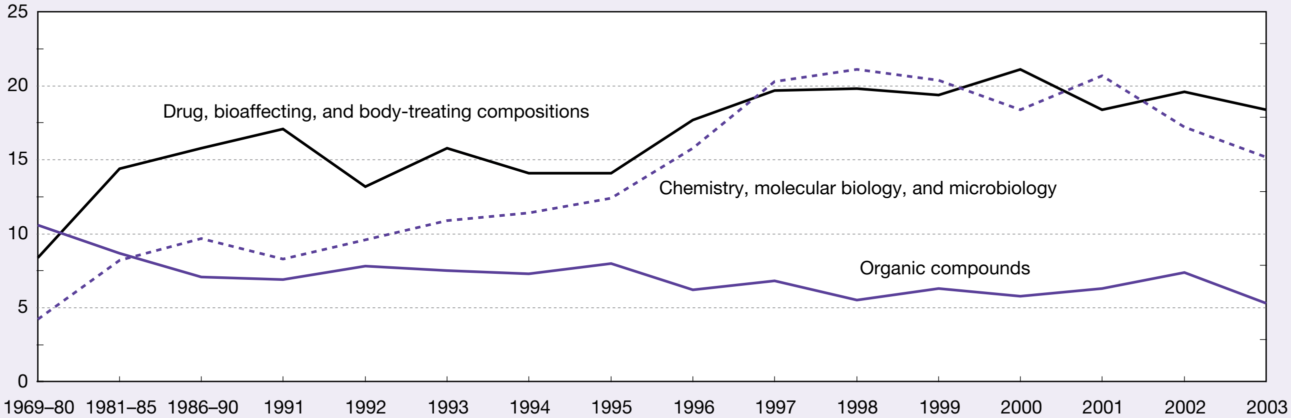
Invention Disclosures and Licensing Options

Two indicators related to patents, invention disclosures and new licenses and options, provide a broader picture of university efforts to exploit their technology. *Invention disclosures,* which describe the prospective invention and are submitted before a patent application or negotiation of a licensing agreement, rose sharply during this period. *New licenses and options,* indicating the commercialization of university-developed technology, grew by more than 40% between FY 1997 and FY 2003 (table 5-28; appendix table 5-69).

The majority of licenses and options are executed with small companies, either existing or startups (figure 5-61). In cases of unproven or very risky technology, universities often opt to make an arrangement with a startup company because existing companies may be unwilling to take on the risk. Faculty involvement in startups may also play a key role in this form of alliance. The majority of licenses granted to startups are exclusive, which do not allow the technology to be commercialized by other companies.

With the continuing increase of revenue-generating licenses and options, income to universities from patenting and licenses grew substantially during the 1990s and the early part of this decade, reaching more than $850 million in FY 2003, more than twice as much as the FY 1997

Figure 5-60
Academic patents in three largest utility classes: 1969–2003



SOURCES: U.S. Patent and Trademark Office, *Technology Assessment and Forecast Report: U.S. Colleges and Universities, Utility Patent Grants, 1969–2002* (2001); and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2006

Table 5-28
Academic patenting and licensing activities: Selected years, 1991–2003

Activity indicator	1991 (98)	1993 (117)	1995 (127)	1997 (132)	1999 (139)	2001 (139)	2003 (165)
				Millions of dollars			
Net royalties	NA	195.0	239.1	391.1	583.0	753.9	866.8
Gross royalties	130.0	242.3	299.1	482.8	675.5	868.3	1,033.6
Royalties paid to others	NA	19.5	25.6	36.2	34.5	41.0	65.5
Unreimbursed legal fees expended	19.3	27.8	34.4	55.5	58.0	73.4	101.3
New research funding from licenses[a]	NA	NA	112.5	136.2	149.0	225.7	212.8
				Number			
Invention disclosures received	4,880	6,598	7,427	9,051	10,052	11,259	13,718
New U.S. patent applications filed	1,335	1,993	2,373	3,644	4,871	5,784	7,203
U.S. patents granted	NA	1,307	1,550	2,239	3,079	3,179	3,450
Startup companies formed	NA	NA	169	258	275	402	348
Revenue-generating licenses/options	2,210	3,413	4,272	5,659	6,663	7,715	11,118
New licenses/options executed	1,079	1,737	2,142	2,707	3,295	3,300	3,855
Equity licenses/options	NA	NA	99	203	181	328	316
				Percent[b]			
Sponsored research funds	65	75	78	82	82	84	87
Federal research funds	79	85	85	90	90	92	94

NA = not available

[a]Directly related to license or option agreement.
[b]Of national academic total represented by number of institutions reporting.

NOTES: Number of institutions reporting given in parentheses. See appendix table 5-55.

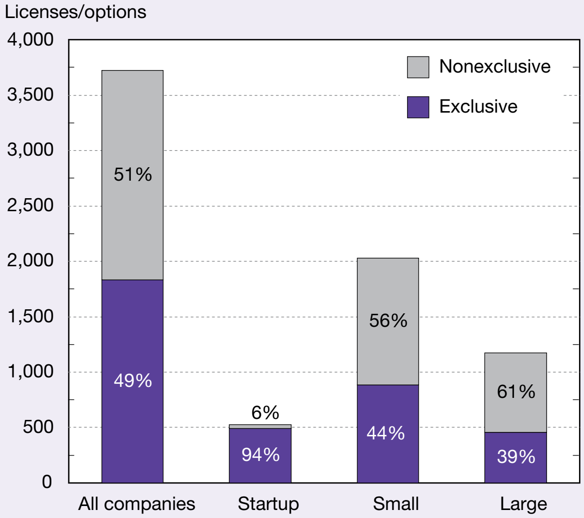
SOURCE: Association of University Technology Managers, *AUTM Licensing Survey* (various years). See appendix table 5-69.

Science and Engineering Indicators 2006

level.[53] Licensing income, however, is only a small fraction of overall academic research spending, amounting to less than 3% in FY 2003.[54] Licensing income is highly concentrated among a few universities and blockbuster patents. Of the institutions reporting data on royalties from patenting and licensing in FY 2003, less than 10% received $25 million or more in gross income, whereas more than half received less than $1 million (table 5-29).

Because licensing income has been highly concentrated among relatively few universities, technology transfer has not been financially lucrative for most universities (Powers 2003).[55] Universities are motivated by factors other than

Figure 5-61
Characteristics of licenses and options executed by U.S. universities: 2003



NOTES: Exclusive agreements do not allow sharing or marketing of technology to other companies, whereas this is permitted under nonexclusive agreements. Numbers in bars are percent share of exclusive and nonexclusive licenses of each type of company. Large companies are firms with >500 employees when license/option was signed. Small companies are firms with <500 employees when license/option was signed. Start-up companies are companies that were dependent on licensing of academic institution's technology for initiation.

SOURCE: Association of University Technology Managers, *AUTM Licensing Survey: FY 2003* (2004).

Science and Engineering Indicators 2006

profitability, such as signaling the technological capability of their research, encouraging collaboration with industry, and helping their professors disseminate their research for commercialization.[56]

Because university-industry collaboration and successful commercialization of academic research in the United States contributed to the rapid transformation of new and often basic knowledge into industrial innovations, other nations are trying to strengthen innovation by adopting similar practices. (See sidebar, "Academic Patenting and Licensing in Other Countries".)

Table 5-29
University income from patenting and licensing activities, by income level: 2003

Gross income ($ millions)	Number of institutions
>50.00	3
25.00–50.00	7
10.00–24.99	13
5.00–9.99	12
1.00–4.99	38
<1.00	81

NOTE: Income excludes income paid to other institutions.

SOURCE: Association of University Technology Managers, *AUTM Licensing Survey: FY 2003* (2004).

Science and Engineering Indicators 2006

Academic Patenting and Licensing in Other Countries

Beginning in the mid-1990s, several countries, particularly members of the Organisation for Economic Co-operation and Development (OECD), sought to encourage and increase commercialization of technology developed at universities and other publicly supported research institutions (table 5-30). The focus has been on clarifying and strengthening ownerships and exploitation of an institution's intellectual property and on granting ownership of intellectual property to universities and other public research organizations in countries where the inventor or government was the owner. The justification for these legal and policy changes is that institutional ownership provides greater legal certainty, lowers transaction costs, and fosters more formal and efficient channels for technology transfer as compared with ownership by the government or the inventor (OECD 2002). Changes in intellectual property protection of academic institutions were through a variety of means, including reforming national patent policies, employment law, and research funding regulation and clarifying policy and administrative procedures of technology license offices.

The motivation for consideration and change of these countries' regulations and policies is due to a variety of factors (OECD 2002; Mowery and Sampat 2002):

- **Emulation of the United States.** Many countries believe that the United States has been very successful at commercializing its university technology, especially following the passage of the Bayh-Dole Act, which they consider a key factor in allowing the United States to benefit economically from its scientific research through encouraging and speeding up the commercialization of university inventions. This is especially true of European countries that would like to create indigenous science-based industries and believe that the level of commercialization from their public research and development is inadequate.
- **Exploitation of inventions developed from publicly funded research.** There is concern that current regulations and practices limit and slow the commercialization of technology developed from publicly funded research. Countries would like a greater commercial return from their investments in public scientific

Continued on page 5-58

Continued from page 5-57

research and believe that strengthening and clarifying policies toward licensing and patenting will encourage and speed up commercialization.

- ♦ **Generation of licensing revenues.** Countries believe an increase in patenting and licensing by universities will increase revenue from licensing technology, which could support university technology activities or university research. Some countries, however, acknowledged that licensing offices lose money on their operations and are considering subsidizing their operations with public funding.
- ♦ **Formation of spinoff companies.** Countries believe that commercialization of university-developed technology could yield formation of startup companies. Forming spinoff companies is viewed as desirable for creating new high-technology or science-based jobs and industries, fostering entrepreneurial skills and culture, and increasing competition among existing firms.
- ♦ **Promotion of international scientific collaboration.** The European Union (EU)-15 countries, in particular, are concerned that differing national laws and policies, particularly with regard to ownership of university technology, inhibit scientific collaboration within the EU by raising transaction costs due to legal complications and uncertainty.

The OECD conducted a survey in 2001 of member countries' technology transfer offices and examined national laws and regulations. The survey found that in countries that enacted legislation, awareness of and support for technology transfer increased among the major stakeholders, although relatively little growth in patenting, licensing, or spinoffs occurred. In addition, most licensing of technology from universities and public research organizations does not originate from patentable inventions. These findings raise the question of whether specific features of the U.S. education, research, and legal systems play a key part in the commercialization of the results of academic R&D in the United States.

Table 5-30
Ownership of academic intellectual property in OECD countries: 2003

	Owner of invention			
Country	University	Faculty	Government	Status/recent initiatives
Australia	x	na	na	
Austria	x	na	na	
Belgium	x	na	na	
Canada[a]	x	x	na	
Denmark	x	na	na	
Finland	na	x	na	Consideration of legislation in 2003 to restrict faculty's right to retain ownership of publicly funded research.
France	x	na	na	
Germany	x	na	na	Debate during 2001 over awarding ownership to universities.
Iceland	na	x	na	
Ireland	x	na	na	
Italy	na	x	na	Legislation passed in 2001 to give ownership rights to researchers. Legislation introduced in 2002 to grant ownership to universities and create technology transfer offices.
Japan[b]	na	x	o	Private technology transfer offices authorized in 1998.
Mexico	x	na	na	
Netherlands	x	na	na	
Norway	na	x	na	Legislation passed in 2003 to allow universities to retain ownership of publicly funded research.
Poland	x	na	na	
South Korea	x	na	na	
Sweden	na	x	na	Recent debate and consideration of legislation to allow universities to retain ownership of publicly funded research.
United Kingdom	x	o	na	Universities, rather than government, given rights to faculty inventions in 1985.
United States[c]	x	o	o	

x = legal basis or most common practice; na = not applicable; o = allowed by law/rule but less common
OECD = Organisation for Economic Co-operation and Development

[a]Ownership of intellectual property funded by institutional funds varies, but publicly funded intellectual property belongs to institution performing research.
[b]President of national university or interuniversity institution determines right to ownership of invention by faculty member, based on discussions by invention committee.
[c]Universities have first right to elect title to inventions resulting from federally funded research. Federal government may claim title if university does not. In certain cases, inventor may retain rights with agreement of university/federal partner and government.

SOURCES: OECD, *Questionnaire on the Patenting and Licensing Activities of PROs* (2002); and D.C. Mowery and B.N. Sampat, International emulation of Bayh-Dole: Rash or rational? Paper presented at American Association for the Advancement of Science symposium on International Trends in the Transfer of Academic Research (February 2002).

Science and Engineering Indicators 2006

Conclusion

Strengths combined with emerging challenges characterize the position of academic R&D in the United States during the first decade of the 21st century. U.S. universities and colleges continued to be an important participant in the U.S. R&D enterprise, performing nearly half the basic research nationwide and having a significant presence in applied research. Funding of academic R&D continues to expand. The size of both the overall academic S&E doctoral workforce and the academic research workforce continues to increase. Citation data indicate that U.S. scientific publications remain influential relative to those of other countries. However, the volume of U.S. article output has not kept up either with the increases in academic R&D funding and research personnel or with the increasing outputs of the EU-15 and several East Asian countries. In fact, the number of U.S. articles published in the world's leading S&E journals has essentially been level since the early to mid-1990s, a trend that remains unexplained.

Although funding for academic R&D has been increasing, a number of shifts in funding sources have occurred, the long-term implications of which are uncertain. After declining for many years in relative share, although not in absolute dollars, the federal government's role in funding academic R&D has begun to increase. Research-performing universities have also increased the amount of their own funds devoted to research. Industry support for academic R&D, after growing faster than any other source of support through the turn of the century, declined in real absolute dollars for 3 successive years. The share of state and local support for academic R&D reached an all-time low in 2003.

The structure and organization of the academic R&D enterprise have also changed. Research-performing colleges and universities continue to expand their stock of research space and are investing substantially greater amounts in constructing research space than in previous years. However, spending on research equipment as a share of all R&D expenditures declined to an all-time low of 4.5% by 2003. With regard to personnel, a researcher pool has grown, independent of growth in the faculty ranks, as academic employment continued a long-term shift toward greater use of nonfaculty appointments. The shift has been marked by a substantial increase in the number of postdocs over a long period, although the number began to decline during the past several years. These changes have occurred during a period in which both the median age of the academic workforce and the percentage of that workforce age 65 or older have been rising.

A demographic shift in academic employment has also been occurring, with increases in the shares of women, Asians/Pacific Islanders, and underrepresented minorities. This shift is expected to continue into the future. Among degree holders who are U.S. citizens, white males were earning a decreasing number of S&E doctorates. On the other hand, the number of S&E doctorates earned by U.S. women and members of minority groups has been increasing, and these new doctorate holders were more likely to enter academia than white males. A more demographically diverse faculty, by offering more varied role models, may attract students from a broader range of backgrounds to S&E careers.

The academic R&D enterprise is also becoming more globalized in a number of ways. U.S. academic scientists and engineers are collaborating extensively with international colleagues: in 2003, one U.S. journal article in four had at least one international coauthor. The intimate linkage between research and U.S. graduate education, regarded as a model by other countries, helps to lure large numbers of foreign students to the United States, many of whom stay after graduation. Academia has also been able to attract many talented foreign-born scientists and engineers into its workforce, with the percentage of foreign-born degree holders approaching half the total in some fields. However, tighter visa and immigration restrictions instituted after the terrorist attacks of September 11, 2001, may have complicated the prospects for current and future foreign students and scientists living in the United States.

Intersectoral collaboration within the United States is also increasing, particularly between universities and industry. Academic articles are increasingly cited in U.S. patents, attesting to the usefulness of academic research in producing economic benefits. Academic patenting and licensing continue to increase. Academic licensing and option revenues are growing, as are spinoff companies, and universities are increasingly moving into equity positions to maximize their economic returns. As a result, questions have arisen about the changing nature of academic research, the uses of its results, and the broader implications of closer ties between academia and industry.

Notes

1. Federally funded research and development centers (FFRDCs) associated with universities are tallied separately and are examined in greater detail in chapter 4. FFRDCs and other national laboratories (including federal intramural laboratories) also play an important role in academic research and education, providing research opportunities for both students and faculty at academic institutions.

2. For this discussion, an academic institution is generally defined as an institution that has a doctoral program in science or engineering, is a historically black college or university that expends any amount of separately budgeted R&D in S&E, or is some other institution that spends at least $150,000 for separately budgeted R&D in S&E.

3. Despite this delineation, the term "R&D" (rather than just "research") is primarily used throughout this discussion because data collected on academic R&D do not always differentiate between research and development. Moreover, it is often difficult to make clear distinctions among basic research, applied research, and development.

4. The academic R&D funding reported here includes only separately budgeted R&D and institutions' estimates

of unreimbursed indirect costs associated with externally funded R&D projects, including mandatory and voluntary cost sharing.

5. This follows a standard of reporting that assigns funds to the entity that determines how they are to be used rather than to the one that necessarily disburses the funds.

6. The medical sciences include fields such as pharmacy, veterinary medicine, anesthesiology, and pediatrics. The biological sciences include fields such as microbiology, genetics, biometrics, and ecology. These distinctions may be blurred at times because boundaries between fields often are not well defined.

7. In this chapter, the broad S&E fields refer to the physical sciences; mathematics; computer sciences; the earth, atmospheric, and ocean sciences; the life sciences; psychology; the social sciences; other sciences (those not elsewhere classified); and engineering. The more disaggregated S&E fields are referred to as "subfields."

8. The recent creation of the Department of Homeland Security (DHS) should have major implications for the future distribution of federal R&D funds, including federal academic R&D support, among the major R&D funding agencies. DHS's Directorate of Science and Technology is tasked with researching and organizing the scientific, engineering, and technological resources of the United States and leveraging these existing resources into technological tools to help protect the homeland. Universities, the private sector, and the federal laboratories are expected to be important DHS partners in this endeavor.

9. Another hypothesis is that some of the difference may be due to many public universities not having the incentive to negotiate full recovery of indirect costs of research because the funds are frequently captured by state governments.

10. The Carnegie Foundation for the Advancement of Teaching classified about 3,600 degree-granting institutions as higher education institutions in 1994. See chapter 2 sidebar, "Carnegie Classification of Academic Institutions," for a brief description of the Carnegie categories. These higher education institutions include 4-year colleges and universities, 2-year community and junior colleges, and specialized schools such as medical and law schools. Not included in this classification scheme are more than 7,000 other postsecondary institutions such as secretarial schools and auto repair schools.

11. Inflation averaged less than 2% over the period discussed. For an analysis of this trend among the top 200 institutions with the largest R&D expenditures and for a comparison of institutions that increased their R&D expenditures by more than 3% over the preceding year with those that did not, see NSF/SRS 2004.

12. Although the number of institutions receiving federal R&D support between 1973 and 1994 increased overall, a rather large decline occurred in the early 1980s, most likely due to the fall in federal R&D funding for the social sciences during that period.

13. Research-performing academic institutions are defined as colleges and universities that grant degrees in science or engineering and expend at least $1 million in R&D funds. Each institution's R&D expenditure is determined through the NSF Survey of Research and Development Expenditures at Universities and Colleges.

14. Research space here is defined as the space used for sponsored research and development activities at academic institutions that is separately budgeted and accounted for. Research space is measured in NASF, the sum of all areas on all floors of a building assigned to, or available to be assigned to, an occupant for a specific use, such as research or instruction. NASF is measured from the inside faces of walls. Multipurpose space that is at least partially used for research is prorated to reflect the proportion of time and use devoted to research.

15. Some of this space will likely replace existing space and therefore will not be a net addition to existing stock.

16. Institutional funds may include operating funds, endowments, tax-exempt bonds and other debt financing, indirect costs recovered from federal grants/contracts, and private donations.

17. Institutions rated space using four categories: (1) space in superior condition that is suitable for the most scientifically competitive research in the field over the next 2 years; (2) space in satisfactory condition that is suitable for continued use over the next 2 years for most levels of research in the field but that may require minor repairs or renovation; (3) space that requires renovation and that will no longer be suitable for current research without undergoing major renovation with the next 2 years; and (4) space that requires replacement and that should stop being used for current research within the next 2 years.

18. The "bricks and mortar" section of the Survey of Science and Engineering Research Facilities asked institutions to report on their research space only. The reported figures therefore do not include space used for other purposes such as instruction or administration. In the networking and computing section of the survey, however, respondents were asked to identify all of their computing and networking resources, regardless of whether these resources were used for research.

19. Innovation is the generation of new or improved products, processes, and services. For more information, see chapter 6.

20. This set of institutions constitutes the Carnegie Research I and II institutions, based on the 1994 classification. These institutions have a full range of baccalaureate programs, have a commitment to graduate education through the doctorate, award at least 50 doctoral degrees annually, and receive federal support of at least $15.5 million (1989–91 average); see Carnegie Foundation for the Advancement of Teaching (1994). The other Carnegie categories include doctorate-granting institutions, master's (comprehensive) universities and colleges; baccalaureate (liberal arts) colleges; 2-year community and junior colleges; and specialized schools such as engineering and technology, business

and management, and medical and law schools. The classification has since been modified, but the older schema is more appropriate to the discussion presented here.

21. The academic doctoral S&E workforce includes those with a doctorate in an S&E field in the following positions: full and associate professors (referred to as *senior faculty*); assistant professors and instructors (referred to as *junior faculty*); postdocs; other full-time positions such as lecturers, adjunct faculty, research and teaching associates, and administrators; and part-time positions of all kinds. Unless specifically noted, data on S&E doctorate holders refer to persons with an S&E doctorate from a U.S. institution, as surveyed biennially by NSF in the Survey of Doctorate Recipients. All numbers are estimates rounded to the nearest 100. The reader is cautioned that small estimates may be unreliable.

22. It is impossible to establish causal connections among these developments with the data at hand.

23. For more information on this subject, see the discussion of postdocs in chapter 3.

24. See also the discussion of retirements from the S&E workforce in chapter 3.

25. A 1986 amendment to the Age Discrimination in Employment Act of 1967 (Public Law 90-202) prohibited mandatory retirement on the basis of age for almost all workers. Higher education institutions were granted an exemption through 1993 that allowed termination of employees with unlimited tenure who had reached age 70.

26. For more information about the effects of mentoring, see *Diversity Works: The Emerging Picture of How Students Benefit* (Smith et al. 1997).

27. See chapter 2, "Doctoral Degrees by Sex."

28. See chapter 2, "S&E Bachelor's Degrees by Race/Ethnicity."

29. Both the number and share of Asian/Pacific Islander S&E doctorate recipients employed in academia are probably larger than is reported here because those who received S&E doctorates from universities outside the United States are not included in the analysis.

30. In 2003, 58% of those who were foreign born were U.S. citizens.

31. For a more thorough discussion of the role of foreign scientists and engineers, including the possible impact of security policies set in place after September 11, 2001, see chapters 2 and 3.

32. Public service includes activities established primarily to provide noninstructional services beneficial to individuals and groups external to the institution. These activities include community service programs and cooperative extension services.

33. The survey question on which this analysis is based encompasses four separate items that are considered to be academic research: basic research, applied research, development, and design. In the following discussion, unless specifically stated otherwise, the term *research* refers to all four.

34. For technical reasons, the postdoc number excludes holders of S&E doctorates awarded by foreign universities. Data from NSF's Survey of Graduate Students and Postdoctorates in Science and Engineering suggest that in 2003, the number of postdocs in U.S. academic institutions with doctorates from foreign institutions was approximately twice that of those with U.S. doctorates. Most of them could be expected to have research as their primary work activity.

35. For a more detailed treatment of graduate education in general, including the mix of graduate support mechanisms and sources, see chapter 2.

36. This measure was constructed slightly differently in the 1980s and in the 1990s, starting in 1993, and is not strictly comparable across these periods. Therefore, the crossing over of the two trends in the 1990s could reflect only a methodological difference. However, the very robust trend in the life sciences, in which researchers started outnumbering teachers much earlier, suggests that this methodological artifact cannot fully explain the observed trend. Individuals can be counted in both groups.

37. The field of computer sciences, in which scientists disseminate much of their research through peer-reviewed conference proceedings, is one exception.

38. The EU-15 are the 15 EU countries before the expansion of EU membership on May 1, 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

39. Changes over time in journal coverage could distort U.S. output for reasons that have little or nothing to do with publishing intensity, such as coverage of new non-English journals. To control for changes in *SCI/SSCI* journal coverage that may have occurred for these extraneous reasons, we also performed analyses on a fixed set of journals indexed in 1985. These analyses found the U.S. trend relative to other publishing centers to be accentuated, with U.S. output falling 10% between 1992 and 2003, whereas output grew in the EU-15, Japan, and the East Asia-4.

40. The social and behavioral sciences consist of psychology, the social sciences, the health sciences, and professional fields.

41. International articles may also have multiple U.S. addresses.

42. A moderately high correlation ($r^2 = 0.66$) exists between the number of U.S. doctorates awarded to foreign-born students, by country, in 1994–98 and the volume of papers coauthored by the United States and those countries in 1997–2003.

43. Articles jointly authored exclusively between or among the economies of the East Asia-4 are not counted as international articles.

44. Citations are not a straightforward measure of quality, for the following reasons: authors' citation of their own previous articles; authors' citation of the work of colleagues, mentors, and friends; and a possible nonlinear relationship between a country's output of publications and citations to that output.

45. The relative citation index is the share of a region or country's S&E literature cited by the rest of world adjusted

for its share of published S&E literature. A region or country's citations of its own literature are excluded from the relative citation index to remove the potential bias of authors citing their own research, institutions, or national literature.

46. The U.S. PTO evaluates patent applications on the basis of whether the invention is useful, novel, and nonobvious. The novelty requirement leads to references to other patents, scientific journal articles, meetings, books, industrial standards, technical disclosures, etc. These references are termed *prior art.*

47. Citation data must be interpreted with caution. The use of patenting varies by type of industry, and many citations in patent applications are to prior patents. Patenting is only one way that firms seek returns from innovation and thus reflects, in part, strategic and tactical decisions (e.g., laying the groundwork for cross-licensing arrangements). Most patents do not cover specific marketable products but might conceivably contribute in some fashion to one or more products in the future. (See Geisler 2001.)

48. Citations are references to S&E articles in journals indexed and tracked by the *Science Citation Index* and *Social Sciences Citation Index*. Citation counts are based on articles published within a 12-year period that lagged 3 years behind the issuance of the patent. For example, citations for 2000 are references made in U.S. patents issued in 2000 to articles published in 1986–97.

49. Research articles also are increasingly cited in patents, attesting to the close relationship of some basic academic research to potential commercial applications. See the previous section, "Citations in U.S. Patents to S&E Literature."

50. Other means of technology transfer are industry hiring of students and faculty, consulting relationships between faculty and industries, formation of firms by students or faculty, scientific publications, presentations at conferences, and informal communications between industrial and academic researchers.

51. The institution count is a conservative estimate because several university systems are counted as one institution, medical schools are often counted with their home institution, and universities are credited for patents on the basis of being the first-name assignee on the patent, which excludes patents where they share credit with another first-name assignee. Varying and changing university practices in assigning patents, such as to boards of regents, individual campuses, or entities with or without affiliation to the university, also contribute to the lack of precision in the estimate. The data presented here have been aggregated consistently by the U.S. PTO since 1982.

52. Universities report data to AUTM on a fiscal-year basis, which varies across institutions.

53. Licensing income for 2000 was boosted by several one-time payments, including a $200 million settlement of a patent infringement case, and by several institutions' cashing in of their equity held in licensee companies.

54. See *Academic Research and Development Expenditures: Fiscal Year 2001* (NSF/SRS 2003). This is a rough estimate because of the lack of data on the R&D expenditures of a few smaller institutions.

55. Data on costs are not available, but can be considerable, such as patent and license management fees (Sampat 2002). Thursby and colleagues (2001) report that universities allocate an average of 40% of net income to inventors, 16% to the inventor's department or school (often returned to the inventor's laboratory), 26% to central administrations, and 11% to technology transfer offices, with the remainder allocated to "other."

56. Patenting by U.S. universities appears to have had no impact on publishing output, a concern voiced by some policymakers and researchers. S&E article output trends by top patenting universities between 1981 and 2001 were consistent with those of nonpatenting universities and the entire U.S. academic sector.

Glossary

Abilene: A high-performance network dedicated to research led by a consortium of universities, governments, and private industry; often called Internet2.

Academic institution: In the Financial Resources for Academic R&D section of this chapter, an institution that has a doctoral program in science or engineering, is a historically black college or university that expends any amount of separately budgeted R&D in S&E, or is some other institution that spends at least $150,000 for separately budgeted R&D in S&E. In the remaining sections, any accredited institution of higher education.

Cyberinfrastructure: Infrastructure based on distributed computer, information, and communication technology.

Federal obligations: Dollar amounts for orders placed, contracts and grants awarded, services received, and similar transactions during a given period, regardless of when funds were appropriated or payment was required.

Federally funded research and development center: R&D-performing organizations exclusively or substantially financed by the federal government either to meet particular R&D objectives or, in some instances, to provide major facilities at universities for research and associated training purposes; each FFRDC is administered either by an industrial firm, a university, or a nonprofit institution.

Innovation: Generation of new or improved products, processes, and services.

Intellectual property: Intangible property that is the result of creativity; the most common forms of intellectual property include patents, copyrights, trademarks, and trade secrets.

Net assignable square feet (NASF): The unit for measuring research space; NASF is the sum of all areas on all floors of a building assigned to, or available to be assigned to, an occupant for specific use, such as research or instruction.

Nontraditional student: One who does not move directly from high school to college; i.e., a transfer student, adult student, or part-time student.

Research space: the space used for sponsored R&D activities at academic institutions that is separately budgeted and accounted for.

Underrepresented minority: blacks, Hispanics, and American Indians/Alaska Natives are considered to be underrepresented in academic R&D.

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Chapter 6
Industry, Technology, and the Global Marketplace

List of Sidebars

List of Tables

List of Figures

Highlights

Changing Global Marketplace

High-technology manufacturing industries are key contributors to economic growth in the United States and around the world.

- The global market for high-technology goods is growing faster than that for other manufactured goods.
- Over the past 24 years (1980–2003), world output by high-technology manufacturing industries grew at an inflation-adjusted average annual rate of 6.4%. Output by other manufacturing industries grew at just 2.4%.
- The European Union (EU) had the world's largest high-technology manufacturing sector between 1980 and 1995.
- Beginning in 1996 and for each year thereafter, U.S. high-technology manufacturers generated more domestic production (value added) than the EU or any other single country. Estimates for 2003 show U.S. high-technology industry accounting for more than 40% of global value added, the EU for about 18%, and Japan for about 12%.

Asia's status as both a consumer and a developer of high-technology products continues to advance, enhanced by the technological development of many Asian economies, particularly Taiwan, South Korea, and China. Several smaller European countries (e.g., Ireland, Finland, and the Netherlands) also have strengthened their capacities to develop new technologies and successfully supply high-technology products in global markets. However, the technological competencies in these latter countries are in a narrower set of technologies.

- Current data on domestic production by high-technology industries in Asia and in several smaller European countries reveal a capacity to compete successfully with high-technology industries operating in the United States and other advanced countries.
- High-technology domestic production within Asian nations has grown over the past two decades, led first by Japan in the 1980s and then by South Korea, Taiwan, and China in the 1990s. Recently, China's high-technology industries have surpassed those of South Korea and Taiwan and may soon rival those of Japan in size.
- In 2003, domestic production by China's high-technology industry accounted for an estimated 9.3% of global value added. In 1980, domestic production in China's high-technology industry accounted for less than 1% of global value added.
- Although some smaller European countries have become important sources for technology products, they tend to specialize more. For example, Ireland was the top supplier of biotechnology and life science products to the United States in 2004, as the source for 24% and 36% of U.S. imports in these categories.

From 1980 through 2003, market competitiveness of individual U.S. high-technology industries varied, although each sector maintained strong market positions.

- In 1998, U.S. manufacturers replaced Japanese manufacturers as the leading producers of communication equipment and have retained that position. In 2003, the United States accounted for nearly 51% of world production (value added), Japan for 16%, and the EU for 9%.
- In 1997, U.S. manufacturers also replaced Japanese manufacturers as the leading producers of office and computer machinery; by 2003, U.S. manufacturers accounted for an estimated 40% of global production while China's industry secured second place at 26%, with the EU in third place at 9%.
- The U.S. aerospace industry has long maintained a leading if not dominant position in the global marketplace. In recent years however, the aerospace industry's manufacturing share has fallen more than any other U.S. industry. U.S. industry share of global aerospace production is estimated to have fallen to about 35% in 2003. At its highest level in 1985, U.S. aerospace accounted for 57% of global production.
- The EU and the United States were the leading producers of drugs and medicines in the world market for the entire 24-year period examined, each accounting for about 32% of global production in both 2002 and 2003.
- The EU and the United States were also the leading producers of scientific instruments. Led by Germany and France, the EU accounted for an estimated 38% of global production in 2003, while the U.S. share was nearly 35%.

Shifting Export Trends

Historically, U.S. high-technology industries have been more successful exporting their products than other U.S. industries, positively contributing to the overall U.S. trade balance. Although U.S. high-technology industries continue to export a larger proportion of their total shipments than other U.S. manufacturing industries, their advantage has narrowed considerably.

- Throughout the 1990s and continuing through 2003, U.S. industry supplied 12%–14% of the world's general manufacturing exports. By comparison, during the 1990s, U.S. high-technology industries accounted for 19%–23% of world high-technology industry exports.
- The EU is the world's leading exporter, but if intra-EU shipments were excluded, the United States likely would rank above the EU. Estimates for 2003 show exports by U.S. high-technology industries account for about 16% of world high-technology industry exports. Japan accounts for about 9% and Germany for nearly 8%.

- The gradual drop in the U.S. share was partly due to competition from emerging high-technology industries in newly industrialized and industrializing economies, especially in Asia. China stands out, with its share of global high-technology industry exports reaching 7% in 2003, up considerably from slightly more than 1% in 1990.

The comparative advantage in U.S. trade in advanced technology products, historically a strong market segment for U.S. industry, has turned negative.

- In 2002, U.S. imports of advanced technology products exceeded exports, resulting in a first-time U.S. trade deficit in this market segment. The trade deficit has grown each year since. The U.S. trade deficit in advanced technology products was $15.5 billion in 2002; it increased to $25.4 billion in 2003 and to $37.0 billion in 2004.
- The imbalance of U.S. trade with Asian countries (imports exceeding exports), especially with China, Malaysia, and South Korea, overwhelms U.S. surpluses and relatively balanced trade with other parts of the world.

Knowledge-intensive service industries are key contributors to service-sector growth around the world.

- Global sales in knowledge-intensive service industries rose every year from 1980 through 2003 and exceeded $14 trillion in 2003.
- The United States was the leading provider of knowledge-intensive services, responsible for about one-third of world revenue totals during the 24-year period examined.
- Business services, which includes computer and data processing and research and engineering services, is the largest of the five service industries, accounting for 35% of global knowledge-intensive revenues in 2003.
- Business-service industries in the EU and United States are close in size and the most prominent in the world; together they account for more than 70% of services provided worldwide. Japan ranked a distant third at about 12%.

The United States continues to be a net exporter of manufacturing technological know-how sold as intellectual property.

- On average, royalties and fees received from foreign firms were three times greater than those paid out to foreigners by U.S. firms for access to their technology.
- In 2003, U.S. receipts from the licensing of technological know-how to foreigners totaled $4.9 billion, 24.4% higher than in 1999. The most recent data show a trade surplus of $2.6 billion in 2003, 28% higher than the prior year but still lower than the $3.0 billion surplus recorded in 2000.

New High-Technology Exporters

Based on a model of leading indicators, Israel and China received the highest composite scores of the 15 nations examined. Both nations appear to be positioning themselves for greater prominence as exporters of technology products in the global marketplace.

- Israel ranked first in national orientation based on strong governmental and cultural support promoting technology production, and first in socioeconomic infrastructure because of its large number of trained scientists and engineers, its highly regarded industrial research enterprise, and its contribution to scientific knowledge. Israel placed second and third on the two remaining indicators, technological infrastructure and productive capacity.
- Although China's composite score for 2005 fell just short of that calculated for Israel, the rise in its overall score over the past 2 years is noteworthy. China's large population helped to raise its score on several indicator components; this shows how scale effects, both in terms of large domestic demand for high-technology products and the ability to train large numbers of S&Es, may provide advantages to developing nations.

Global Trends in Patenting

Recent patenting trends, a leading indicator of future competition for U.S. industry, show growing capacities for technology development in Asia and in a transitioning Europe.

- Patents issued to foreign inventors have increased slightly since 1999. Inventors from Japan and Germany continue to receive more U.S. patents than inventors from any other foreign countries.
- Although patenting by inventors from leading industrialized countries has leveled off or declined in recent years, two Asian economies, Taiwan and South Korea, have increased their patenting activity in the United States.
- The latest data indicate that Taiwan (in 2001) and South Korea (in 2003) moved ahead of France and the United Kingdom to rank third and fourth as the residences of foreign inventors who obtained patents in the United States.
- In 2003, the top five economies receiving patents from the United States were Japan, Germany, Taiwan, South Korea, and France.
- Recent U.S. patents issued to foreign inventors emphasize several commercially important technologies. Japanese patents focus on photography, photocopying, office electronics technology, and communications technology. German inventors are developing new products and processes associated with heavy industry, such as motor vehicles, printing, metal forming, and manufacturing technologies. Taiwanese and South Korean inventors are earning more U.S. patents in communication and computer technology.
- In 2003, more than 169,000 patents for inventions were issued in the United States, 1% more than a year earlier.
- U.S. resident inventors received nearly 88,000 new patents in 2003, which accounted for about 52% of total patents granted.

U.S. patenting of biotechnologies accelerated during the 1990s, especially during the latter half of the decade.

The effort to map the human genome contributed to this trend as evidenced by a surge in applications to patent human DNA sequences. Since 2001, the number of biotechnology patents has remained high, but the trend has turned slightly negative.

- U.S. resident inventors accounted for more than 60% of all biotechnology patents issued by the U.S. patent office, a share about 10% higher than U.S. inventors hold when U.S. utility patents for all technologies are counted.
- Foreign sources accounted for about 36% of all U.S. biotechnology patents granted, and the patents are more evenly distributed among a somewhat broader number of countries than is the case when all technology areas are combined.
- Given the ongoing controversies surrounding this technology area, foreign inventors may be less inclined than U.S. inventors to file biotechnology patents in the United States.
- Also evident is the more prominent representation of European countries in U.S. patents of biotechnologies than Asian inventors.
- In the biotechnology area, universities, government agencies, and other nonprofit organizations are among the leading recipients of U.S. patents, although corporations are still awarded the most patents overall.

One limitation of patent counts as an indicator of national inventive activity is the inability of such counts to differentiate between minor inventions and highly important inventions. A database has recently been developed that counts *triadic patent families* (inventions for which patent protection is sought in three important markets: the United States, Europe, and Japan). This database may more accurately indicate important inventions than simple patent counts.

- The United States has been the leading producer of triadic patent families since 1989, even when compared to inventors from the EU.
- Inventors residing in EU countries produced nearly as many triadic patented inventions as did inventors living in the United States since the late 1980s, and from 1985 through 1988 produced more than U.S. inventors.
- Estimates for 2000 show U.S. inventors' share of triadic patents at 34%, the EU's share at 31%, and Japan's share at 27%.
- Inventors residing in Japan produced only slightly fewer triadic patents than inventors in the United States or the EU. Given its much lower population, however, Japan's inventive productivity would easily exceed that of the United States or the EU if the number of inventions per capita were used as the basis for comparison. Among the big three (the United States, the EU, and Japan), Japan clearly is the most productive when size is factored into the measurement.
- Rankings change dramatically when national activity is normalized by population or by size of the economy as reflected in the gross domestic product. When data are normalized for size, smaller countries emerge, Switzerland and Finland in particular, and demonstrate high output of important inventions.
- Counts of triadic patent families also can be used to further examine patenting in biotechnology. During 1998 and 1999, the most recent 2 years that complete data are available, biotechnologies accounted for a larger share of the U.S. triadic patent portfolio compared with that in the European Union or Japan.

Venture Capital Investment Trends

The funds and management expertise provided by venture capitalists can aid the growth and development of small companies and new products and technologies, especially in the formation and expansion of small high-technology companies. Trends in venture capital investments also provide indicators of which technology areas venture capitalists view as the most economically promising.

- Internet-specific businesses involved primarily in online commerce were the leading recipients of venture capital in the United States during 1999 and 2000. They collected more than 40% of all venture capital funds invested in each year. Software and software services companies received 15%–17% of disbursed venture capital funds. Communication companies (including telephone, data, and wireless communication) were a close third, receiving 14%–15% of dispersed funds.
- The U.S. stock market suffered a dramatic downturn after its peak in early 2000, with the sharpest drops in the technology sector. Nonetheless, venture capital investments continued to favor Internet-specific companies over other industries from 2000–2003.
- In 2003 and 2004, however, venture capital funds preferred other technology areas over Internet-specific companies for investments, in particular those identified as software and medical/health companies.
- Software companies attracted the most venture capital in 2003 and 2004, receiving about 21% of the total invested each year, followed by companies in the medical/health field that received 16% in 2003 and 18% in 2004. Internet-specific companies fell to only about 13% of all money disbursed by venture capital funds during this period.
- The decline in enthusiasm for Internet companies seems to have benefited other technology areas as well. Since 2000, biotechnology companies have gained steadily to receive 11% of total venture capital investments in 2003 and 2004—more than triple their share of 4% received in 1999 and 2000. Medical/health companies also have received higher shares: in 1999 and 2000, they received about 4% of total venture capital disbursements, rising to

an average of 11% in 2001 and 2002 and to 17% during this period.

- ♦ Contrary to popular perception, only a relatively small amount of dollars invested by venture capital funds ends up as seed money to support research or early product development. Seed-stage financing has never accounted for more than 8% of all disbursements over the past 23 years and most often has represented 1%–5% of the annual totals. The latest data show that seed financing represented just 1.3% in 2003 and less than 1% in 2004.
- ♦ Over the past 25 years, the average amount invested in a seed-stage financing (per company) increased from a low of $700,000 in 1980 to a high of $4.3 million per disbursement in 2000. Since then, the average level of seed-stage investment has fallen steadily, to just $1.8 million in 2003 and $1.4 million in 2004.

Introduction

Chapter Overview

Science and engineering and the technological innovations that emerge from research and development activities enable high-wage nations like the United States to engage in today's highly competitive global marketplace. Many of the innovative new products exported around the world, many of the process innovations that have raised worker productivity, and many of the technological innovations that have created whole new industries can be traced back to earlier national investments in R&D. These innovations also make large contributions to national economic growth and industry competitiveness.

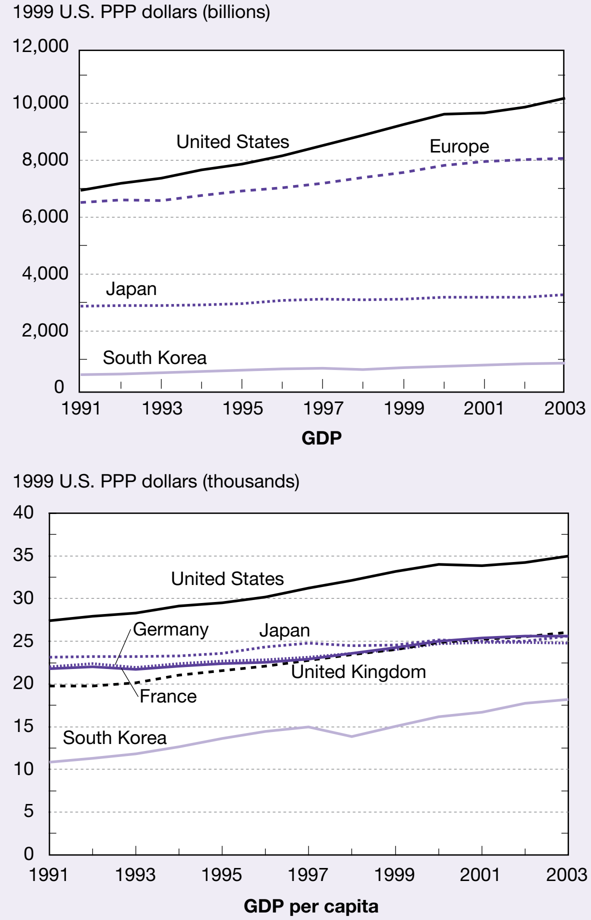
An international standard used to judge a nation's competitiveness rests on the ability of its industries to produce goods that find demand in the marketplace while simultaneously maintaining, if not improving, the standard of living for its citizens (OECD 1996). By this measure, the nation continues to be competitive; U.S. industry leads all others in the production of goods, and Americans continue to enjoy a high standard of living (figure 6-1; appendix table 6-1).

Faced with many of the same pressures from globalization as the United States, high-wage nations in Asia and Europe also have invested heavily in science and technology (S&T). Over the past decade, South Korea and Taiwan have advanced their technological capacity and increasingly challenge U.S. prominence in many technology areas and product markets. More recently, China, Finland, India, and Ireland have begun to distinguish themselves as producers of world-class S&T.

This chapter focuses on industry's vital role in the nation's S&T enterprise and how the national S&T enterprise develops, uses, and commercializes S&T investments by industry, academia, and government.[1] It presents various indicators that track U.S. industry's national activity and standing in the international marketplace for technology products and services and technology development. Using public and private data sources, U.S. industry's technology activities are compared with those of other major industrialized nations, particularly the European Union (EU) and Japan and, wherever possible, the newly or increasingly industrialized economies of Asia, Central Europe, and Latin America.[2]

Past assessments showed the United States to be a leader in many technology areas. *Science & Engineering Indicators 2004* showed that advancements in information technologies (computers and communication products and services) drove the rising trends in new technology development and dominated technical exchanges between the United States and its trading partners. In this 2006 edition, many of the same indicators are reexamined from new perspectives influenced by international data on manufacturing and selected service industries for the advanced nations and trends in biotechnology patenting. Also presented are updates to the Georgia Institute of Technology high-technology indicators model, which identifies developing nations with increased technology capacities as well as recent data on trends in venture capital investments in the United States.

Figure 6-1
International comparisons of GDP and GDP per capita, by country/region: 1991–2003



GDP = Gross domestic product; PPP = purchasing power parity

NOTES: GDP converted to U.S. dollars using PPP at 1999 prices. Top panel, Europe includes Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Sweden, and United Kingdom; bottom panel, Europe includes France, Germany, and the United Kingdom.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, special tabulations (December 2004). See appendix table 6-1.

Science and Engineering Indicators 2006

Chapter Organization

This chapter begins with a review of industries that rely heavily on R&D, referred to herein as *high-technology* or *knowledge-intensive industries*. Because no single authoritative methodology exists for identifying high-technology industries, most calculations rely on a comparison of R&D intensities. R&D intensities are determined by comparing industry R&D expenditures with the value of the industry's shipments. In this chapter, high-technology industries are identified using the R&D intensities calculated by the Organisation for Economic Co-operation and Development (OECD).

High-technology industries are noted for their R&D spending and performance, which produce innovations that can be applied to other economic sectors. These industries also employ and train new scientists, engineers, and other technical personnel. Thus, the market competitiveness of a nation's technological advances, as embodied in new products, processes, and services associated with high-technology or knowledge-intensive industries, can serve as an indicator of the economic and technical effectiveness of that country's S&T enterprise.

The global competitiveness of the U.S. high-technology manufacturing industry is assessed by examining domestic and worldwide market share trends. (Unless otherwise noted, trends in high-technology industry production are derived from data on industry value added, i.e., the value of industry shipments minus the value of purchased inputs, to better measure manufacturing activity taking place in each country or region.) Only limited trend data tracking gross revenues are available for the knowledge-based service industries. Data on royalties and fees generated from U.S. imports and exports of manufacturing know-how that is sold or rented as intangible (intellectual) property are used to further gauge U.S. competitiveness. Also discussed are indicators that identify developing and transitioning countries with the potential to become more important exporters of high-technology products over the next 15 years.[3]

The chapter also explores several leading indicators of technology development by presenting measures of inventiveness. This is done by comparing U.S. patenting patterns with those of other nations.

Finally, the disbursement in the United States of venture capital, which is money used to form and expand small companies, is examined by both the stage of development in which financing is awarded and the technology area receiving funds (see sidebar, "Comparison of Data Classification Systems Used").

U.S. Technology in the Global Marketplace

Policies in many countries reflect a belief that a symbiotic relationship exists between investment in S&T and success in the marketplace: S&T supports industry's competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new S&T. Consequently, a nation's economic health is a performance measure for the national investment in R&D and S&T. This is true for the United States and for many countries around the world.

OECD currently identifies five industries as *high-technology,* i.e., science-based industries that manufacture products while performing above-average levels of R&D: aerospace, pharmaceuticals, computers and office machinery, communication equipment, and scientific (medical, precision, and optical) instruments.[4] Identified as the most R&D intensive by OECD, these industries also rank as the most R&D intensive for the United States (table 6-1).

This section examines the U.S. position in the global marketplace from three vantage points: U.S. high-technology industry share of global production and exports, the competitiveness of individual industries, and trends in U.S. exports and imports of manufacturing know-how. Before assessing the U.S. role in the global high-technology marketplace, however, it may be useful to consider how high-technology industries are driving global economic growth.

Importance of High-Technology Industries to Global Economic Growth

High-technology industries are driving economic growth around the world. According to the Global Insight World Industry Service database, which provides production data for the 70 countries that account for more than 97% of global economic activity, the global market for high-technology goods is growing at a faster rate than for other manufactured goods. During the 24-year period examined (1980–2003), high-technology production grew at an inflation-adjusted average annual rate of nearly 6.4%, compared with 2.4% for other manufactured goods. Global economic activity in high-technology industries was especially strong during the late 1990s (1995–2000), when high-technology industry manufacturing, led by manufacturing in those industries producing communication and computer equipment, grew at more than four times the rate of growth for all other manufacturing industries (figure 6-2; appendix table 6-2).

Even during the recent, slow-growth, "postbubble" period (2000–03), high-technology industry continued to lead global growth at about four times the rate of all other manufacturing industries. Output by the five high-technology industries represented 8.1% of global production of all manufactured goods in 1980; by 2003, it had doubled to 17.7%.

High-technology industries are R&D intensive; R&D leads to innovation, and firms that innovate tend to gain market share, create new product markets, and use resources more productively (NRC, Hamburg Institute for Economic Research, and Kiel Institute for World Economics 1996; Tassey 2000).[5] These industries tend to develop high value-added products, tend to export more, and, on average, pay higher salaries than other manufacturing industries. Moreover, industrial R&D performed by high-technology industries benefits other commercial sectors by developing new products, machinery, and processes that increase productivity and expand business activity.

High-Technology Industries and Domestic Production

Increasingly, manufacturers in countries with high standards of living and labor costs have moved manufacturing operations to locations with lower labor costs. High-technology industries and their factories are coveted by local, state, and national governments because these industries consistently

Comparison of Data Classification Systems Used

This chapter incorporates several thematically related but very different classification systems. These measure activity in high-technology manufacturing and knowledge-intensive service industries, measure U.S. trade in advanced technology products, and track both the patenting of new inventions and trends in venture capital investments. Each classification system is described in the introduction to the section that presents those data. This sidebar shows the classification systems used in the chapter in tabular format for easy comparison.

System	Type of data	Basis	Coverage	Methodology	Data provider
High-technology manufacturing industries	Industry value added and exports in constant (1997) dollars	Industry by International Standard Industrial Classification	Aerospace, pharmaceuticals, office and computing equipment, communication equipment, scientific instruments	Organisation for Economic Co-operation and Development (OECD), research and development intensity (i.e., R&D/value added)	Global Insight, Inc., proprietary special tabulations
Knowledge-intensive service industries	Industry production (revenues from services) in constant (1997) dollars	Industry by International Standard Industrial Classification	Business, financial, communication, health, education services	OECD, R&D intensity (R&D/value added)	Global Insight, Inc., proprietary special tabulations
Trade in advanced technology products	U.S. product exports and imports, in current dollars	Product by technology area, harmonized code	Biotechnology, life sciences, optoelectronics, information and communications, electronics, flexible manufacturing, advanced materials, aerospace, weapons, nuclear technology, software	U.S. Census Bureau, Foreign Trade Division	U.S. Census Bureau, Foreign Trade Division, special tabulations
Patents	Number of patents for inventions, triadic patents (invention with patent granted or applied for in U.S., European Patent Office, and Japan Patent Office)	Technology class, country of origin	More than 400 U.S. patent classes, inventions classified according to technology disclosed in application	U.S. Patent and Trademark Office, OECD	U.S. Patent and Trademark Office, OECD
Venture Capital	Funds invested by U.S. venture capital funds	Technology area defined by data provider	Biotechnology, communications, computer hardware, consumer related, industrial/energy, medical/health, semiconductors, computer software, Internet specific	Thomson Financial/ National Venture Capital Association	Thomson Financial Services, special tabulations

show greater levels of domestic production (value added) in the final product than that typically performed by other manufacturing industries. (Gross value added equals gross output minus the cost of purchased intermediate inputs and supplies.) In the United States, high-technology industries reported about 30% more value added than other manufacturing industries (figure 6-3; appendix tables 6-2 and 6-3). High-technology industries also generally pay higher wages than other manufacturing industries.[6] Recognition of these contributions has led to intense competition among nations and localities to attract, nurture, and retain high-technology industries.[7]

Data on manufacturing value added that follows are presented for the United States and other advanced countries in order to better examine domestic production by manufacturing industries. Value-added data also can be important indicators of economic and technological progress in developing countries. When foreign investments and foreign corporations control major portions of a developing country's manufacturing base, data on domestic value added and its contribution to final output can indicate the extent to which those foreign corporations are transferring technological and manufacturing know-how to the host country.

During the 1980s, manufacturing output in the United States and other high-wage countries shifted resources to produce higher value-added, technology-intensive goods, often referred to as *high-technology manufactures*. In 1980,

Table 6-1
Classification of manufacturing industries based on average R&D intensity: 1991–97
(Percent)

Industry	ISIC rev. 3	R&D intensity: Total[a]	R&D intensity: United States
Total manufacturing	15–37	2.5	3.1
High-technology industries			
Aircraft and spacecraft	353	14.2	14.6
Pharmaceuticals	2423	10.8	12.4
Office, accounting, and computing machinery	30	9.3	14.7
Radio, television, and communication equipment	32	8.0	8.6
Medical, precision, and optical instruments	33	7.3	7.9
Medium-high-technology industries			
Electrical machinery and apparatus NEC	31	3.9	4.1
Motor vehicles, trailers, and semi trailers	34	3.5	4.5
Chemicals excluding pharmaceuticals	24 excl. 2423	3.1	3.1
Railroad equipment and transport equipment NEC	352 + 359	2.4	na
Machinery and equipment NEC	29	1.9	1.8
Medium-low-technology industries			
Coke, refined petroleum products, and nuclear fuel	23	1.0	1.3
Rubber and plastic products	25	0.9	1.0
Other nonmetallic mineral products	26	0.9	0.8
Building and repairing of ships and boats	351	0.9	na[b]
Basic metals	27	0.8	0.4
Fabricated metal products, except machinery and equipment	28	0.6	0.7
Low-technology industries			
Manufacturing NEC and recycling	36–37	0.4	0.6
Wood, pulp, paper, paper products, printing, and publishing	20–22	0.3	0.5
Food products, beverages, and tobacco	15–16	0.3	0.3
Textiles, textile products, leather, and footwear	17–19	0.3	0.2

na = not applicable
ISIC = International Standard Industrial Classification; NEC = not elsewhere classified

[a]Aggregate R&D intensities calculated after converting R&D expenditures and production with 1995 gross domestic product purchasing power parities.
[b]R&D expenditures in shipbuilding (351) included in other transport (352 and 359).

NOTE: R&D intensity is direct R&D expenditures as percentage of production (gross output).

SOURCES: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm; and STAN database, http://www.oecd.org/document/15/0.2340,en_2649_201185_1895503_1_1_1_1,000.html (May 2001).

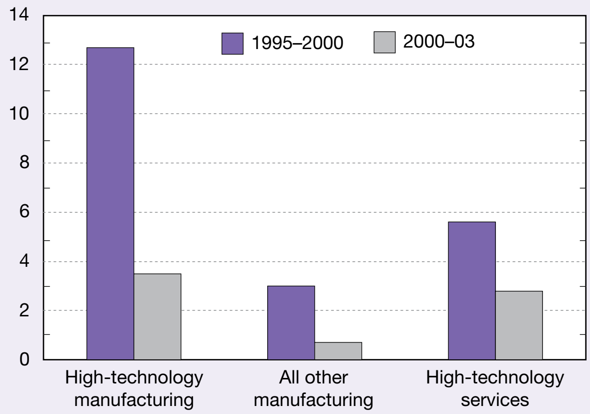
Science and Engineering Indicators 2006

high-technology manufactures accounted for about 11% of total U.S. domestic production. By 1990, this figure had increased to 13.5% and, led by demand for communication and computer equipment, exceeded 27% by 2000. By contrast, high-technology manufactures represented about 17% of total Japanese domestic production in 2000, double that in 1980 but only up about 1 percentage point from 1990. European nations[8] also saw high-technology manufactures account for a growing share of their total domestic production, although to a lesser degree. High-technology manufactures accounted for 9.5% of total EU manufacturing domestic output in 1980 and rose to 11% in 1990 and 13.2% by 2000 (figure 6-4; appendix table 6-3). The latest data, through 2003, show domestic output in high-technology industries continuing to grow faster than output in other manufacturing industries in the United States, flattening in the EU, and declining in Japan. In 2003, high-technology manufactures were estimated to be 34.2% of manufacturing domestic output in the United States, 13.4% in the EU, and 15.7% in Japan.

South Korea and Taiwan typify how R&D-intensive industries have grown in the newly industrialized economies. In 1980, high-technology manufactures accounted for 9.6% of South Korea's total domestic manufacturing output; this proportion jumped to 14.8% in 1990 and reached an estimated 21.5% in 2003. The transformation of Taiwan's manufacturing base is even more striking. High-technology manufacturing in Taiwan accounted for 9.7% of total domestic output in 1980, 15.9% in 1990, and jumped to an estimated 28.5% in 2003.

Other fast-moving economies also are converting to a focus on high technology. Directed national policies that combine government measures and corporate investments, including R&D facilities, have spurred growth in high-technology industries in Ireland, as well as in China and other Asian countries. Perhaps the clearest example, Ireland's high-technology manufacturing industries accounted for 12.4% of total domestic output in 1980, 26.4% in 1990, and for more than half its total domestic production since 1999.

Figure 6-2
Global industry sales, average annual growth rate, by sector: 1995–2003

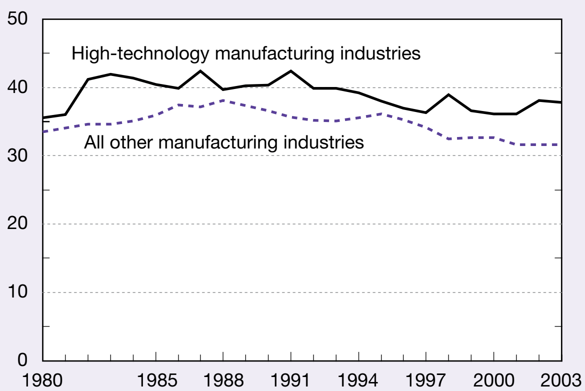


NOTE: Growth rates calculated from inflation adjusted 1997 dollars.

SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix tables 6-2 and 6-5.

Science and Engineering Indicators 2006

Figure 6-3
Value added by U.S. industries as percentage of gross output: 1980–2003



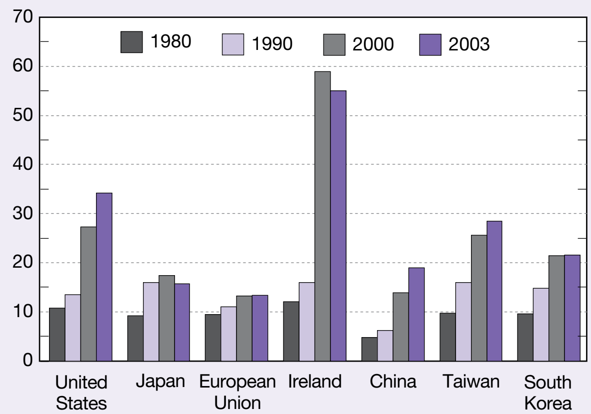
NOTE: Value added is value of final production minus value of purchased inputs used in production process.

SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix tables 6-2 and 6-3.

Science and Engineering Indicators 2006

China's economy is also changing and, given its size, its transformation will have a large impact on the global marketplace. China's high-technology manufacturing accounted for just 4.8% of total domestic output in 1980, 6.2% in 1990, and an estimated 19.0% in 2003. However, the value of China's domestic high-technology production in 2003 is estimated to be twice that of Germany, nearly identical to production in Japan, and nearly five times that of Ireland.

Figure 6-4
High-technology value added as a share of total manufacturing value added in selected countries/ regions: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

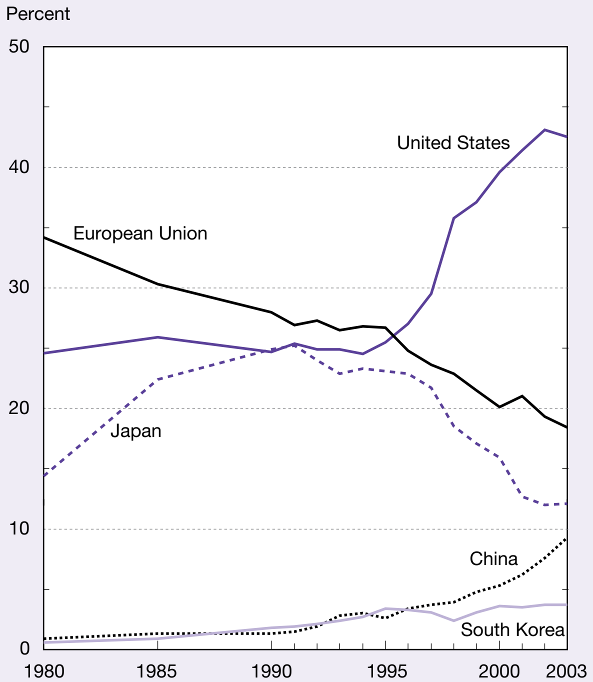
Global Market Shares

Over the 24-year period examined (1980–2003), the United States has consistently been one of the world's leading manufacturers of high-technology products. The same can be said of Japan. Although no single European country has a high-technology industry the size of the United States or Japan, the EU consistently ranks among the world's leading manufacturers of high-technology products. In fact, the EU contained the world's largest high-technology manufacturing sector from 1980 through 1995, but beginning in 1996 and for each year thereafter, U.S. high-technology manufacturers have accounted for more domestic output than the EU, Japan, or any other country.

U.S. high-technology industry value added (domestic production) accounted for about one-quarter of global production from 1980 to 1995 (figure 6-5). Its share began moving up sharply in the late 1990s, peaking in 2002 at 43.1%. Estimates for 2003 show the U.S. share dropping slightly (42.5%). Value added by Japan's high-technology industries and its share of global production peaked in the early 1990s and has trended downward each year thereafter. At its highest point in 1991, Japan's high-technology manufacturers accounted for 25.2% of global production; at its lowest point, in 2002, this fell to 12.0%. Estimates for 2003 show little change in Japan's share. Value added by the EU's high-technology manufacturing sector accounted for its largest global share at 34.2% in 1980. The EU share has fallen since then, to 28.0% in 1990, 20.1% in 2000, and an estimated 18.4% in 2003.

In Asia, high-technology manufacturing has grown dramatically over the past two decades, led first by Japan in the 1980s, then by South Korea, Taiwan, and China in the 1990s. The most recent data show that China's high-technology

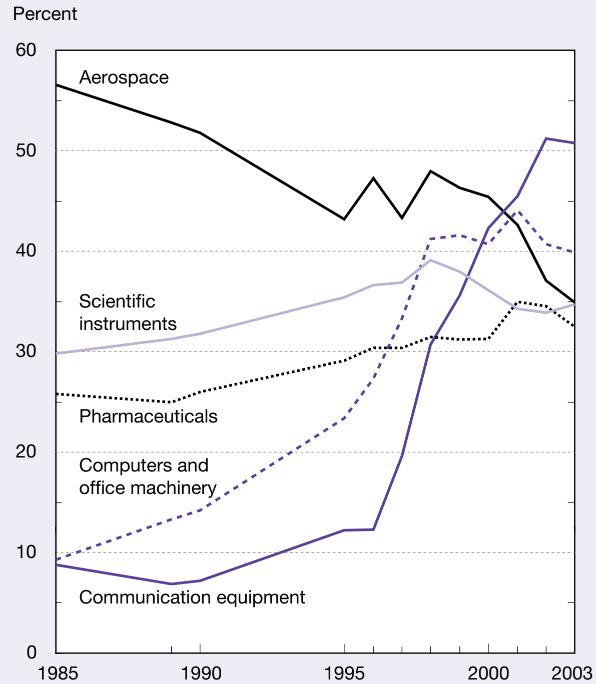
Figure 6-5
Share of global high-technology value added, by country/region: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

Figure 6-6
U.S. share of global value added, by high-technology industry: 1985–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

industries have surpassed those in South Korea and Taiwan. If these trends continue, China may soon rival Japan in size if not sophistication. Compared with Japan, however, China does not have the long record of large investments in R&D, has not produced the number of scientific articles across a broad range of technology areas, and has not been as successful patenting new inventions around the world. That may change in the near future, because China's investments in R&D are growing rapidly. (See chapter 4 for data on trends in U.S. and foreign R&D performance, chapter 5 for data on scientific article publishing trends, and the subsequent section on patenting in this chapter.) In 2003, domestic production (value added) by China's high-technology industry accounted for an estimated 9.3% of global production, whereas just 23 years earlier (in 1980), domestic production in China's high-technology industry accounted for less than 1% of world output.

Global Competitiveness of Individual Industries

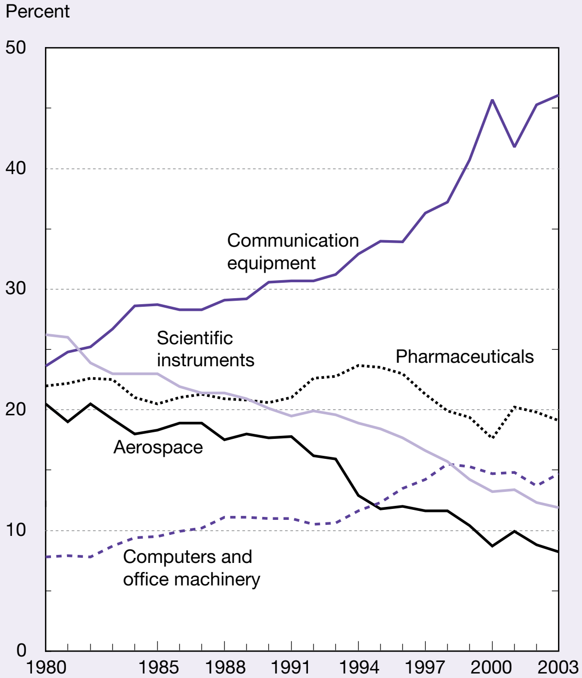
In each of the five industries that make up the high-technology group, the United States maintained strong, if not leading, positions in the global marketplace (figure 6-6). The U.S. market is large and mostly open, which benefits U.S. high-technology producers in the global market in two important ways. First, supplying a domestic market with many consumers offers scale effects for U.S. producers, resulting from potentially large rewards for new ideas and innovations. Second, the openness of the U.S. market to competing foreign-made technologies pressures U.S. producers to be more innovative to maintain domestic market share. Additionally, the U.S. government influences the size and growth of the nation's high-technology industries through investments in industrial R&D purchases of new products and through laws regulating sales to foreign entities of certain products produced by each of the five high-technology industries.[9]

Communication Equipment and Computers and Office Machinery

The global market for communication equipment is the largest of the high-technology markets, accounting for nearly half of global sales by all five high-technology industries (figure 6-7).[10] The market for computers and office machinery is a distant second, accounting for about 19% of global sales by the five high-technology industries. In these two industries, U.S. manufacturers reversed downward trends evident during the 1980s to grow and gain market share in the mid- to late 1990s, due in part to increased capital investment by U.S. businesses (see sidebar, "U.S. IT Investment").

From 1980 through 1997, Japan was the world's leading supplier of communication equipment, exceeding output in the United States and the EU. In 1998, however, U.S. manufacturers once again became the leading producers of

Figure 6-7
Global high-technology value added, by industry share: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

communication equipment in the world and have since retained that position. In 2003, the latest year for which data are available, the United States accounted for approximately 50.8% of world production of communication equipment, compared with Japan at 16.0% and the EU at 9.4%.

Since 1997, the United States has been the leading manufacturer of office and computer machinery, overtaking longtime leader Japan. EU countries, led by Germany and the United Kingdom, were also major producers.

In 2001, China replaced Japan as Asia's largest producer of office and computer machinery. This gap has been widening. In 2003, domestic production by U.S. high-technology manufacturers accounted for an estimated 39.9% of global production; China's industry is estimated to account for 26.4% of global production, and the EU's industry is estimated to account for 9.0%.

Aerospace

The U.S. aerospace industry has long maintained a leading if not dominant position in the global marketplace. The U.S. government is a major customer for the U.S. aerospace industry, contracting for military aircraft and missiles and for spacecraft. Since 1989, production for the U.S. government has accounted for approximately 40%–60% of total annual sales (AIA 2005). The U.S. aerospace industry position in the global marketplace is enhanced by this longstanding, customer-supplier relationship.

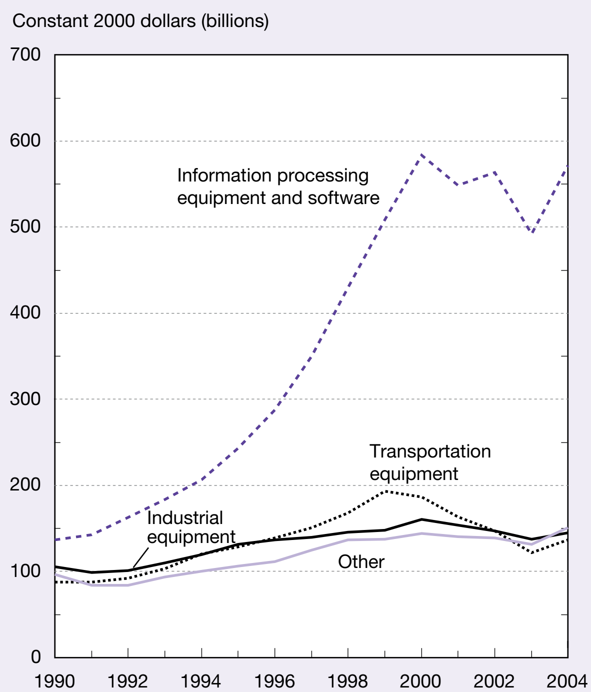
U.S. IT Investment

Information technology (IT) was a major contributor to innovation and productivity gains during the 1990s. In addition to technical changes within the IT field, companies used IT to transform how their products performed and how their services were delivered. IT applications also improved the flow of information within and among organizations, which led to productivity gains and production efficiencies.

From 1990 through 2004, U.S. industry purchases of IT equipment and software exceeded industry spending on all other types of capital equipment (figure 6-8). At its peak in 2000, U.S. industry spending on IT was more than three times the amount that all industries spent on industrial equipment and exceeded combined industry spending on industrial, transportation, and all other equipment.

Despite the bursting of the dot.com bubble beginning in the spring of 2000 and the economic downturn that began in March 2001, U.S. companies continued to place a high value on investments in IT. Industry spending on IT equipment and software accounted for 38% of all nonresidential investment (including structures and equipment) by industries in 2000, about 41% in 2002, and about 47% in 2004.

Figure 6-8
Industry spending on capital equipment: 1990–2004



SOURCE: U.S. Bureau of Economic Analysis, http://www.bea.doc.gov/bea/dn/nipaweb/

Science and Engineering Indicators 2006

In recent years however, the aerospace industry's manufacturing share has fallen more than any other U.S. industry. Since peaking at 57% of global production in 1985, U.S. aerospace domestic production fell to 43% of global production by 1995. The U.S. share increased slightly during the late 1990s, then proceeded to fall each year thereafter. In 2003, the U.S. share of global aerospace production is estimated to have fallen to about 35%. European aerospace manufacturers, particularly within France and Germany, made gains during this time. By 2003, the EU accounted for 29% of world aerospace production, up from 25% in 1985 and 26% in 1995.

China's aerospace industry began to grow very rapidly in the early 1990s, quickly overtaking Japan by the mid-1990s to become the largest producer of aerospace products in Asia. In 1980, China's aerospace industry output accounted for less than 1% of world output; by 1995, its market share had risen to 3%. A succession of year-to-year gains from 1995 through 2000 followed, eventually lifting China's market share to nearly 7%. Production in China's aerospace industry is estimated at about 10% of world production in 2003. In Latin America, Brazil exhibited a very different trend, falling from about 18% of world aerospace production in 1980 to about 15% in 1995 and an estimated 10% in 2003.

Pharmaceuticals

The EU and the United States were the leading producers of drugs and medicines in the world market for the entire 24-year period examined, together accounting for about two-thirds of global production in 2002 and 2003. As a result of differing national laws governing the distribution of foreign pharmaceuticals, domestic population dynamics play a more important role than global market forces and affect the overall demand for a country's pharmaceutical products. In Asia, Japan and China are the largest producers of drugs and medicines. Although Japan has the larger domestic industry, China's share has grown steadily while Japan's has generally declined. In 1990, domestic production by Japan's industry accounted for nearly 19% of global production, but this proportion gradually fell to 11% by 2003. In 2003, China's pharmaceutical industry is estimated to account for 6% of global production, up from about 1% in 1990.

Scientific Instruments

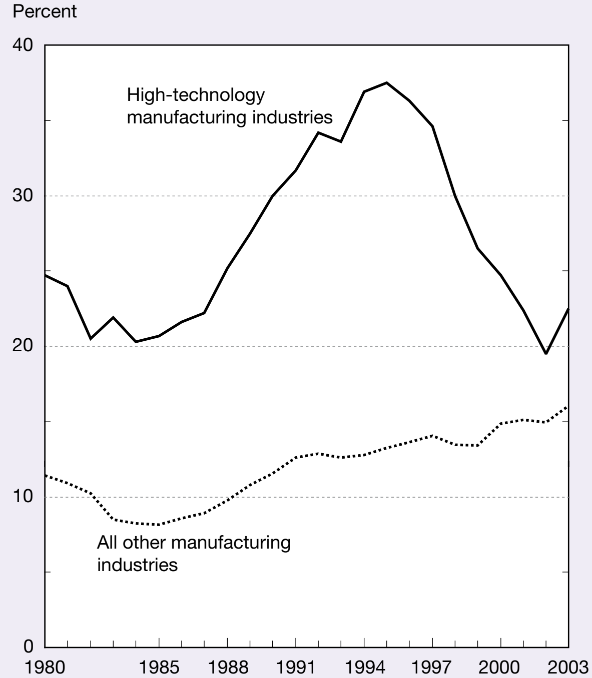
In 2001, the industry that produces scientific instruments (medical, precision, and optical instruments) was added to the group of high-technology industries, reflecting that industry's high level of R&D in advanced nations (table 6-1). From 1980 through 2003, the EU and the United States were the leading producers of scientific instruments. Since 2001, the EU, led by Germany and France, has been the world's largest manufacturer of scientific instruments, accounting for an estimated 37.5% of global production in 2003. This share has risen irregularly since the late 1990s. In 2003, the United States accounted for 35% of global production, down slightly from the 36%–39% share held during the late 1990s.

In Asia, Japan and China are the largest producers, and once again, Japan's share of global production is declining while China's is increasing. In 1990, Japan's industry producing scientific instruments accounted for about 15% of world production; however, this declined to about 10% in 2000 and is estimated to have fallen to about 8% in 2003. China's industry, which accounted for less than 1% of global production in 1990, rose to 2% in 2000 and is estimated to account for slightly more than 3% in 2003.

Exports by High-Technology Industries

Although U.S. producers benefit from having the world's largest home market as measured by gross domestic product (GDP), mounting U.S. trade deficits highlight the need to serve foreign markets as well. (See figure 6-1 for comparisons of country GDPs.) Traditionally, U.S. high-technology industries have been more successful exporting their products than other U.S. industries; therefore, these industries can play a key role in restoring the United States to a more balanced trade position.[11] Although U.S. high-technology industries continue to export a larger proportion of their total shipments than other U.S. manufacturing industries, that advantage has narrowed considerably (figure 6-9).[12]

Figure 6-9
U.S. exports as percentage of sector output: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix tables 6-2 and 6-4.

Science and Engineering Indicators 2006

Foreign Markets

In addition to serving its large domestic market, the United States was an important supplier of manufactured products to foreign markets from 1980 to 2003. Throughout the 1990s and continuing through 2003, U.S. industry supplied 12%–14% of the world's general manufacturing exports (appendix table 6-4).[13] In 2003, the United States ranked second only to the EU in its share of world exports, and if intra-EU shipments were excluded, would likely rank above the EU. Japan accounted for 8%–10% of world exports during this same period.

Exports by U.S. high-technology industries grew rapidly during the mid-1990s, contributing to the nation's strong export performance (figure 6-10). During the 1990s, U.S. high-technology industries accounted for 19%–23% of world high-technology exports, at times nearly twice the level achieved by all other U.S. manufacturing industries. However, by 2003, the latest year for which data are available, exports by U.S. high-technology industries had fallen to about 16% of world high-technology exports, whereas Japan accounted for about 9% and Germany nearly 8%.

The gradual drop in the U.S. share during 1990–2003 was partly due to competition from emerging high-technology industries in newly industrialized and industrializing economies, especially in Asia. China stands out, with its share of global high-technology industry exports reaching 7% in 2003, up from just 1% in 1990. High-technology industries in South Korea and Taiwan each accounted for about 2.5% of world high-technology exports in 1990; 2003 data show that each economy's share nearly doubled. Singapore's share, which was 3.6% in 1990 and 5.7% in 2003, is also noteworthy, especially in light of its relatively small economy.

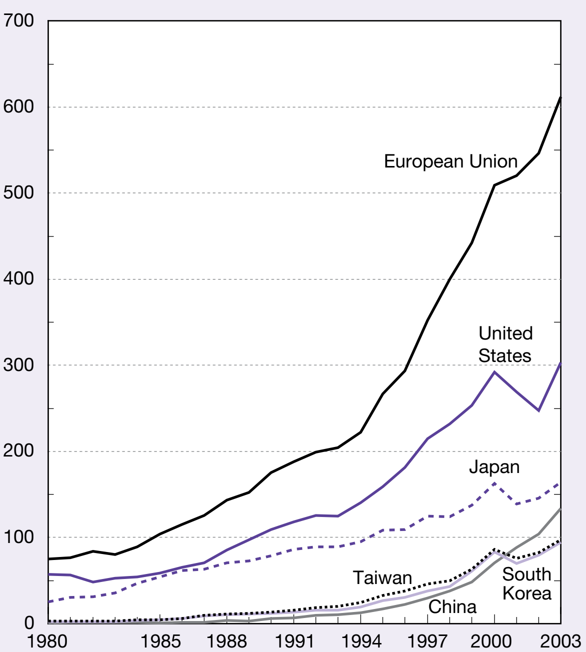
Industry Comparisons

Over the past two decades, U.S. high-technology industries were large and active exporters in each of the five industries that make up the high-technology group. The United States was the export leader in four of the five high-technology industries in 2003 (figure 6-11). However, U.S. aerospace, computers and office machinery, communication equipment, and scientific instruments industries recorded successively smaller shares of world exports in 2003 compared with earlier years (table 6-2).

Communication equipment and computers and office machinery. The export market for communication equipment is the largest of the high-technology industry group, accounting for more than 42% of total exports by all five high-technology industries in 2002 and 2003 (figure 6-12). The export market for computers and office machinery ranks second at about 32% of exports by the five high-technology industries. U.S. shares of exports in both industries have trended downward for most of the period examined (1980–2003),

Figure 6-10
High-technology exports, by selected country/region: 1980–2003

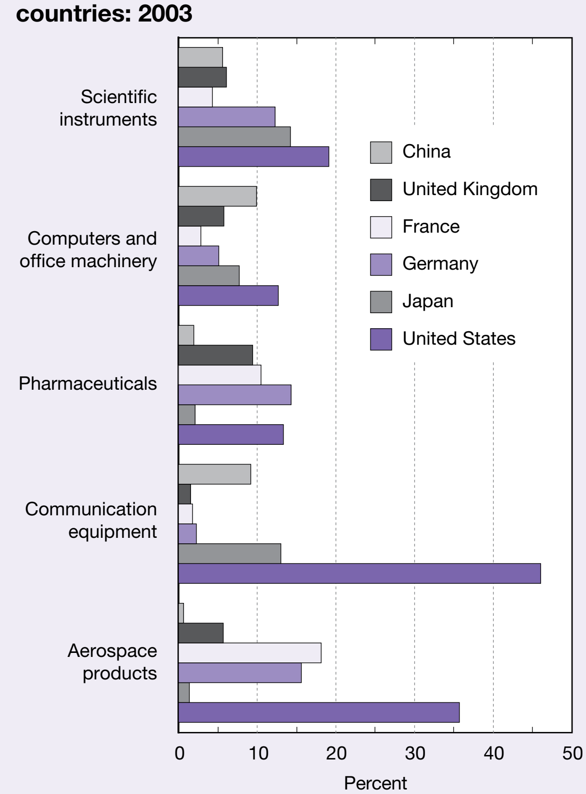
1997 U.S. dollars (billions)



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-4.

Science and Engineering Indicators 2006

Figure 6-11
High-technology industry exports, by selected countries: 2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-4.

Science and Engineering Indicators 2006

Table 6-2
Share of global high-technology industry exports, by country/region: 1990, 2000, and 2003
(Percent)

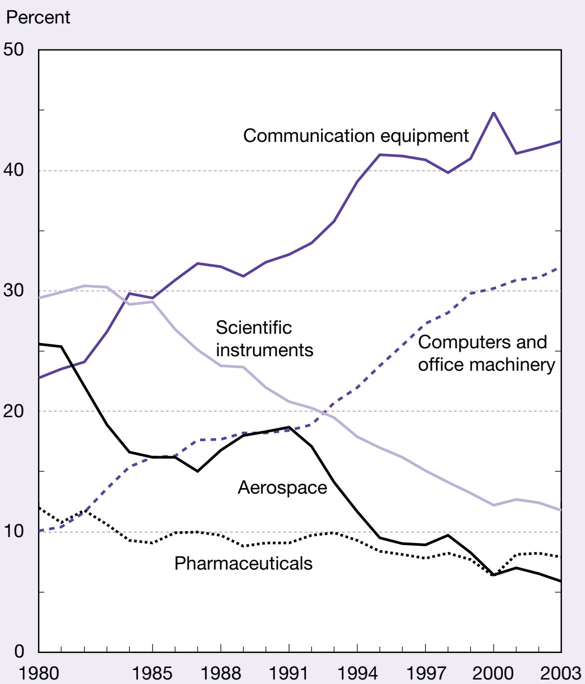
Industry	United States 1990	United States 2000	United States 2003	EU 1990	EU 2000	EU 2003	Japan 1990	Japan 2000	Japan 2003	Germany 1990	Germany 2000	Germany 2003	China 1990	China 2000	China 2003
Top five total	23.0	17.8	16.0	37.0	31.1	32.2	16.6	10.0	8.6	9.7	6.8	7.6	1.3	4.3	7.0
Aerospace	46.1	39.2	35.7	44.4	44.0	45.7	0.7	1.3	1.4	10.3	14.1	15.6	0.0	0.6	0.6
Communication equipment	16.5	16.2	15.2	24.9	25.2	25.4	25.9	11.5	10.0	6.6	5.2	5.9	1.9	4.3	7.1
Pharmaceuticals	10.8	13.6	13.3	64.6	64.8	66.0	2.8	2.4	2.1	15.8	12.6	14.3	2.4	1.8	1.9
Computers/office machinery	21.8	15.1	12.7	33.5	28.4	28.5	19.2	8.8	7.7	6.5	4.7	5.1	0.3	5.6	9.9
Scientific instruments	19.5	21.5	19.1	40.1	35.3	37.3	19.6	15.7	14.2	13.7	11.2	12.3	1.7	4.5	5.6

EU = European Union-15 excluding Luxembourg

SOURCE: Global Insight, Inc. See appendix table 6-4.

Science and Engineering Indicators 2006

Figure 6-12
Global high-technology exports, by industry share: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-4.

Science and Engineering Indicators 2006

although an upturn is estimated for the latest year, 2003. U.S. exports of computers and office machinery represented 29% of world exports in 1980, 22% in 1990, 11% in 2002, and 13% in 2003. The market share for U.S. manufacturers of communication equipment fluctuated within the much narrower range of 14%–18%, reaching highs during the early 1980s and again during the mid-1990s before falling to a low of 14% in 2002. Estimates for 2003 show the U.S. share rising to about 15%.

On the other hand, EU industries are the leading exporters, accounting for about 25% of world communication equipment exports and 28%–34% of world computers and office machinery exports from 1990 through 2003 (table 6-2). In 2003, Germany, the United Kingdom, and France were the leading European exporters of communication equipment, and the Netherlands, the United Kingdom, and Germany led Europe in exports of computers and office machinery.

In Asia, exports from industries located in Japan, China, South Korea, Singapore, Taiwan, and Malaysia together account for a larger share of exports than the EU. China (including Hong Kong) is the leading Asian exporter in these two industries.

Aerospace. U.S. exports of aerospace technologies accounted for 54% of world aerospace exports in 1980, 46% in 1990, and 36% in 2003 (table 6-2). U.S. aerospace products lost out primarily to the EU's aerospace industry, whose shares of world exports increased from 36% in 1980 to 44% in 1990 and to 46% in 2003.

By comparison, aerospace industries within Asia apparently are building mostly for their domestic markets and have supplanted U.S. aerospace exports to the region.[14] In 2003, aerospace industry exports from Japan accounted for 1.4% of global exports, and exports from industries in China, South Korea, and Singapore accounted for about 0.5%. Aerospace industries in Canada and Brazil supplied larger shares of global exports than those in Asia during the 24-year period examined.

Pharmaceuticals. As noted previously, national laws governing the distribution of pharmaceuticals produced in other countries differ widely among countries, consequently affecting comparisons among countries and comparisons with other high-technology industries. Generally, each country's share of industry exports fluctuated within a fairly narrow range during the past 24 years.

The U.S. pharmaceutical industry's share of world industry exports fluctuated 10%–14% during the 1990s and held steady at about 13% from 2000 to 2003 (table 6-2). Among

the EU countries, Germany is the leading exporter with an export share of 14%–16% during the 1990s, settling in at about 14% between 2001 and 2003. France and the United Kingdom are also key exporters, together accounting for 9%–11% of world industry exports from 1990 to 2003. In Asia, Japan and China are the largest producers of drugs and medicines, each accounting for about 2%–3% of world industry exports during the period 1990–2003. Industries in India and Singapore account for about 1% of world exports.

Scientific instruments. In 2001, the industry that produces scientific instruments (medical, precision, and optical instruments) was added to the group of high-technology industries, reflecting the industry's high level of R&D in advanced nations (table 6-1). From 1990 through 2003, the U.S. industry share of world exports changed only slightly: from 20% in 1990 to 21.5% in 2000 and 19% in 2003. Germany is the largest exporter among the EU countries; its share of world industry exports fluctuated 11%–14% during 1990–2003. The United Kingdom, France, and the Netherlands were the other large European exporters of scientific instruments.

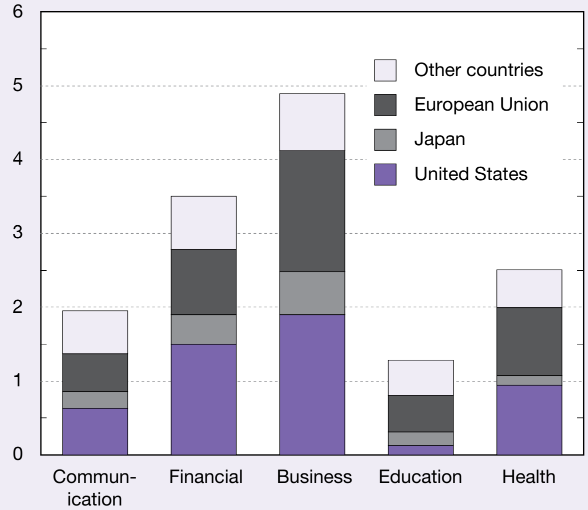
In Asia, Japan and China are the largest producers, and once again, Japan's share of world industry exports is declining while China's is increasing. In 1990, Japan's industry producing scientific instruments accounted for about 20% of world industry exports, but its share fell to less than 16% in 2000 and is estimated to be about 14% in 2003. China's industry accounted for less than 8% of world industry exports in 1990 but rose to 10% in 2000 and is estimated to account for slightly more than 11% in 2003.

Global Business in Knowledge-Intensive Service Industries

For several decades, revenues generated by U.S. service-sector industries grew faster than those generated by the nation's manufacturing industries. Data collected by the U.S. Department of Commerce show that the service sector's share of U.S. GDP grew from 49% in 1959 to 64% in 1997 (National Science Board 2002). This growth has been fueled largely by *knowledge-intensive* industries, i.e., those that incorporate science, engineering, and technology in either their services or the delivery of their services.[15] Five knowledge-intensive industries, as classified by the OECD, are communication services, financial services, business services (including computer software development), education services, and health services. This section presents data tracking the overall revenues earned by these industries in 70 countries[16] (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter).

Combined global sales in knowledge-intensive service industries exceeded $14.1 trillion in 2003 and have risen every year during the 24-year period examined. The United States is the leading provider of high-technology services, responsible for slightly more than one-third of total world service revenues during the period 1980–2003 (figure 6-13; appendix table 6-5).

Figure 6-13
Global revenues generated by five knowledge-intensive service industries: 2003
1997 U.S. dollars (trillions)



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-5.

Science and Engineering Indicators 2006

Business Services

Business services, which include computer and data processing and research and engineering services, is the largest of the five service-sector industries and accounted for 34% of global high-technology service revenues in 2003. Business-service industries in the United States and the EU are the most prominent in the global marketplace and are close in size. Business services in these two economies account for more than 70% of business services provided worldwide; the U.S. share was 38% in 2003 and the EU share was 34%. Japan ranks a distant third at about 12%. Data on country activity in individual business services are not available.

Financial Services and Communication Services

Financial services and communication services each accounted for about 25% of global revenues generated by high-technology service industries in 2003. Forty-three percent of world revenues for financial services in 2003 went to the U.S. financial services industry, the world's largest. The EU was second, earning approximately 25%, followed by Japan at nearly 11%. Communication services, which include telecommunication and broadcast services, could be considered the most technology-driven of the service industries. In this industry, U.S. firms again hold a lead position. In 2003, U.S. firms generated revenues equal to 32% of world revenues. The EU accounted for 26%, and Japan accounted for nearly 12%.

Health Services and Education Services

Many nations' governments serve as the primary provider of the remaining two knowledge-intensive service industries, health services and education services. The size

and distribution of each country's population profoundly affect delivery of these services. For these reasons, global comparisons based on market-generated revenues are less meaningful for health services and education services than for other service industries.

The United States, with arguably the least government involvement, has the largest health-service industry in the world, although the EU's health-service industry comes quite close. In 2003, the U.S. health-service industry accounted for 38% of world revenues, while the EU share was 37%. Again, Japan's industry is a distant third.

Education services, the smallest of the five knowledge-intensive service industries in terms of revenue generated, includes governmental and private educational institutions of all types that offer primary, secondary, and university education, as well as technical, vocational, and commercial schools. In 2003, fees (tuition) and income from education service-related operations accounted for about 9% of revenues generated by all five knowledge-intensive service industries and about one-fourth of the revenues generated by the business-service industry worldwide. Europe's education service industry generated the most revenues by far (39% of worldwide industry revenues), with Japan second (14%), and the United States third (10%).

U.S. Trade Balance in Technology Products

The methodology used to identify high-technology industries relies on a comparison of R&D intensities. R&D intensity is typically determined by comparing industry R&D expenditures or the number of technical people employed (e.g., scientists, engineers, and technicians) with industry value added or the total value of shipments (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter). Classification systems based on industry R&D intensity tend to overstate the level of high-technology exports by including all products shipped overseas by those high-technology industries, regardless of the level of technology embodied in each product, and by the somewhat subjective process of assigning products to specific industries.

In contrast, the U.S. Census Bureau has developed a classification system for exports and imports that embody new or leading-edge technologies. The system allows a more highly disaggregated, better-focused examination of embodied technologies and categorizes trade into 10 major technology areas:

- **Biotechnology—**the medical and industrial application of advanced genetic research to the creation of drugs, hormones, and other therapeutic items for both agricultural and human uses.
- **Life science technologies—**the application of nonbiological scientific advances to medicine. For example, advances such as nuclear magnetic resonance imaging, echocardiography, and novel chemistry, coupled with new drug manufacturing techniques, have led to new products that help control or eradicate disease.
- **Optoelectronics—**the development of electronics and electronic components that emit or detect light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers.
- **Information and communications—**the development of products that process increasing amounts of information in shorter periods of time, including fax machines, telephone switching apparatus, radar apparatus, communications satellites, central processing units, and peripheral units such as disk drives, control units, modems, and computer software.
- **Electronics—**the development of electronic components (other than optoelectronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components, such as capacitors and resistors, that improve performance and capacity and, in many cases, reduce product size.
- **Flexible manufacturing—**the development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention.
- **Advanced materials—**the development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies.
- **Aerospace—**the development of aircraft technologies, such as most new military and civil airplanes, helicopters, spacecraft (communication satellites excepted), turbojet aircraft engines, flight simulators, and automatic pilots.
- **Weapons—**the development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms.
- **Nuclear technology—**the development of nuclear production apparatus (other than nuclear medical equipment), including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges (nuclear medical apparatus is included in life sciences rather than this category).

To be included in a category, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value. In this report, computer software is examined separately, creating an 11th technology area. In official statistics, computer software is included in the information and communications technology area (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter).

Importance of Advanced Technology Products to U.S. Trade

During much of the 1990s, U.S. trade in advanced technology products grew in importance as it accounted for larger and larger shares of overall U.S. trade (exports plus imports) in merchandise and produced consistent trade surpluses for the United States. Beginning in 2000 and coinciding with the dot.com meltdown, the trade balance for U.S. technology products began to erode.[17] In 2002, U.S. imports of advanced technology products exceeded exports, resulting in the first U.S. trade deficit in this market segment in history. The trade deficit has grown each year since then (figure 6-14; appendix table 6-6). In 2002, the U.S. trade deficit in advanced technology products was $15.5 billion; it increased to $25.4 billion in 2003 and $37.0 billion in 2004. The imbalance of U.S. trade with Asia (imports exceeding exports), especially with China, Malaysia, and South Korea, overwhelms U.S. surpluses and relatively balanced trade with other parts of the world.

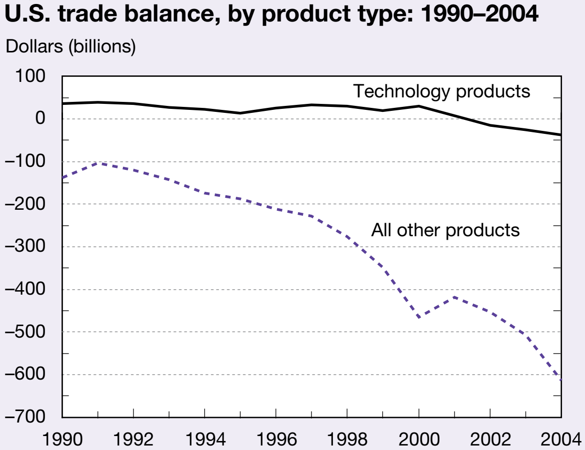
Technologies Generating a Trade Surplus

Throughout most of the 1990s, U.S. exports of advanced technology products generally exceeded imports in 9 of the 11 technology areas.[18] Trade in aerospace products consistently produced the largest surpluses for the United States during this time.

Since 2000, the number of technology areas in which U.S. exports of advanced technology products generally exceeded imports has slipped from nine showing a trade surplus during the 1990s to five or six areas in 2003 (table 6-3). Aerospace products continue to produce the largest surpluses. Surpluses in aerospace trade began to narrow in the mid-1990s as competition from Europe's Airbus Industrie challenged U.S. companies' preeminence at home and in foreign markets. U.S. aerospace exports and imports both declined in 2002 and 2003 and both increased in 2004. In 2004, U.S. trade in aerospace products generated a net inflow of $30.5 billion, creating a surplus 14.6% higher than the 2003 surplus.

U.S. trade classified as electronics products (e.g., electronic components including integrated circuits, circuit boards, capacitors, and resistors) is the only other technology area that has generated large surpluses in recent years. However, unlike the U.S. trade surplus in aerospace products where exports increased between 2000 and 2004, the larger surplus in this technology area resulted mainly from a greater drop in U.S. imports than exports. In 2001, U.S. trade in electronics products generated a net inflow of $14.5 billion and increased to $16.1 billion in 2002, before rising to more than $21 billion in both 2003 and 2004. Trade activity in biotechnologies, flexible manufacturing products (e.g., industrial automation products, robotics), and weapon technologies generated small surpluses over the past few years.

Figure 6-14
U.S. trade balance, by product type: 1990–2004



NOTES: Technology products from special tabulations. All other product trade calculated from data on total product trade.

SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations (2004); and data on total product trade, http://www.fedstats.gov. Accessed February 2005.

Science and Engineering Indicators 2006

Technologies Generating a Trade Deficit

Throughout most of the 1990s, trade deficits were recorded in just 2 of the 11 technology areas: information and communications and optoelectronics. Rapidly rising imports of life science technologies during the late 1990s produced the first U.S. trade deficit in that third technology area in 1999. Since 2000, U.S. imports have exceeded exports in 5 of the 11 technology areas, although the largest trade deficits continue to be in the information and communications technology area (table 6-3). In 2004, U.S. trade in information and communications resulted in a net outflow of $73.3 billion; in life science technologies, the net outflow was $18.3 billion; and in optoelectronics, it was $4.3 billion. Small deficits of about $0.65 billion resulted from trade in both nuclear technologies and advanced materials.

Top Customers by Technology Area

Asia, Europe, and North America together purchase nearly 90% of all U.S. exports of advanced technology products. Asia is the destination for about 40%, Europe about 30%, and Canada and Mexico together about 18% (appendix table 6-6).

Canada, Japan, and Mexico are the largest country customers across a broad range of U.S. technology products, with Canada accounting for about 10% of all U.S. exports of advanced technology products in 2003 and 2004, Japan for about 9%, and Mexico about 8%. In 2004, Canada ranked among the top three customers in 5 of 11 technology areas, Japan in 9, and Mexico in 4 (figure 6-15).

Asia is a major export market for the United States. In addition to the broad array of technology products sold to Japan, the latest data show Taiwan among the top three customers in optoelectronics, flexible manufacturing, and nuclear technologies, while China is among the top three customers in electronics and advanced materials, and South

Table 6-3
U.S. trade in advanced-technology products: 2000–04
(Millions of U.S. dollars)

Category	2000	2001	2002	2003	2004
Exports					
All technologies	225,415.3	202,107.8	180,629.3	181,789.5	201,454.0
Biotechnologies	1,728.8	1,615.0	2,130.5	2,862.8	3,743.2
Life sciences	11,950.6	12,839.6	11,858.6	13,002.0	14,515.9
Optoelectronics	4,113.0	3,402.7	2,430.6	2,467.0	3,506.4
Information and communications	76,250.4	65,260.4	53,309.3	53,127.8	59,210.1
Electronics	56,884.0	45,358.4	42,762.8	46,597.2	48,564.4
Flexible manufacturing	14,295.1	9,451.4	8,562.5	8,319.6	13,044.3
Advanced materials	2,651.2	2,309.6	1,088.9	1,036.5	
Aerospace	52,747.5	56,916.7	53,255.2	49,432.9	54,377.3
Weapons	1,528.8	1,522.7	1,557.7	1,451.8	1,852.1
Nuclear technology	1,266.0	1,430.3	1,671.2	1,488.9	1,503.1
Computer software	118.4	80.0	1,310.9	1,628.1	1,807.6
Imports					
All technologies	195,660.30	195,265.20	196,100.10	207,196.20	238,478.30
Biotechnologies	1,136.00	1,294.40	1,871.90	2,183.90	1,967.40
Life sciences	16,210.50	20,113.00	25,950.30	30,936.90	32,799.00
Optoelectronics	5,822.90	5,607.50	5,436.60	5,254.90	7,795.00
Information and communications	91,864.70	95,158.60	100,765.90	110,088.50	132,539.00
Electronics	41,651.50	30,882.60	26,649.50	25,135.20	27,454.00
Flexible manufacturing	8,684.90	7,473.40	6,562.20	6,262.80	7,587.20
Advanced materials	2,707.40	2,435.90	1,484.90	1,510.50	1,794.40
Aerospace	25,733.10	30,511.00	25,212.90	22,773.10	23,832.80
Weapons	413.2	383.1	407	461.4	539.7
Nuclear technology	1,436.10	1,405.70	1,758.90	2,589.00	2,169.90
Computer software	826	723.6	780.8	955.2	1,053.90
Balance					
All technologies	29,755.00	6,842.50	–15,470.8	–25,406.7	–37,024.3
Biotechnologies	592.8	320.6	258.6	678.9	1,775.80
Life sciences	–4,259.9	–7,273.4	–14,091.7	–17,934.8	–18,283.1
Optoelectronics	–1,710.0	–2,204.8	–3,006.1	–2,787.9	–4,288.6
Information and communications	–15,614.3	–29,898.2	–47,456.6	–56,960.7	–73,328.9
Electronics	15,232.50	14,475.80	16,113.40	21,462.00	21,110.40
Flexible manufacturing	5,610.20	1,978.00	2,000.30	2,056.90	5,457.10
Advanced materials	–56.2	–126.3	–396.0	–474.0	–657.2
Aerospace	27,014.40	26,405.70	28,042.30	26,659.80	30,544.50
Weapons	1,115.60	1,139.60	1,150.70	990.3	1,312.50
Nuclear technology	–170.1	24.6	–87.7	–1,100.1	–666.7
Computer software	–707.6	–643.6	530.1	672.9	753.7

SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations (2005).

Science and Engineering Indicators 2006

Korea is among the top three in nuclear technologies and flexible manufacturing.

European countries are also important consumers of U.S. technology products, particularly Germany, the United Kingdom, France, and the Netherlands. The European market is particularly important in two technology areas: biotechnology and aerospace. The Netherlands and Belgium are the top customers for U.S. biotechnology products, together consuming more than half of all U.S. exports within this technology area. France is the leading consumer of U.S. aerospace technology products (11% of U.S. exports in this technology area) and the United Kingdom is third (nearly 9%).

Top Suppliers by Technology Area

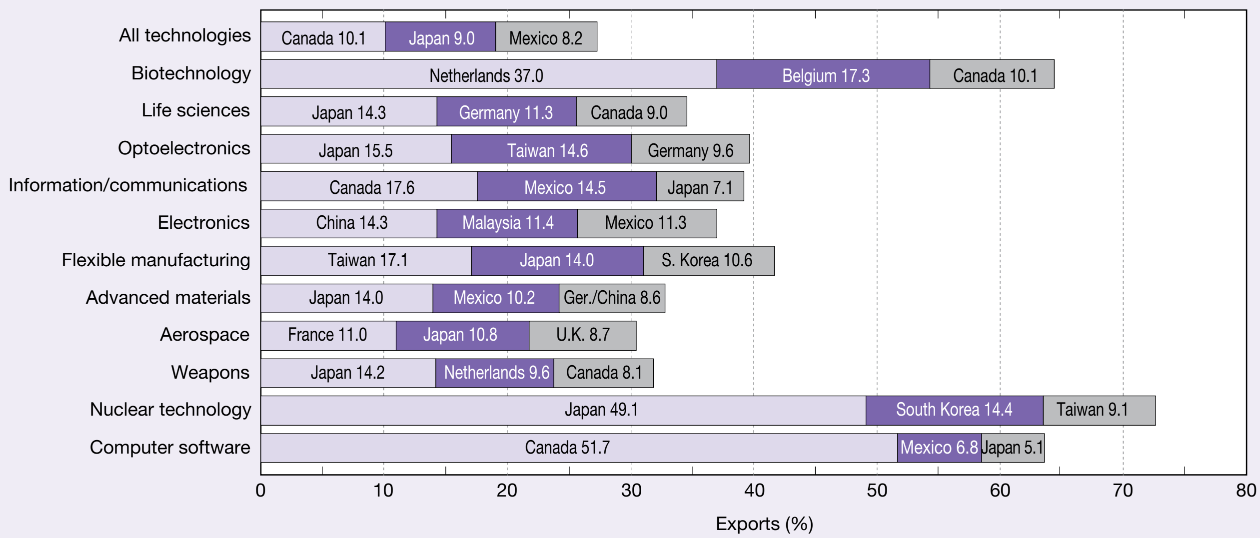
The United States is not only an important exporter of technologies to the world but also is a major consumer of imported technologies. The leading economies in Asia, Europe, and North America are important suppliers to the U.S. market in each of the 11 technology areas examined. Together, they supply about 95% of all U.S. imports of advanced technology products. In 2004, Asia supplied almost 60%, Europe about 20%, and North America about 15%.

China is by far the largest supplier of technology products to the United States, as the source for almost 20% of U.S. imports in 2004 (appendix table 6-6). Japan is a distant

second, as the source for 10% of U.S. technology imports in 2004. Malaysia, South Korea, and Taiwan are other major Asian suppliers. In the electronics technology area, the top three suppliers are all in Asia (figure 6-16).

Among the European countries, Germany, the United Kingdom, and France are major suppliers of technology products to the United States. Many smaller European countries have also become important sources for technology products, although they tend to specialize more. Ireland was the top supplier of biotechnology and life science products to the United States in 2004, as the source for 24% and 36% of U.S. imports in these categories. Hungary supplied 14% of U.S. biotechnology imports, and the Netherlands supplied nearly 8% of U.S. flexible manufacturing technology imports in 2004.

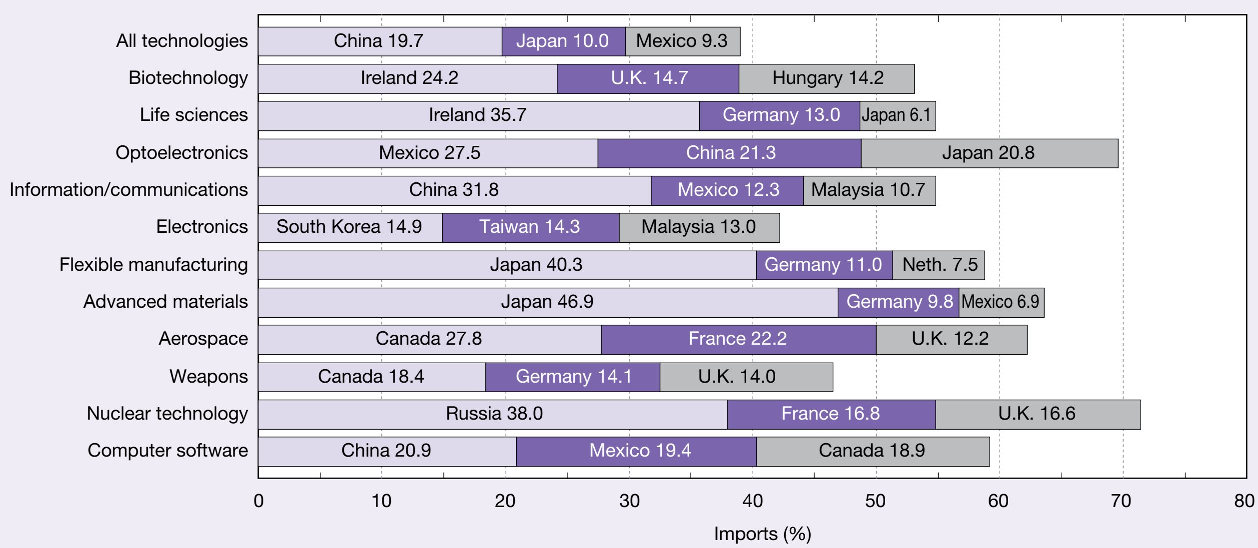
Figure 6-15
Three largest export markets for U.S. technology products: 2004



SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations.

Science and Engineering Indicators 2006

Figure 6-16
Top three foreign suppliers of technology products to United States: 2004



SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations.

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U.S. Royalties and Fees Generated From Intellectual Property

The United States has traditionally maintained a large surplus when trading intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. Trade in intellectual property can involve patented and unpatented techniques, processes, formulas, and other intangible assets and proprietary rights; broadcast rights and other intangible rights; and the rights to distribute, use, and reproduce general-use computer software. These transactions generate revenues in the form of royalties and licensing fees.[19]

U.S. Royalties and Fees From All Transactions

In 2001, U.S. receipts from trade in intellectual property declined for the first time, interrupting a steady succession of year-to-year increases dating back to 1982.[20] New data for 2002 and 2003, however, show a resumption of the prior growth pattern. U.S. receipts grew by 8.7% in 2002 and by nearly 9.2% in 2003. In 2003, U.S. receipts totaled $48.3 billion (figure 6-17; appendix table 6-7).

In contrast to the country's merchandise trade, U.S. receipts for transactions involving intellectual property generally were four to five times greater than U.S. payments to foreign firms. During the late 1990s, however, this gap began to narrow as U.S. payments increased faster than receipts. The ratio of receipts to payments shrunk to about 3:1 by 1999 and nearly 2:1 by 2002.

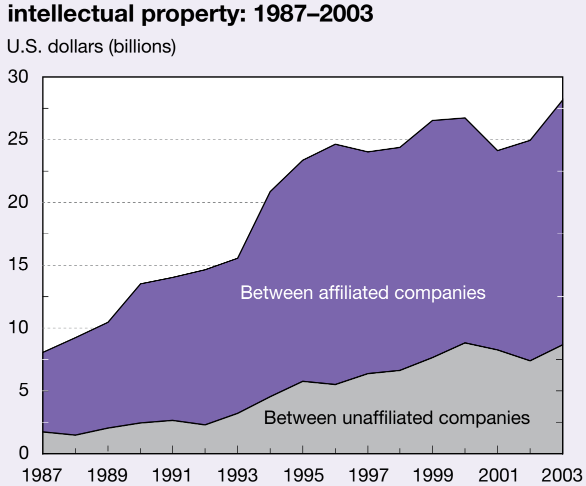
In 2003, U.S. trade in intellectual property produced a surplus of $28.2 billion, up about 5% from the $25.0 billion surplus recorded a year earlier. About 75% of transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates.[21] Exchanges of intellectual property among affiliates grew at about the same pace as those among unaffiliated firms. These trends suggest both a growing internationalization of U.S. business and a growing reliance on intellectual property developed overseas.[22]

U.S. Royalties and Fees From Trade in Manufacturing Know-How

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in manufacturing know-how. Trade in manufacturing know-how described here tracks U.S. trade in industrial processes used in the production of goods. Tracking data on transactions between unaffiliated firms in which prices are set through market-based negotiation may better reflect the value of manufacturing know-how at a given time than tracking data on exchanges among affiliated firms. When receipts (sales of manufacturing know-how) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology. Tracking the record of receipts and payments also provides an indicator of trends in the production and diffusion of manufacturing knowledge.

The United States is a net exporter of manufacturing know-how sold as intellectual property (figure 6-18; appendix table 6-8). The gap between imports and exports narrowed during the late 1990s and has remained somewhat erratic. The most recent data show a trade surplus of $2.6 billion in 2003, which is 28% higher than 2002 and the second highest surplus on record, after the peak $3.0 billion surplus recorded in 2000. U.S. receipts totaled to $4.8 billion in 2003, an increase of 19% over the previous year and the first increase in 2 years. A large part of this increase is due

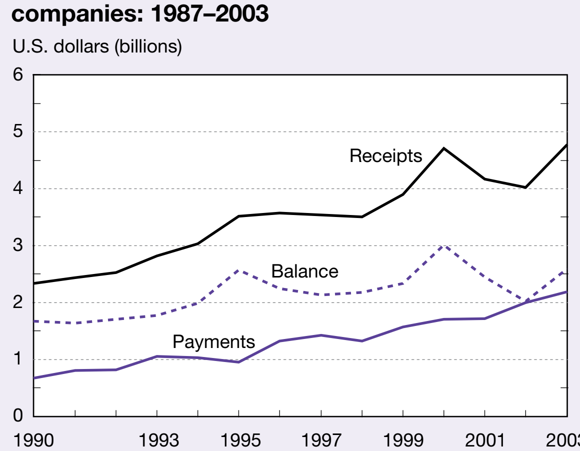
Figure 6-17
U.S. trade balance of royalties and fees paid for intellectual property: 1987–2003



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business* 84(10):25–76 (2004). See appendix table 6-7.

Science and Engineering Indicators 2006

Figure 6-18
U.S. trade in intellectual property involving manufacturing know-how, between unaffiliated companies: 1987–2003



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business* 84(10):25–76 (2004). See appendix table 6-8.

Science and Engineering Indicators 2006

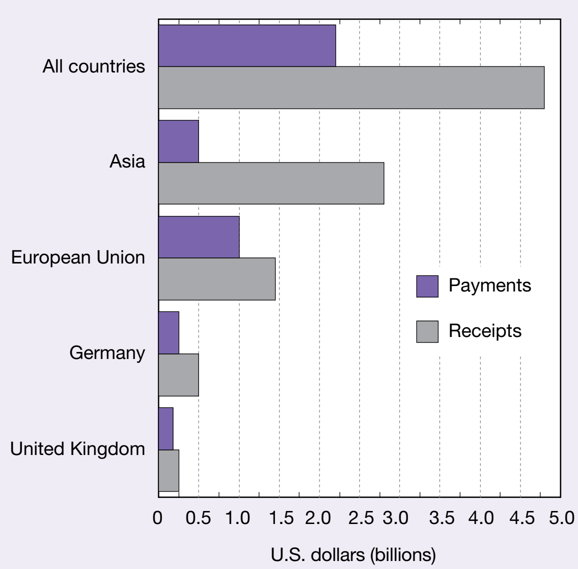
to a rise in receipts reported by several large pharmaceutical and telecommunications companies. This rise in receipts lifted total U.S. 2003 receipts from trade in manufacturing know-how above those earned from licensing use of computer software (Borga and Mann 2004).

Trading Partners

The U.S. surplus from trade in manufacturing know-how is driven largely by trade with Asia (appendix table 6-8). In 1995, U.S. receipts (exports) from manufacturing know-how licensing transactions were nearly seven times the amount of U.S. payments (imports) to Asia. That ratio closed to less than 4:1 by 1999, but has since widened. The most recent data show U.S. receipts from manufacturing know-how licensing transactions at about five times the amount of U.S. payments to Asia (figure 6-19). Japan and South Korea were the biggest customers for U.S. manufacturing know-how sold as intellectual property, accounting for 45% of total receipts in 2003.

Receipts. Japan has consistently been the single largest consumer of U.S. manufacturing know-how, although its purchases have fluctuated downward since the mid-1990s. Japan's share of U.S. receipts peaked in 1993 at approximately 51%; more recently, Japan's share was 30% in 2002 and 28% in 2003. South Korea was the second largest consumer, accounting for 17% of U.S. receipts in 2003. A major consumer of U.S. manufacturing know-how since the early 1990s, South Korea's share of U.S. receipts was 11% in 1990 and reached its highest level, 19%, in 2000.

Figure 6-19
U.S. royalties and fees generated from trade in intellectual property in the form of manufacturing know-how, between unaffiliated companies: 2003



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business*, 84(10):25–76 (2004). See appendix table 6-8.

Science and Engineering Indicators 2006

Unlike trade with Asia, U.S. trade with Europe in manufacturing know-how in the form of intellectual property is fairly balanced. U.S. firms trade manufacturing know-how primarily with Switzerland and the EU countries of France, Germany, Sweden, and the United Kingdom. Receipts from European countries nearly reached $1.7 billion in 2003, or about 36% of all U.S. receipts for technology sold as intellectual property. EU countries accounted for 30%. Germany is the third-largest consumer of U.S. manufacturing know-how, spending twice as much as the other large European customers, the United Kingdom, France, or Switzerland.

Payments. Foreign sources for U.S. firms' purchases of manufacturing know-how have varied over the years (appendix table 6-8). The EU has been the biggest supplier for U.S. firms, accounting for 37%–54% of foreign-supplied U.S. purchases of manufacturing know-how sold as intellectual property over the 15-year period examined (1987–2003). Germany, the United Kingdom, and Switzerland are the principal European suppliers.[23] In 2003, U.S. payments to Switzerland exceeded those paid to any other European country, second only to those paid to Japan.

Asia also has been an important supplier of manufacturing know-how, although its share of U.S. purchases has dropped considerably since 1999. In 2001, Asian countries accounted for 26% of U.S. purchases, down from 39% in 1999. Japan is the source for nearly all of these purchases, with small amounts coming from South Korea, Taiwan, and China. Since 1992, Japan has been the single largest foreign supplier of manufacturing know-how to U.S. firms; about one-fourth of all U.S. payments in 2003 were made to Japanese firms.

New High-Technology Exporters

Several nations made tremendous technological advances over the past decade and are positioned to become more prominent in technology development because of their large, ongoing investments in S&T education and R&D.[24] However, their success also may depend on other factors such as political stability, access to capital, and an infrastructure that can support technological and economic advancement.

This section assesses a group of selected countries and their potential to become more important exporters of high-technology products during the next 15 years, based on the following leading indicators:[25]

- **National orientation**—evidence that a nation is taking action to become technologically competitive, as indicated by explicit or implicit national strategies involving cooperation between the public and private sectors.
- **Socioeconomic infrastructure**—the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to a modern, technology-based industrial nation. Indicators include the existence of dynamic capital markets, upward trends in capital formation, rising levels of foreign investment, and national investments in education.

- **Technological infrastructure—**the social and economic institutions that contribute directly to a nation's ability to develop, produce, and market new technology. Indicators include the existence of a system for the protection of intellectual property rights, the extent to which R&D activities relate to industrial application, competency in high-technology manufacturing, and the capability to produce qualified scientists and engineers.
- **Productive capacity—**the physical and human resources devoted to manufacturing products and the efficiency with which those resources are used. Indicators include the current level of high-technology production, the quality and productivity of the labor force including the presence of skilled labor, and the existence of innovative management practices.

National Orientation

The national orientation indicator identifies nations in which businesses, government, and culture encourage high-technology development. It was constructed using information from a survey of international experts and previously published data. The survey asked the experts to rate national strategies that promote high-technology development, social influences that favor technological change, and entrepreneurial spirit. Published data were used to rate each nation's risk factor for foreign investment during the next 5 years.

Five of the 15 countries examined received high overall scores on this indicator: Israel, Malaysia, the Czech Republic, China, and Ireland. The high scores for this indicator for Israel, China, and Malaysia reflect high ratings for each of the expert-opinion components, while the Czech Republic's score was elevated by its rating as one of the safest countries for foreign investment. Like the Czech Republic, Ireland was considered a safe haven for foreign investment, but its score was strengthened more by the experts' high opinions of Ireland's national strategies promoting high-technology development and social influences favoring technological change. The Czech Republic and China stand apart from the other three countries by showing marked improvement over results published just 2 years ago,[26] when, for example, China's score was more than 13 points lower than the 2005 score (figure 6-20, appendix table 6-9).

Venezuela received the lowest composite score of the economies examined. It was rated low for all variables, but mostly suffered because it was considered the riskiest or least attractive site for foreign investment. Indonesia and Argentina also received consistently low scores on each variable, but mostly were affected by the very low expert ratings of their national strategies for high-technology development.

Socioeconomic Infrastructure

The socioeconomic infrastructure indicator assesses the underlying physical, financial, and human resources needed to support modern, technology-based nations. It was built from published data on percentages of the population in secondary school and in higher education and from survey data evaluating the mobility of capital and the extent to which foreign businesses are encouraged to invest and do business in that country[27] (figure 6-20).

Israel and Ireland received the highest scores among the emerging and transitioning economies examined. In addition to their strong records in general and higher education, Ireland and Israel's scores reflect high ratings for the mobility of capital and the encouragement of foreign investment. Their scores were similar to two other economies that currently export large quantities of high-technology products in the global marketplace—Taiwan and Singapore.

Among the remaining nations, Malaysia and two other Central European countries, Hungary and Poland, all received similar high scores. As with Ireland and Israel, the socioeconomic infrastructure score for Malaysia was bolstered by the experts' high opinion of the mobility of capital in the country and its encouragement of foreign investment, whereas the two Central European countries received high scores for their strong showing in the published education data and expert opinion on the mobility of capital.

As it did 2 years ago, Indonesia received the lowest composite score of the 15 nations examined, largely because of low marks on two of the three variables: educational attainment (particularly university enrollments) and the variable rating of the extent to which foreign businesses are encouraged to invest and do business in Indonesia.

Technological Infrastructure

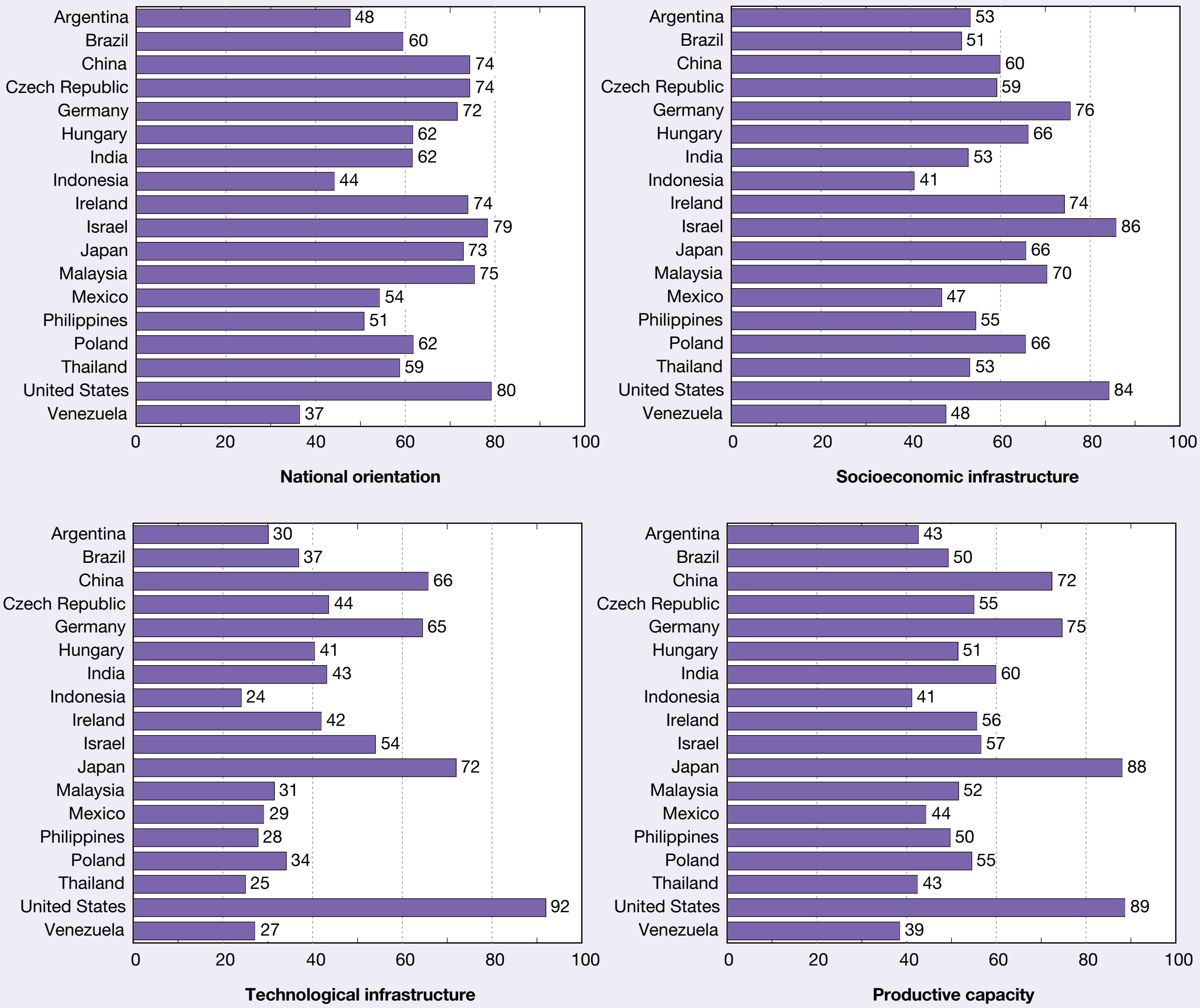
Five variables were used to develop the technological infrastructure indicator, which evaluates the institutions and resources that help nations develop, produce, and market new technology. This indicator was constructed using published data on the number of scientists in R&D, published data on national purchases of electronic data processing (EDP) equipment, and survey data that asked experts to rate each nation's ability to (1) locally train its citizens in academic S&E, (2) make effective use of technical knowledge, and (3) link R&D to industry.

Although the United States and Japan scored highest for technological infrastructure, with Germany close behind, China and Israel received the highest scores in this area among the newly industrialized or transitioning economies examined (figure 6-20). This was also the case 2 years ago, but at that time, the two nations' scores were very close. By 2005, China had surged ahead of Israel by 12 points.

China's high score for this indicator was influenced greatly by the two components that reflect the size of its population: its large purchases of EDP equipment and its large number of scientists and engineers engaged in R&D. Another factor behind China's high score is the experts' higher rating this year for China's ability to locally train its citizens in S&E.

Israel's high score on this indicator was based primarily on high expert ratings for its ability to locally train its

Figure 6-20
Leading indicators of technological competitiveness in selected countries: 2005



NOTE: Raw data were converted into 0–100 scale for each indicator component.

SOURCE: Georgia Institute of Technology, *High Tech Indicators: Preliminary Report* (2005). See appendix table 6-9.

Science and Engineering Indicators 2006

citizens in academic S&E, make effective use of technical knowledge, and link R&D to industry, as well as Israel's contribution to scientific knowledge.

Indonesia and Thailand received the lowest scores among the 15 countries examined.

Productive Capacity

The productive capacity indicator evaluates the strength of a nation's manufacturing infrastructure and uses that evaluation as a baseline for assessing the country's capacity for future growth in high-technology activities. The indicator considers expert opinion on the availability of skilled labor, the number of indigenous high-technology companies, and the level of management ability, combined with published data on current electronics production in each country.

By a wide margin, China had the highest score in productive capacity among the 15 developing and transitioning nations examined. China's score was boosted by its prominence in producing electronics, but it also received strong scores on each expert-derived indicator component. Trailing China on this indicator was a group of five nations that received similar overall scores: India, Israel, Ireland, the Czech Republic, and Poland (figure 6-20). Although all five of these countries posted higher scores than China on each of the expert-derived indicator components, they fell considerably short of China in the current production of electronics. Production of electronics products within Malaysia and Mexico

was greater than all other 15 developing countries examined except for China. Malaysia's overall score was hurt by experts' low ratings of its indigenous electronics components suppliers and of the capabilities of its industrial managers. Mexico's overall score suffered from the experts' low rating of the quality of Mexican skilled manufacturing labor.

Findings From the Four Indicators

Based on this set of four leading indicators, Israel and China received the highest composite scores of the 15 nations examined. Both appear to be positioning themselves for future prominence as exporters of technology products in the global marketplace. Israel ranked first in national orientation based on strong governmental and cultural support promoting technology production, and first in socioeconomic infrastructure because of its large number of trained scientists and engineers, its highly regarded industrial research enterprise, and its contribution to scientific knowledge. Israel placed second and third on the two remaining indicators (figure 6-21, appendix tables 6-9, 6-10, and 6-11).

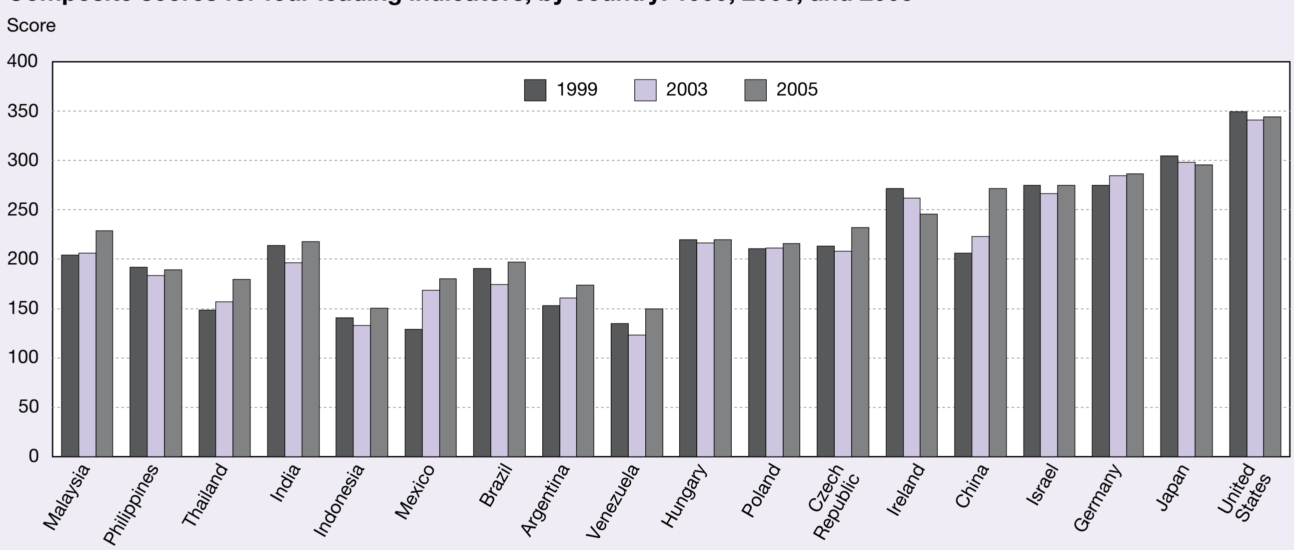
China's composite score for 2005 fell just short of Israel's, but the rise in its overall score over the past 2 years is noteworthy. China showed improvement in all four indicators and significant improvement in three: national orientation, technological infrastructure, and productive capacity. Its large population helped raise its score on several indicator components; this shows how scale effects, both in terms of large domestic demand for high-technology products and the ability to train large numbers of scientists and engineers, provide advantages to developing nations.[28]

Ireland, the co-leader with Israel two years ago, fell below China in this latest round of data, although it still made a strong showing across all four indicators. The Czech Republic and Malaysia posted high composite scores bolstered by high scores in the national orientation and productive capacity indicators.

Although not yet compiling high composite scores, several other countries appear to be laying the foundation for manufacturing and exporting high-tech products in the near future. Overall scores for Thailand, Mexico, and Argentina have trended upward in each of the last two periods, 2003 and 2005. Thailand's 2003 score was elevated because of a jump in a statistical rating for a rise in the number of Thai students enrolled in tertiary education, while its score in 2005 was elevated by a jump in electronics production. Mexico's overall score rose in 2003 based on higher expert-derived ratings in national orientation and technological infrastructure and improved statistical scores on student enrollments in secondary and tertiary education. In 2005 Mexico's scores held steady on these three indicators while its rating in the productive capacity indicator increased. Argentina showed gradual steady increases in most indicators during 2003 and 2005.

These indicators provide a systematic way to compare future technological capability for a wider set of nations than would be available using other indicators. The results highlight how the group of nations that compete in high-technology markets may broaden in the future. Results also reflect the large differences among several emerging and transitioning economies.

Figure 6-21
Composite scores for four leading indicators, by country: 1999, 2003, and 2005



SOURCE: Georgia Institute of Technology, *High Tech Indicators: Preliminary Report* (2005). See appendix tables 6-9, 6-10, and 6-11.

Science and Engineering Indicators 2006

Patented Inventions

Inventions are of great economic importance to a nation because they often result in new or improved products, more efficient manufacturing processes, or entirely new industries. To foster inventiveness, nations assign property rights to inventors in the form of patents. These rights allow the inventor to exclude others from making, using, or selling the invention for a limited period of time. Inventors obtain patents from government-authorized agencies for inventions judged to be new, useful, and not obvious.[29]

Although the U.S. Patent and Trademark Office (PTO) grants several types of patents, this discussion is limited to utility patents, commonly known as patents for inventions. They include any new, useful, or improved-on method, process, machine, device, manufactured item, or chemical compound.

Patenting indicators have several well-known drawbacks, including:

- **Incompleteness—**many inventions are not patented at all, in part because laws in some countries already protect industrial trade secrets.
- **Inconsistency across industries and fields—**the propensity to patent differs by industry and technology area.
- **Inconsistency in importance—**the importance of patented inventions can vary considerably.

Despite these limitations, patent data provide useful indicators of technical change and serve as a way to measure inventive output over time. In addition, information about foreign inventors seeking U.S. patents enables the measurement of inventiveness in foreign countries and can serve as a leading indicator of new technological competition (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter).

U.S. Patenting

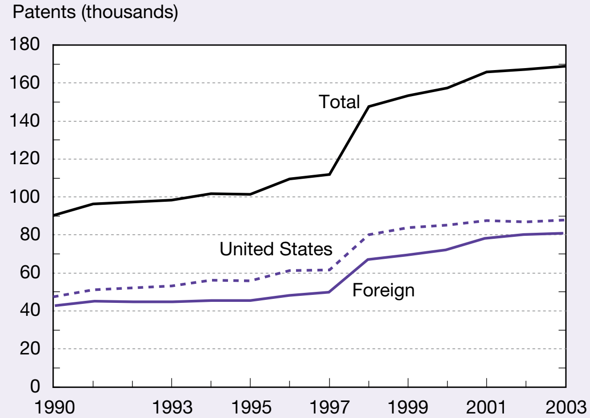
Although a record number of patents (more than 169,000) were issued in the United States in 2003, the rate of growth in U.S. patenting has slowed since 2000[30] (figure 6-22; appendix table 6-12). Nonetheless, U.S. patents have enjoyed a period of nearly uninterrupted growth since the late 1980s.

Patents Granted to U.S. Inventors

The share of U.S. patents granted to U.S.-resident inventors has been fairly stable over the years, fluctuating within a narrow range (52%–56%). Since peaking at 56% in 1996, the share of U.S. patents granted to and held by U.S. resident inventors has declined slightly. In 2003, U.S. inventors were awarded nearly 88,000 new patents, or about 52% of the total patents granted in the United States. The increase in the share of U.S. patents granted to foreigners (from 44% in 1996 to 48% in 2003) reflects the growing global capacity for technological innovation in a broader array of countries as well as the openness of the U.S. market to new products.

Patents granted to U.S. inventors can be further analyzed by patent ownership at the time of the grant. Inventors who work for private companies or the federal government commonly assign ownership of their patents to their employers; self-employed or independent inventors typically retain ownership of their patents. The owner's sector of employment is thus a good indication of the sector in which the inventive work was done. In 2003, corporations owned 84% of patents granted to U.S. entities.[31] This percentage has risen rapidly since the late 1990s. From 1987 to 1997, corporate-owned patents accounted for 73%–78% of all U.S.-owned patents. Since 1997, corporations have increased this share to 80% in 1999, 82% in 2001, and 84% in 2003.

Figure 6-22
U.S. patents granted, by country of origin: 1990–2003



NOTE: Country of origin determined by residence of first-named inventor.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-12.

Science and Engineering Indicators 2006

Individuals (independent inventors) are the second-largest group of U.S. patent owners. Before 1990, individuals owned, on average, 24% of all patents granted to U.S. entities.[32] This figure has trended downward to a low of 12% in 2003. Government's share (whether U.S. federal or state or foreign government) of issued patents averaged 3% from 1963 to 1990 and has stayed around 1% since the mid-1990s.[33]

Patents Granted to Foreign Inventors

Patents issued to foreign inventors represented 48% of all patents granted by the United States in 2003. This share reflects a slight increase since 1999, but has changed little since 1990. In 2003, the top five countries receiving patents from the United States were Japan, Germany, Taiwan, South Korea, and France. (See sidebar "Top Patenting Corporations" for discussion of the top 10 corporations receiving U.S. patents.)[34] During the period examined (1990–2003), inventors from Japan and Germany consistently were awarded more U.S. patents than inventors from any other country. The share of U.S. patents granted to inventors from Japan fluctuated 20%–23% during the 14-year span examined, and the share granted to inventors from Germany fluctuated 6%–8%. In 2003, Japan's share was 21%, Germany's share was 7%, and France's share was 3%.

Top Patenting Corporations

A review of corporations that received the largest number of patents in the United States during the past 25 years illustrates Japan's technological transformation over a relatively short period. During the 1970s, no Japanese companies ranked among the top 10 corporations seeking patents in the United States. During the 1980s, several Japanese companies became a part of the top 10 and by the early 1990s, Japanese companies outnumbered U.S. companies.

The number of U.S. patents granted to inventors residing in South Korea and Taiwan has risen quite sharply in recent years. One company headquartered in South Korea cracked the top 10 in 1999 and has remained there every year since, except for 2002 (its final rank was 11 that year). The most recent data (2003) show 1 South Korean company, 1 Dutch company, 3 U.S. companies, and 5 Japanese companies among the top 10 (table 6-4). In 2003, IBM was again awarded more patents than any other U.S. or foreign organization, the 11th consecutive year that the company earned this distinction. Micron Technology, Inc., joined the top 10 in 2000 and Intel Corporation in 2003. IBM, Micron, and Intel were the only U.S. companies to make the top 10 in 2003.

Table 6-4
Top patenting corporations in United States: 1999, 2001, and 2003

Company	Patents
1999	
International Business Machines	2,756
NEC	1,842
Canon	1,795
Samsung Electronics	1,545
Sony	1,417
Toshiba	1,200
Fujitsu	1,193
Motorola, Inc.	1,192
Lucent Technologies	1,163
Mitsubishi Denki	1,054
2001	
International Business Machines	3,411
NEC	1,953
Canon	1,877
Micron Technology, Inc.	1,643
Samsung Electronics	1,450
Matsushita Electric Industrial	1,440
Sony	1,363
Hitachi	1,271
Mitsubishi Denki	1,184
Fujitsu	1,166
2003	
International Business Machines	3,415
Canon	1,992
Hitachi	1,893
Matsushita Electric Industrial	1,774
Micron Technology	1,707
Intel Corporation	1,592
Koninklijke Philips Electronics	1,353
Samsung Electronics	1,313
Sony	1,311
Fujitsu	1,302

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (November 2004).

Science and Engineering Indicators 2006

Although patenting by inventors from leading industrialized countries has leveled off or declined in recent years, two Asian economies, Taiwan and South Korea, have stepped up their patenting activity in the United States and are proving to be strong inventors of new technologies (figure 6-23; appendix table 6-12).[35] The latest data show Taiwan (in 2000) and South Korea (in 2003) ahead of France and the United Kingdom, ranking third and fourth as residences for foreign inventors that obtain U.S. patents. Only inventors from Japan and Germany receive more U.S. patents.

Between 1963 (the year data first became available) and 1990, Taiwan received just 2,341 U.S. patents. During the subsequent 13 years, inventors from Taiwan were awarded more than 38,000 U.S. patents. U.S. patenting activity by inventors from South Korea shows a similar growth pattern. Before 1990, South Korean inventors received just 599 U.S. patents; since then, they have been awarded nearly 29,000 new patents.

Trends in Applications for U.S. Patents

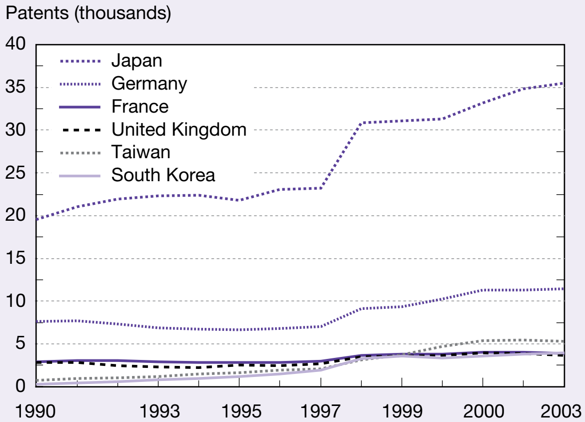
The review process leading up to the official grant of a new patent takes an average of 2 years, therefore, examining year-to-year trends in the number of patents granted does not always show the most recent changes in patenting activity.[36] Consequently, the number of patent applications filed with the PTO is examined to obtain an earlier, albeit less certain, indication of changes to patterns of inventiveness.

Patent Applications From U.S. and Foreign Inventors

Applications for U.S. patents reached 342,400 in 2003, an increase of only 2.4% from 2002, similar to the increase in 2001. Still, these latest data add to what has been nearly a decade of annual increases (figure 6-24; appendix table 6-13).

Shares of patent applications from U.S. residents have fluctuated between 54%–56% of all applications since the

Figure 6-23
U.S. patents granted to foreign inventors, by country/economy of origin: 1990–2003

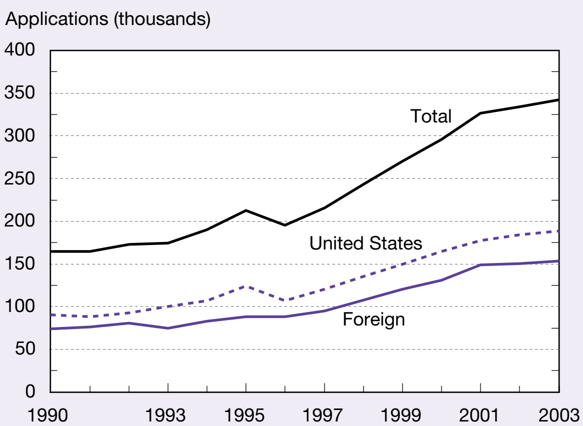


NOTES: Selected countries/economies are top six recipients of U.S. patents during 2003. Country of origin is determined by residence of first-named inventor.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-12.

Science and Engineering Indicators 2006

Figure 6-24
U.S. patent applications, by country of residence of first-named inventor: 1990–2003



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations (2005). See appendix table 6-13.

Science and Engineering Indicators 2006

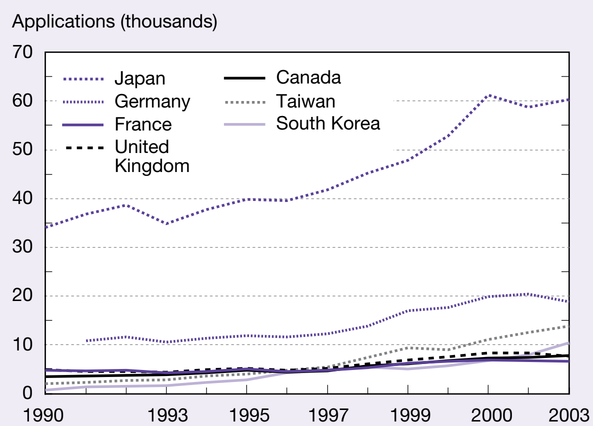
mid-1990s; in 2002 and 2003, U.S. residents accounted for 55%. Because patents granted to foreign inventors generally accounted for about 44%–48% of total U.S. patents granted, the success rate for foreign applications appears to be about the same or slightly higher than that for U.S. inventor applications.[37]

Over time, residents of Japan have applied for more U.S. patents than residents of any other foreign country. Since 1990, they accounted for 39%–48% of yearly U.S. patent applications made by foreign residents, generally at least three times that of Germany, which had the next most active group of applicants (figure 6-25). Japan's share slipped in the late 1990s, falling to a decade low of 40% in 1999. Its share has hovered around 40% since then. The German share has generally exhibited a downward trend, falling from a high of 16% in 1989 to about 12% in 2003.

Although patent filings by inventors from the leading industrialized countries have leveled off or begun to decline, other countries, particularly Asian economies, have stepped up their patenting activity in the United States. This is especially true for Taiwan and South Korea, and data on recent patent applications suggest that the rising trend in U.S. patents granted to residents of these two Asian economies is likely to continue. Since 1997, Taiwan and South Korea replaced France and Canada in the top five foreign sources of inventors seeking U.S. patents. In 2003, Taiwan accounted for 9% of foreign sources of U.S. patent applications and South Korea for close to 7%. Canada and the United Kingdom accounted for 5% and France for 4%. If recent patents granted to residents of Taiwan and South Korea are indicative of the technologies awaiting review, many of these applications will prove to be for new computer and electronic inventions.

Also impressive is the growth in patent applications by inventors from Israel, Finland, India, and China. In 2003, inventors from Israel filed more than 2,500 U.S. patent applications, up from about 600 in 1990; inventors from Finland filed more than 1,900 U.S. patent applications, up from about 600 in 1990; inventors from India filed for nearly 1,200 U.S. patent applications, up from 58 in 1990; and inventors from China filed for 1,034 U.S. patent applications, up from 111 in 1990. These dramatic increases over the past several years provide yet another indication of the ever-widening community of nations active in global technology development and diffusion.

Figure 6-25
U.S. patent applications filed by selected foreign inventors, by country/economy of residence: 1990–2003



SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-13.

Science and Engineering Indicators 2006

Technical Fields Favored by Foreign Inventors

A country's inventors and the distribution of its patents by technical area is a reliable indicator of the country's technological strengths as well as its focus on product development. This analysis can also indicate which U.S. product markets are likely to see increased foreign competition. The following section discusses the key technical fields favored by U.S. resident inventors and inventors from the top five foreign countries obtaining patents in the United States.[38]

Fields Favored by U.S. and Leading Foreign Resident Inventors

Corporate patenting patterns reflect activity in several technology areas that have already greatly contributed to the nation's economic growth. In 2003, for example, corporate patent activity indicated U.S. technological strengths in business methods, computer hardware and software, medical and surgical devices, and biotechnology (table 6-5).

The 2003 data also show Japan's continued emphasis on photography, photocopying, and office electronics technology, as well as its broad range of U.S. patents in communication technology. From improved information storage technology for computers to wave transmission systems, Japanese inventors have earned many U.S. patents in areas that aid in the processing, storage, and transmission of information.

German inventors continue to develop new products and processes in areas associated with heavy manufacturing, a field in which they traditionally have maintained a strong presence. The 2003 U.S. patent activity index shows that Germany emphasizes inventions for printing, motor vehicles, metal forming, and material-handling equipment.

In addition to inventions for traditional manufacturing applications, British patent activity is high in oil-drilling technologies, biotechnology, communications, and chemistry (appendix table 6-14). Like German and British inventors, French inventors are quite active in patent classes associated with manufacturing applications; however, they also show added activity in aeronautics and automotive technologies (appendix table 6-15). They share U.S. and British inventors' emphasis on biotechnology.

As recently as 1980, Taiwan's U.S. patent activity was concentrated in the area of toys and other amusement devices. But by the 1990s, Taiwan was active in communication technology, semiconductor manufacturing processes, and internal combustion engines. Data from 2003 show that Taiwan's inventors also added semiconductors, semiconductor manufacturing devices, and electrical systems to their technology portfolio.

U.S. patenting by South Korean inventors also reflects that country's rapid technological development. The 2003 data show that South Korean inventors are currently patenting heavily in a broad array of computer technologies that include liquid crystal cells, devices for dynamic and static information storage, and television technologies (table 6-6).

Patents for Biotechnologies

When inventions result in new or improved products or processes, patent owners can reap economic benefits that, in turn, typically spill over to users and consumers. But inventions that lead to the creation of entire new industries have more profound impact on national economies and on international relations. Patented biotechnologies are an example of industry-creating inventions.

Shadowing the widely anticipated economic and medical benefits associated with this technology area is a great deal of controversy. Proponents argue that biotechnology patents are necessary to allow for commercial development of many new diagnostic and therapeutic products. Others voice concerns

Table 6-5
Top 15 most-emphasized U.S. patent classes for corporations from United States, Japan, and Germany: 2003

Rank	United States	Japan	Germany
1	Business practice, data processing	Electrophotography	Printing
2	Surgery: light, thermal, and electrical applications	Television signal processing	Clutches and power-stop control
3	Computers and digital processing systems	Computer storage and retrieval	Land vehicles, bodies, and tops
4	Data processing, file management	Photography	Machine element or mechanism
5	Surgery instruments	Photocopying	Brake systems
6	Data-processing software	Liquid crystal cells	Power delivery controls, engines
7	Wells	Ceramic compositions	Internal combustion engines
8	Prosthesis	Facsimile	Metal forming
9	Processing achitectures	Power delivery controls, engines	Valves
10	Input/output digital processing systems	Optical image projector	Joints and connections
11	Data processing, artificial intelligence	Incremental printing of symbolic information	Sheet-feeding machines
12	Analytical and immunological testing	Bearings	Land vehicles
13	Surgical, medicators, and receptors	Electric lamp and discharge devices	X-ray or gamma-ray systems
14	Multicellular living organisms	Electrical generators	Rotary motors or pumps
15	Computer memory	Radiation imagery chemistry	Chairs, seats

NOTES: Rank based on patenting activity index for nongovernmental U.S. or foreign organizations, which are primarily corporations. Patenting by individuals and governments excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (December 2004).

Science and Engineering Indicators 2006

Table 6-6
Top 15 most-emphasized U.S. patent classes for corporations from South Korea and Taiwan: 2003

Rank	South Korea	Taiwan
1	Liquid crystal cells, elements, and systems	Semiconductor device manufacturing process
2	Electric lamp and discharge devices	Electrical connectors
3	Semiconductor device manufacturing process	Electrical systems and devices
4	Dynamic magnetic information storage or retrieval	Circuit makers and breakers
5	Electric lamp and discharge systems	Electric power conversion systems
6	Static information storage and retrieval	Active solid-state devices
7	Brushing, scrubbing, and general cleaning	Typewriting machines
8	Television	Substrate etching process
9	Refrigeration	Sheet-feeding machines
10	Active solid-state devices	Illumination
11	Pumps	Heat exchange
12	Power delivery controls, engines	Cleaning
13	Electrical audio signal systems	Optical image projector
14	Television recording systems	Communication radio wave antennas
15	Electrical nonlinear devices	Facsimile

NOTES: Rank based on patenting activity index for nongovernmental organizations, which are primarily corporations. Patenting by individuals and governments excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division (2004).

Science and Engineering Indicators 2006

about the patenting of naturally occurring elements and more general concerns that giving companies monopoly rights in certain biotechnologies may hinder scientific progress (see sidebar "A Patent System for the 21st Century"). Ethical issues surrounding cloning for reproductive and therapeutic purposes are also part of the debate.

Despite these ongoing controversies, patent offices worldwide have issued thousands of patents for biotechnologies. This section examines recent trends in biotechnology patenting in the United States and Europe and identifies countries that are the source for most of the biotechnology patenting in these two major markets.

U.S. Patenting of Biotechnologies

U.S. patenting of biotechnologies accelerated during the 1990s, especially during the latter half of the decade (figure 6-26; appendix table 6-16). The effort to map the human genome certainly contributed to this trend, as evidenced by the surge in applications to patent human DNA sequences. Although the number of biotechnology patents has remained high since 2001, the trend has turned slightly negative.[39]

U.S. resident inventors accounted for more than 60% of all biotechnology patents issued by PTO. This share is about 10% higher than U.S. inventors hold when U.S. patents for all technologies are counted.[40] Given the ongoing controversies surrounding this technology area, foreign inventors may be less inclined than U.S. inventors to file biotechnology patents in the United States.

Foreign sources account for about 36% of all U.S. biotechnology patents. These patents are more evenly distributed among a somewhat broader number of countries than that for all technology areas combined. Another evident pattern is the more prominent representation of European countries in U.S. patents of biotechnologies and the smaller representation by Asian inventors (figure 6-27). Not only are Japan and Germany the leading foreign sources for U.S. patents overall, they are the leading foreign sources for U.S. patents granted for biotechnologies. Recently, however, Germany's share of U.S. biotechnology patents granted has been rising while Japan's share has been falling. In 2003, Germany was still the leading foreign source, accounting for 6.5% of U.S. biotechnology patents granted, up from around 4% in the late 1990s, while Japan's share was 6.4%, about half the share held by Japanese inventors in the early 1990s.

Like Germany, inventors from the United Kingdom, France, Canada, and the Netherlands also accounted for a larger share of U.S. patents granted in the biotechnology area compared with their shares of U.S. patents granted in all other technology areas. Conversely, inventors from Taiwan and South Korea are far less active in this technology area than for all technology areas combined.

Top Biotechnology Patenting Organizations

In the biotechnology area, universities, government agencies, and other nonprofit organizations are among the leading recipients of U.S. patents, although corporations are still awarded the most patents overall (table 6-7; appendix tables 6-16 and 6-17). The University of California system has been awarded the most patents; its total represents 1.6% of total patents granted in this technology area since 1977.[41] The U.S. Department of Health and Human Services was the second leading recipient with more than 1,000 U.S. biotechnology patents, accounting for about 1.1% of the total. Corporations, U.S.- and foreign-based, are well represented among the top 25 and include most of the large pharmaceutical companies and several companies closely identified with this field.

A Patent System for the 21st Century

For some time there has been a growing concern that patents and other forms of exclusive ownership of intellectual property may discourage research into, communication about, and diffusion of new technologies. This concern led to the question whether, in some cases, the extension of intellectual property rights (IPR) has stifled rather than stimulated innovation. To provide answers and guide IPR policy over the next decade and beyond, the Science, Technology, and Economic Policy Board of the National Research Council reviewed the purposes and functioning of the IPR legal framework in the United States and assessed how well those purposes are being served.

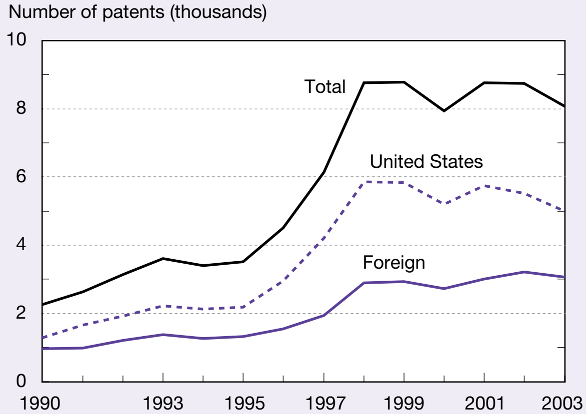
The board held several conferences and workshops and commissioned new data collection and analysis efforts to investigate issues of patent quality, licensing, and litigation, especially as these issues relate to patents for information technology and biotechnology. They identified the following concerns for the research enterprise:

- Standards of patentability, in particular the nonobviousness standard, are eroding.
- A proliferation of upstream patents on scientific discoveries, especially in biomedical science, could impede research.
- Rising patent costs, longer patent pendancy, and differences in national patent systems are contributing to unnecessary costs and delays.
- The U.S. intellectual property system is struggling with the accelerating pace of technological developments in the knowledge economy.

The committee composed of economists, legal experts, technologists, and university and corporate officials made the following recommendations to address these concerns:

- *Institute an "open review" procedure.* The committee recommended that Congress pass legislation creating a streamlined, relatively low-cost procedure for third parties to challenge issued patents in a proceeding before administrative patent judges of the U.S. Patent and Trademark Office (PTO).
- *Reinvigorate the nonobviousness standard.* The requirement that to qualify for a patent an invention cannot be obvious to a person of ordinary skill in the art should be assiduously observed.
- *Shield some research uses of patented inventions from liability for infringement.* In light of the ruling that even noncommercial scientific research enjoys no protection from patent infringement liability, the committee recommended that Congress consider appropriately narrow legislation to protect certain cases of academic researcher use of patented inventions.
- *Strengthen PTO capabilities.* The PTO should be provided additional budget resources to hire and train additional examiners and improve its electronic processing capabilities.
- *Harmonize U.S., European, and Japanese patent examination systems.* This would help reduce redundancy in search and examination and could eventually lead to mutual recognition of results.

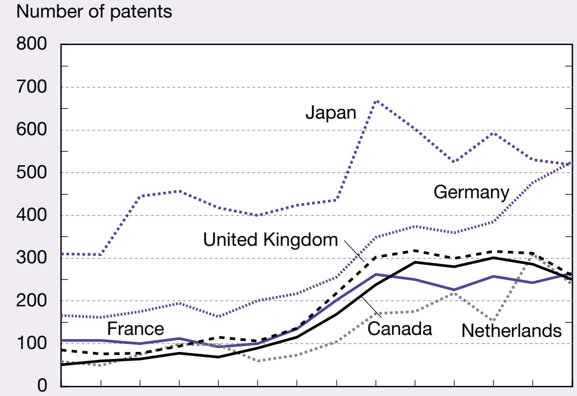
Figure 6-26
U.S. biotechnology patents granted, by residence of first-named inventor: 1990–2003



SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-16.

Science and Engineering Indicators 2006

Figure 6-27
U.S. biotechnology patents granted to foreign inventors, by residence of inventor: 1990–2003



NOTE: Selected countries are top six recipients of U.S. patents during 2003.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-16.

Science and Engineering Indicators 2006

Table 6-7
Top 25 biotechnology patenting organizations: 1977–2003

Company	Patents	Share of group	Share of total
All organizations	89,448	na	100.00
University of California	1,585	10.54	1.77
U.S. Department of Health and Human Services	1,021	6.79	1.14
Merck and Co., Inc.	943	6.27	1.05
Genentech, Inc.	792	5.27	0.89
Yoder Brothers, Inc.	729	4.85	0.82
Pioneer Hi-Bred International, Inc.	693	4.61	0.77
Eli Lilly and Company	674	4.48	0.75
Abbott Laboratories	654	4.35	0.73
Smithkline Beecham Corporation	636	4.23	0.71
University of Texas	576	3.83	0.64
Incyte Pharmaceuticals, Inc.	572	3.80	0.64
Boehringer Mannheim G.M.B.H.	549	3.65	0.61
Isis Pharmaceuticals, Inc.	512	3.40	0.57
Novo Nordisk A/S	490	3.26	0.55
Chiron Corporation	484	3.22	0.54
E. I. Du Pont De Nemours and Company	461	3.07	0.52
Becton, Dickinson and Company	427	2.84	0.48
Hoffmann-La Roche Inc.	426	2.83	0.48
U.S. Department of Agriculture	418	2.78	0.47
General Hospital Corporation	414	2.75	0.46
Johns Hopkins University	412	2.74	0.46
Hoechst Aktiengesellschaft	402	2.67	0.45
Institut Pasteur	395	2.63	0.44
Miles Inc.	387	2.57	0.43
Takeda Chemical Industries Ltd.	387	2.57	0.43
Subtotal	15,039	100.00	16.81

na = not applicable

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (January 2005).

Science and Engineering Indicators 2006

Patenting of Valuable Inventions: Triadic Patent Families

One limitation of using patent counts as an indicator of national inventive activity is that such counts cannot differentiate between minor inventions and highly important inventions. A database developed through an international partnership of patent offices in the United States, Europe, and Japan provides a new tool for patent researchers that helps to address this problem.[42] This data set counts only those inventions for which patent protection is sought in three important markets: the United States, Europe, and Japan.[43] Each invention that satisfies this condition forms a *triadic patent family.*[44]

The high cost of filing for patents from three separate patent offices makes triadic patent families a more accurate measure of important inventions than simple patent counts, because generally only highly valuable inventions justify the costs (see sidebar "Identifying Valuable Inventions: A Comparison of Results When Using PTO, EPO, and PCT Patent Citations"). For example, application fees alone can exceed several thousand dollars, not counting related legal costs. The costs for an inventor to file for patent protection in his or her country of residence are significant. The costs to file in other countries are even greater.

Counts of triadic patent families, sorted by the inventor's residence for selected countries, are listed by priority year, i.e., the year of the first patent filing. The United States has been the leading producer of triadic patent families since 1989, even when compared with European inventors. Inventors residing in EU countries produced nearly as many triadic patented inventions as did inventors living in the United States since the late 1980s, and they produced more than the U.S. inventors from 1985 through 1988 (figure 6-28). Within the EU, Germany had more triadic patent inventors than the next three leading European countries: France, the United Kingdom, and the Netherlands. Inventors residing in Japan produced only slightly fewer triadic patents than inventors in the United States or the EU. Estimates for 2000 show U.S. inventors' share at 34%, EU's share at 31%, and Japan's share at 27%. However, given its much lower population, Japan's inventive productivity would easily exceed that of the United States or the EU if the number of inventions per capita were used as the basis for comparison.

When the data are examined by the patent applicant's or owner's country of residence rather than by the inventor's residence, the overall rankings for the United States, the EU, and Japan do not change, although the U.S. share increases, the EU share decreases, and Japan's share stays about the

Identifying Valuable Inventions: A Comparison of Results When Using PTO, EPO, and PCT Patent Citations

When applying for a patent, the applicant usually includes references to previous patents or nonpatent literature to distinguish the subject invention from previous inventions. These references to "prior art" are used by the granting agency to investigate and establish the validity of the applicant's claims. During the examination of the application, the patent examiner considers the applicant's citations to prior art and may add other citations that the examiner feels are relevant. Patent citations typically reference other patents and nonpatent literature, such as scientific or technical journal articles, books, reference works, and other forms of public disclosure.

Technology analysts can use patent citations to develop indicators that measure the value or importance of a group of patents. Data on patent citations from the U.S. patent system often are used for this purpose. In recent years, as patent data at the European Patent Office (EPO) and other granting authorities have become increasingly accessible, researchers have raised the question whether a citation analysis using EPO or other patent data than U.S. patent citations would provide different or better results.

U.S. Patent System Citations

Some observers have noted that features of the U.S. patent system (such as the duty of candor and the Information Disclosure Statement) can result in large numbers of references, many of which may be only marginally relevant to the validity of the claims made on the patent application. Moreover, there is no categorization of citations on U.S. patents identifying those that are directly relevant to patentability and distinguishing them from citations that are merely background information. Therefore, it is possible that large numbers of marginally relevant citations on U.S. patents either undermine the effectiveness of citation analysis or distort the results.

Another criticism of U.S. patent citations is that they are biased toward other U.S. patents and English-language patents in general.

Comparison of U.S. and Other Patent Systems

Those who examine patents in the EPO and for the Patent Cooperation Treaty (PCT) are instructed to include only the most important documents in the references. In addition, EPO and PCT references are categorized by their relevance to the submitted application. Thus, citations on EPO and PCT patent documents (especially citations that directly anticipate some or all of the subject matter of the citing patent application) may be more directly related to value and therefore provide better data for citation analysis.

Under contract with the National Science Foundation, Mogee Research & Analysis conducted a statistical comparison of citations from U.S., EPO, and PCT patent documents to determine whether better information could be extracted from EPO and/or PCT patent citations or from using U.S. patent citations alone.* The analysis was conducted on patent families (i.e., groups of equivalent patent documents in different patent systems) that included at least one patent document each from the United States, EPO, and PCT. These are called *triadic patent families*. Citations to and from the U.S., EPO, and PCT documents within a given triadic patent family were compared, thus keeping the subject invention constant. Issued patents and published applications from the U.S. Patent and Trademark Office (PTO) were covered, as were issued patents and published applications from the EPO and published applications from the PCT system. References on the front page of the U.S. patent were compared with references in the search report for the EPO and PCT patent documents. The patenting and referencing processes in the three systems also were studied.

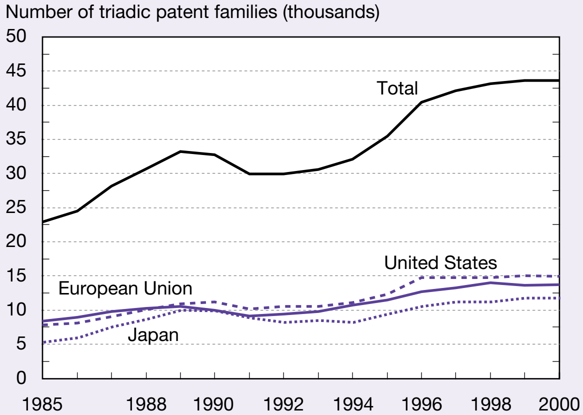
Two cases were studied: Solid Waste Disposal, with 332 triadic families, and Advanced Batteries for Automobiles, with 324 triadic families.

Preliminary Findings

- In these two cases, ranking the inventions (triadic families) by the number of citations received by EPO or PCT patent documents did not give drastically different results from their ranking by the number of citations received by U.S. patents.
- U.S. patent documents referenced patents from a broader range of priority countries than EPO and PCT patent documents referenced.
- U.S. patent documents tended to cite U.S. patents more than EPO patent documents cited EPO patents.
- U.S. patent citations by themselves are a satisfactory source to develop citation indicators, as measured by their ability to predict the value distribution of a group of patents. However, a citation analysis that also includes citations from the EPO and PCT may lead to a more robust analysis in the sense of a better accounting for patent value.
- EPO and PCT citations provided more information than could be obtained from the U.S. citations alone and improved the predictions of patent value, as measured by both patent renewals and the number of family members.

*Full report forthcoming in 2006.

Figure 6-28
Triadic patent families, by residence of inventor: 1985–2000



SOURCE: Organisation for Economic Co-operation and Development/World Intellectual Property Organization, Triadic Patent Families, unpublished tabulations (2004).

Science and Engineering Indicators 2006

same (table 6-8). The shift in shares between the United States and the EU is nearly identical; it appears that the percentage increase in the U.S. share comes almost completely from the EU. The difference in country shares when triadic patent families are sorted by the owner's residence as opposed to the inventor's residence suggests that U.S. companies (corporations own most triadic patent families) employ or otherwise purchase ownership of more European innovations than European firms employ or otherwise purchase ownership of U.S. innovations. Another explanation might be that U.S. companies' European operations are more R&D- or discovery-oriented than European operations in the United States. The near-constant shares for Japan tend to reinforce the image of Japanese firms as more insular, relying mostly on the discoveries of inventors residing in Japan.

Rankings change dramatically when national activity is normalized by population or by size of the economy as reflected in the GDP (figure 6-29). When data are normalized for size, smaller countries emerge, Switzerland and Finland in particular, and demonstrate high output of important inventions. Among the big three (the United States, the EU, and Japan), Japan clearly is the most productive when size is factored into the measurement.

Counts of triadic patent families also can be used to further examine patenting in biotechnology. During 1998 and 1999, which are the most recent 2 years for which complete data are available, the United States, the EU, and Japan together accounted for more than 90% of all biotechnology triadic patents, a percentage slightly lower than their share of all triadic patents formed during this period. Biotechnologies account for a larger share of the U.S. patent portfolio compared with the EU or Japan. Combining these 2 years, biotechnology patents accounted for 6.8% of total U.S. triadic patent families, 3.5% for the EU, and 1.5% for Japan (figure 6-30).

Venture Capital and High-Technology Enterprise

Venture capitalists typically invest in small, young companies that may not have access to public or credit-oriented institutional funding. Such investments can be long term and high risk and, in the United States, almost always include hands-on involvement in the firm by the venture capitalist. The funds and management expertise venture capitalists provide can aid the growth and development of small companies and new products and technologies. In fact, venture capital is often an important source of funds used in the formation and expansion of small high-technology companies. These new high-technology companies play a vital role in the U.S. economy and have become important employers of recent S&E graduates (National Venture Capital Association 2002). Tracking venture capital investments also provides indicators of technology areas that venture capitalists consider the most economically promising.

Table 6-8
Triadic patent families, by inventor and applicant (owner) place of residence and priority year: 1988–99
(Percent)

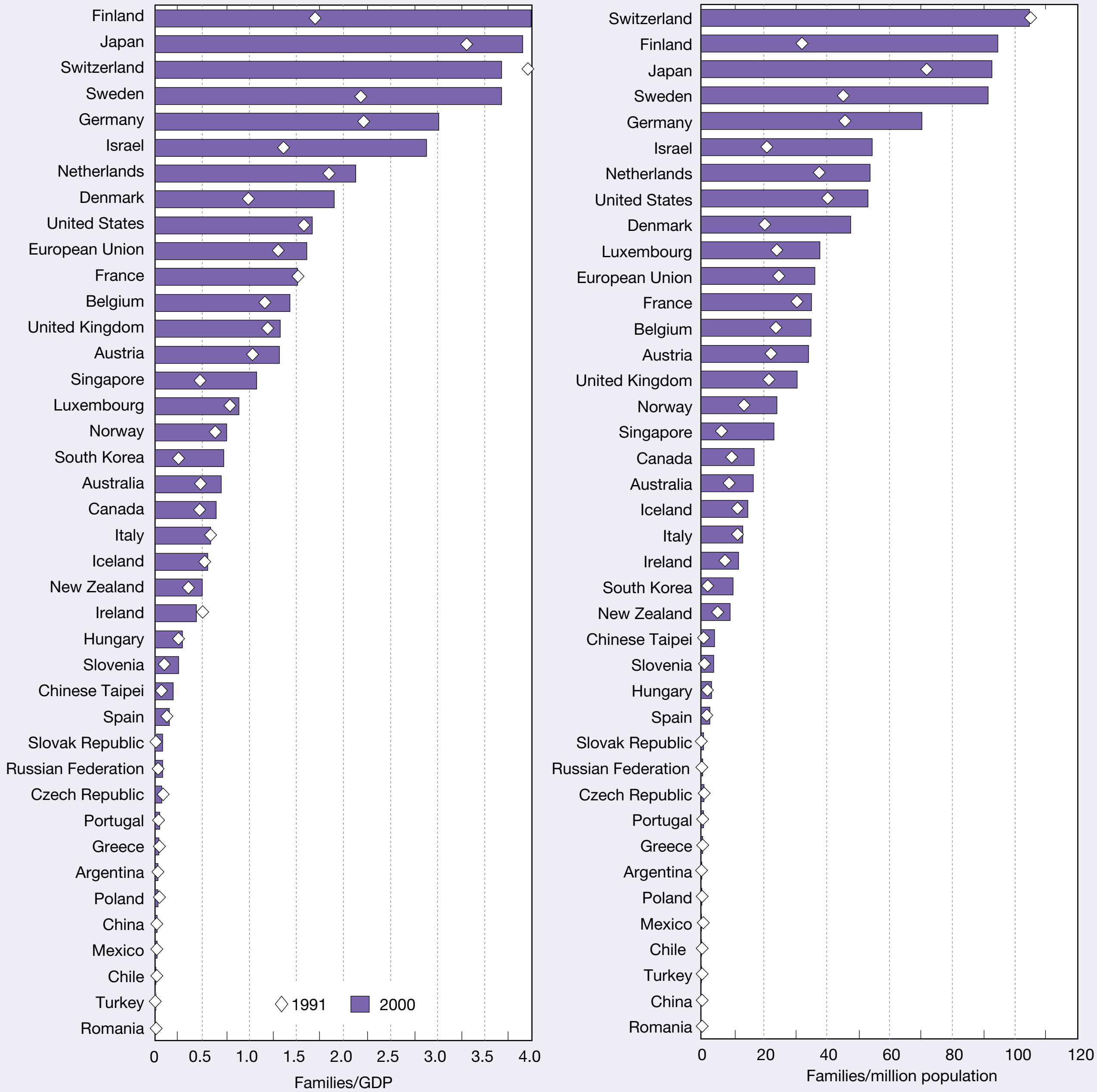
Place of residence	Total	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Inventor													
United States	34.9	33.0	33.0	34.4	34.9	36.2	35.4	34.8	34.3	33.9	35.6	36.2	36.1
European Union	31.6	33.5	31.7	30.2	30.5	31.3	31.8	33.6	32.7	32.8	31.0	35.4	28.7
Japan	27.5	28.3	30.2	30.3	29.1	26.7	26.8	25.3	26.5	26.9	26.6	29.8	28.6
Applicant													
United States	39.4	37.9	37.5	38.8	39.4	40.8	40.3	40.0	38.8	38.4	39.3	39.7	37.9
European Union	27.7	29.4	28.0	26.7	26.7	27.3	27.7	29.4	28.6	28.5	27.5	32.1	27.0
Japan	27.3	28.0	30.0	29.9	28.9	26.5	26.6	24.9	26.3	26.8	26.7	29.9	28.6

NOTE: A triadic patent family is formed when patent applications for same invention are filed in Europe, Japan, and United States.

SOURCE: Organisation for Economic Co-operation and Development/World Intellectual Property Organization, Triadic Patent Families, unpublished tabulations (2004).

Science and Engineering Indicators 2006

Figure 6-29
Triadic patent families, by residence of inventor: Priority years 1991 and 2000



GDP = gross domestic product

NOTES: Applications for patents filed with European Patent Office, U.S. Patent and Trademark Office, and Japanese Patent Office. 2000 values are estimates. GDP calculated is 1995 U.S. dollars using purchasing power parity.

SOURCE: Organisation for Economic Co-operation and Development, patent database (September 2004).

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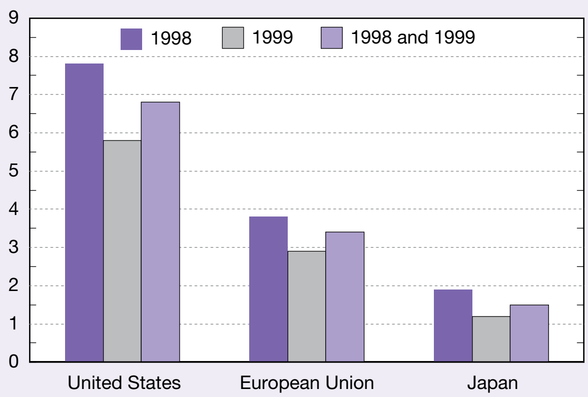
Figure 6-30
Share of biotechnology triadic patents, by country/region: 1998 and 1999



SOURCE: Organisation for Economic Co-operation and Development, patent database (September 2004)

Science and Engineering Indicators 2006

Table 6-9
New capital committed to U.S. venture capital funds: 1980–2002
(Billions of U.S. dollars)

Year	New capital
1980	2.1
1981	1.6
1982	1.7
1983	4.1
1984	3.1
1985	4.0
1986	3.9
1987	4.4
1988	4.9
1989	5.6
1990	3.5
1991	2.1
1992	5.4
1993	3.9
1994	7.8
1995	10.0
1996	12.2
1997	19.0
1998	29.7
1999	62.8
2000	105.8
2001	37.9
2002	7.7

SOURCE: Thomson Financial Services, special tabulations (June 2003).

Science and Engineering Indicators 2006

This section examines venture capital investment patterns in the United States since 1980, with special emphasis on a comparison of trends in 1999 and 2000 (hereafter called the *bubble years*) with trends in 2001 and 2002 (the *postbubble years*) and most recently in 2003 and 2004. It discusses changes in the overall level of investment, those technology areas U.S. venture capitalists find attractive, and the types of investments made.[45]

U.S. Venture Capital Resources

Several years of high returns on venture capital investments during the early 1990s led to a sharp increase in investor interest. The latest data show new commitments rising vigorously each year from 1996 through 2000, with the largest increase in 1999 (table 6-9). Investor commitments to venture capital funds jumped to $62.8 billion that year, a 111% gain from 1998. By 2000, new commitments reached $105.8 billion, more than 10 times the level of commitments recorded in 1995. Evidence of a slowdown emerged in 2001, when new commitments declined for the first time in 10 years.[46] Commitments fell by more than 64% that year, to $37.9 billion. Still, this sharply reduced total was quite large compared with capital investments before the bubble years. Another sharp drop in 2002 reduced the amount of new money coming into venture capital funds to only $7.7 billion, a level not seen since 1994.

The pool of money managed by venture capital firms grew dramatically over the past 20 years as pension funds became active investors, following the U.S. Department of Labor's clarification of the "prudent man" rule in 1979.[47] In fact, pension funds became the single largest supplier of new funds. During the entire 1990–2002 period, pension funds supplied about 44% of all new capital. Endowments and foundations were the second-largest source, supplying 17% of committed capital, followed closely by financial and insurance companies at 16% (table 6-10). California, New York, and Massachusetts together account for about 65% of venture capital resources, because venture capital firms tend to cluster around locales considered to be "hotbeds" of technological activity, as well as in states where large amounts of R&D are performed (Thomson Financial Venture Economics 2002).

U.S. Venture Capital Disbursements

High returns on venture capital investments during the 1990s made the funds attractive for risk-tolerant investors. Starting in 1994, the amount of new capital raised exceeded that disbursed by the industry, creating a large pool of money available for investments in new or expanding firms and leading to a period of large year-to-year jumps in venture capital disbursements. In 1994, money disbursed by venture capital funds totaled to $4.1 billion and increased to $11.6 billion in 1996 and $21.4 billion in 1998, before peaking at $106.3 billion in 2000 (figure 6-31).

As early as 1990, firms producing computer software or providing computer-related services began receiving large amounts of venture capital (appendix table 6-18). Software companies received 17% of all new venture capital disbursements in 1990, more than any other technology area. This figure fluctuated between 12% and 21% thereafter. Communication companies also attracted large amounts of venture capital during the 1990s, receiving 12%–21% of total

Table 6-10
Capital commitments, by limited partner type: 1990–2002
(Billions of U.S. dollars)

Limited partner type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All types	2.55	1.48	3.39	4.12	7.35	8.42	10.47	15.18	25.29	60.14	93.44	2.81	2.54
Pension funds	1.34	0.63	1.41	2.43	3.36	3.12	5.74	5.77	15.03	26.16	37.47	0.83	1.12
Banks and insurance	0.24	0.08	0.49	0.43	0.70	1.62	0.30	0.91	2.59	9.32	21.77	0.37	0.24
Endowments and foundations	0.32	0.36	0.63	0.44	1.57	1.65	1.18	2.43	1.58	10.34	19.72	0.29	0.25
Individuals and families	0.29	0.18	0.37	0.30	0.87	1.36	0.68	1.82	2.83	5.77	11.03	0.75	0.35
Corporations	0.17	0.06	0.11	0.34	0.67	0.35	1.98	3.64	2.97	8.54	3.46	0.41	0.21
Foreign investors	0.19	0.17	0.38	0.18	0.18	0.32	0.59	0.61	0.29	0.00	0.00	0.15	0.00
Other NEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Intermediaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18

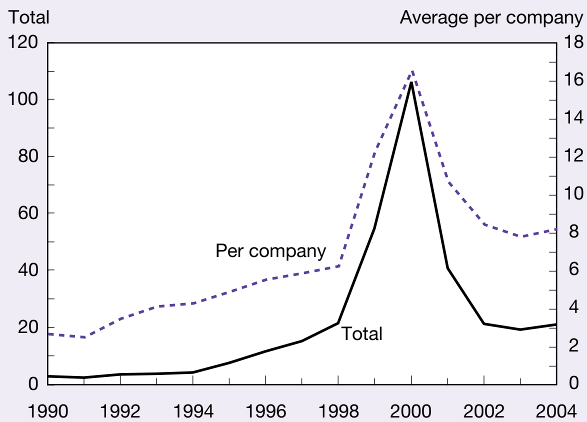
NEC = not elsewhere classified

SOURCE: Thomson Financial Services, special tabulations (June 2003).

Science and Engineering Indicators 2006

Figure 6-31
Venture capital disbursements, total and by company: 1990–2004

Dollars (millions)



SOURCES: Thomson Financial Services, special tablulations (May 2005). See appendix tables 6-18 and 6-19.

Science and Engineering Indicators 2006

disbursements. Medical and health care-related companies received a high of almost 21% of venture capital in 1992 before dropping almost each year thereafter to just 5% in 1999 and to 4% in 2000.

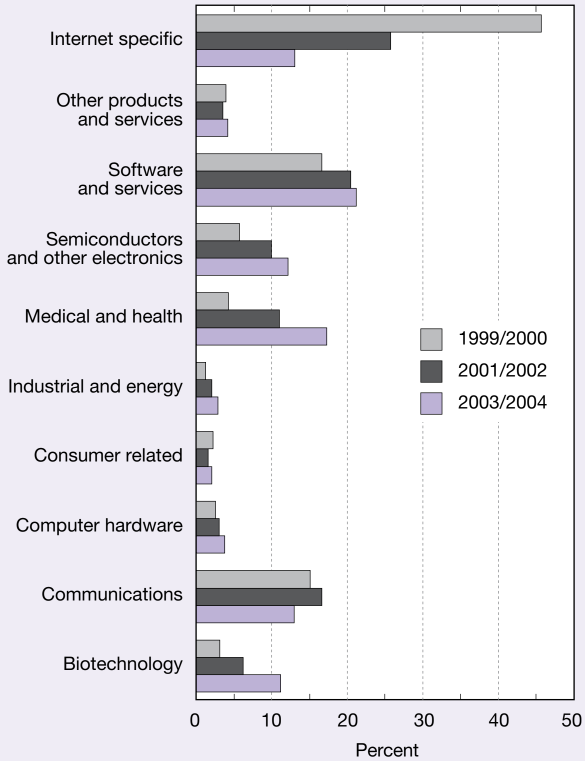
In the late 1990s, the Internet emerged as a business tool, and companies developing Internet-related technologies drew venture capital investments in record amounts. Beginning in 1999, investment dollars disbursed to Internet companies were classified separately, whereas before 1999, some of these funds were classified as going to companies involved in computer hardware, computer software, or communication technologies. Internet-specific businesses involved primarily in online commerce were the leading recipients of venture capital in the United States during the bubble years, collecting more than 40% of all venture capital funds invested each year. Software and software services companies received 15%–17% of disbursed venture capital funds. Communication companies (including telephone, data, and wireless communication) were a close third with 14%–15%.

The U.S. stock market suffered a dramatic downturn after its peak in early 2000, with the sharpest drops in the technology sector. Led by a dot.com meltdown, technology stock valuations generally plummeted, and many Internet stocks were sold at just a fraction of their initial price. Venture capital investments, however, continued to favor Internet-specific companies over other industries in the postbubble period. During this period (2001–02), Internet companies received 28% and 21%, respectively, of the total venture capital dollars disbursed. Although a sharp drop from the previous 2 years, this still exceeded the amount received by any other industry area.

In 2003 and 2004, however, venture capital funds preferred other technology areas for investment, in particular software and medical/health companies, over Internet-specific companies. Software companies attracted the most venture capital in 2003 and 2004, receiving about 21% of the total invested each year. Companies in the medical/health field received 16% in 2003 and 18% in 2004. Internet-specific companies received about 13% of all money disbursed by venture capital funds in the latest 2 years (figure 6-32).

The decline in enthusiasm for Internet companies seems to have benefited other technology areas as well. Biotechnology companies were only attracting about 3% of total venture capital when Internet-specific companies were hot. Since 2000, however, biotechnology companies have gained steadily to receive 11% of total venture capital investments in 2003 and 2004, more than triple their share of 4% received in 1999 and 2000. Medical/health companies also have received higher shares, rising from a level of about 4% in 1999 and 2000 to an average of 11% in 2001 and 2002, and to 17% during 2003–04. Other industries attracting larger shares of the smaller pool of investment funds in the postbubble period are semiconductor and other electronics companies, and, to a lesser extent, industrial and energy companies.

Figure 6-32
U.S. venture capital disbursements, by industry: 1999–2004



SOURCE: Thomson Financial Services, special tabulations (May 2005). See appendix table 6-18.

Science and Engineering Indicators 2006

Venture Capital Investments by Stage of Financing

Investments made by venture capital firms can be categorized by the stage at which the financing is provided (Venture Economics Information Services 1999):

- **Seed financing** usually involves a small amount of capital provided to an inventor or entrepreneur to prove a concept. It may support product development but is rarely used for marketing.
- **Start-up financing** provides funds to companies for product development and initial marketing. This type of financing usually is provided to companies that have just organized or that have been in business just a short time and have not yet sold their products in the marketplace. Generally, such firms already have assembled key management, prepared a business plan, and completed market studies.
- **First-stage financing** provides funds to companies that have exhausted their initial capital and need funds to initiate commercial manufacturing and sales.
- **Expansion financing** includes working capital for the initial expansion of a company, funds for major growth expansion (involving plant expansion, marketing, or development of an improved product), and financing for a company expecting to go public within 6–12 months.
- **Acquisition financing** provides funds to finance the purchase of another company.
- **Management and leveraged buyout** provides funds to enable operating management to acquire a product line or business from either a public or private company. Often these companies are closely held or family owned.

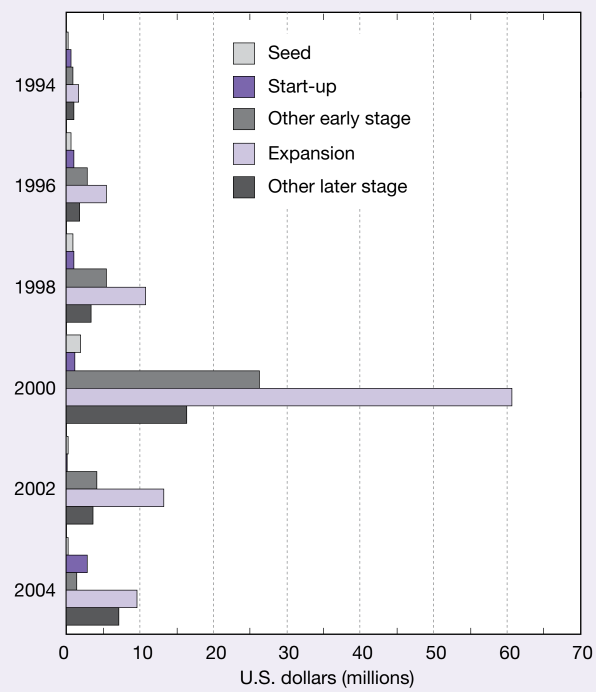
For this report, the first three types of funds are referred to as *early-stage* financing and the remaining three as *later-stage* financing.

Two patterns stand out when venture capital disbursements are examined by financing stage: (1) most funds' investment dollars are directed to later-stage investments, and (2) during the postbubble period, venture capital funds directed more money to later-stage investments than ever before.

Later-stage investments ranged from 50% to 80% of total venture capital disbursements, with the highest point reached in 2003 and the lowest point back in 1980. In 1999 and 2000, later-stage investments made up 72% of total disbursements, rising to 79%–80% in the postbubble period. Although early-stage, venture-backed investments as a share of total disbursements have gradually declined over time, during 2003–04 they fell to their lowest level ever (figure 6-33; appendix table 6-19).

The postbubble trend toward later-stage investing is also evident when analyzing the three early-stage categories. In

Figure 6-33
U.S. venture capital disbursements, by stage of financing: 1994–2004



SOURCE: Thomson Financial Services, special tabulations (May 2005). See appendix table 6-19.

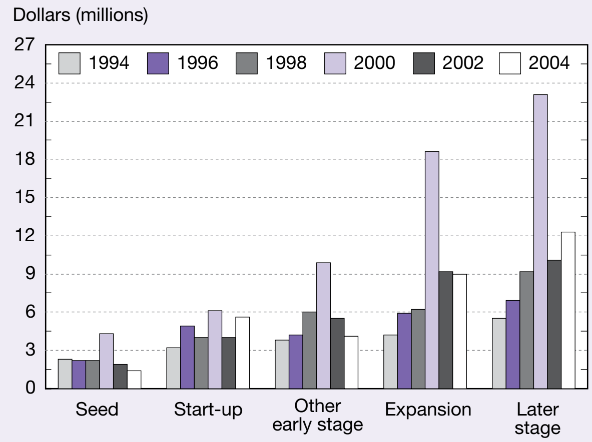
Science and Engineering Indicators 2006

2001 and 2002, seed and start-up financing were the hardest hit among the three early stages. During a period when venture capital became increasingly scarce, the highest-risk, early-stage projects suffered the most.

Expansion financing has typically been favored by venture capital funds. This stage alone accounts for more than half of all venture capital disbursements from 1997 through 2003. In 2000, the amount of venture capital invested to finance company expansions reached 57% of total disbursements. This upward trend continued into the postbubble period, with the share rising to 62% in 2002.

The latest data show two seemingly contrary trends. In 2003 and 2004, among the three early stages, venture capital is shifting to riskier start-up investments. Start-up financings jumped to 13% of total venture capital investments in both years. Conversely, later-stage financing investments are moving away from company expansions and toward even later-stage investments that involve acquisitions of existing companies (appendix table 6-19). These contrary trends may simply reflect companies' efforts to mitigate risk by rebalancing the stage diversification in their investment portfolio.

Figure 6-34
Value of average investment by venture capital funds, by stage of financing: 1994–2004



SOURCE: Thomson Financial Services, special tabulations (May 2005). See appendix table 6-19.

Science and Engineering Indicators 2006

Venture Capital as Seed Money

Contrary to popular perception, only a relatively small amount of dollars invested by venture capital funds ends up as seed money to support research or early product development. Seed-stage financing has never accounted for more than 8% of all venture capital disbursements over the past 23 years and most often has represented 1%–5% of the annual totals. The latest data show that seed financing represented just 1.3% in 2003 and less than 1% in 2004.

Over the past 25 years, the average amount invested in a seed-stage financing (per company) increased from a low of $700,000 in 1980 to a high of $4.3 million per disbursement in 2000. Since then, the average level of seed-stage investment has fallen steadily, providing just $1.8 million in 2003 and only $1.4 million in 2004 (figure 6-34).

Internet, communication, and computer software companies were the largest recipients of venture capital seed financing during the 1999 and 2000 bubble years. Internet companies were the preferred investment, receiving 58% of all disbursements in 1999 and 43% in 2000 (appendix table 6-20). In 2001 and 2002, seed investments going to Internet companies fell off considerably but still represented 21% of all such investments in 2001 and 7% in 2002. Most recently, Internet companies received 8% in 2003 and 13% in 2004.

As dot.com panic replaced dot.com mania, other technology areas attracted more attention. Medical and health care-related companies received 10% of seed money in 2001 and 20% in 2002, up from 4% and 5% during the bubble years. In 2003 and 2004, medical and health-related companies received more seed money than any other technology area. The share going to biotechnology companies rose to 5% in 2001 and 15% in 2002 and 2003. Semiconductor companies received 8% in 2001 and 15% in 2002, up from 4% in 1999. In 2004, semiconductor companies and software companies each received about 22% of venture capital seed money.

In sum, over the past 25 years, venture capital investment has consistently supported technology-oriented businesses, particularly companies and industries that develop and rely on information technologies. Although information technologies continue to attract the largest shares of total U.S. venture capital and seed money, life sciences (including medical, health, and biotechnology companies) have gained favor in the past few years.

Conclusion

The United States continues to rank high among the world leaders in major technology areas. Advances in U.S. biotechnology, computer, and telecommunication industries continue to influence new technology development and dominate technical exchanges between the United States and its trading partners. New data on patenting trends in the United States bear this out.

Although it also continues to be a leading provider of knowledge-intensive services, the United States may face greater competition in the near future as European countries devote more resources to service-sector R&D. For now, however, exports of U.S. technological know-how sold as intellectual property continue to exceed U.S. imports of technological know-how.

Asia's status as both a consumer and developer of high-technology products is advancing, enhanced by the technological development of many Asian economies, particularly Taiwan, South Korea, and China. Several small European countries, in particular Ireland, Finland, and the Netherlands, also exhibit strong national capacities to develop new technologies and to lead in global markets.

Current data on manufacturing output by high-technology industries in Asia and the several smaller European countries show that these industries already have a capacity to compete successfully with high-technology industries operating in the United States and other advanced countries. A leading indicator of future competition for U.S. industry, recent patenting trends show capacities for technology development growing and broadening within Asia and a transitioning Europe.

The U.S. trade balance in advanced technology products, historically a strong market segment for U.S. industry, has turned negative. Imports of technology products from Asia have grown to the point that they overwhelm trade surpluses with other world regions.

Despite the growing pressures of today's fast-moving global marketplace, the United States continues to be a leading developer and supplier of high-technology at home and abroad. Most likely this success has been influenced by a combination of factors: the nation's long commitment to S&T investments; the scale effects derived from serving a large, demanding domestic market; and the U.S. market's willingness to adopt new technologies. However, these same market dynamics already show signs of benefiting Asia and a more unified Europe and will likely continue to enhance the value of their investments in S&T in the future.

Notes

1. Educating for a workforce so that it can fully participate in an S&T-oriented economy is critical to its success. Three chapters of this report track trends in education: elementary and secondary education (chapter 1), higher education in S&E (chapter 2), and the S&E workforce (chapter 3).

2. This chapter presents data from various public and private sources. Consequently, the countries included vary by data source.

3. Other factors (e.g., business cycles, commodity shortages, international financial markets) also affect industry competitiveness but are not discussed in this chapter.

4. In designating these high-technology manufacturing industries, OECD took into account both the R&D done directly by firms and R&D embedded in purchased inputs (indirect R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct intensities were calculated as the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated by using the technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several nonmanufacturing industries have equal or greater R&D intensities. See Godin (2004a) for additional perspectives on OECD's methodology.

5. One of the earliest quantitative analyses of R&D was done in 1955 by R.H. Ewell and the National Science Foundation. This study showed a definite correlation between research and productivity. Also see Godin (2004b).

6. This conclusion is derived from an examination of weighted U.S. data on average annual pay for 1997–2001 (BLS/OES).

7. Europe's success in growing its aerospace industry and China's efforts to develop a semiconductor industry are two examples.

8. Reported here are EU aggregate data from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

9. In 1999, the U.S. State Department's responsibilities under the International Traffic in Arms Regulation were expanded to include research activity formerly covered under the U.S. Commerce Department's export regulations. The transfer placed scientific satellites, related data, and certain computer components and software on the U.S. Munitions List. Related research activities and the country of origin of researchers working on related research activities also became subject to many of the same regulations controlling exports of sensitive products.

10. In February 1996, the Telecommunications Act became U.S. law. This Act was the first major telecommunications reform in more than 60 years. It facilitated competition between cable companies and telephone companies and may have contributed to increased U.S. manufacturing activity in both the communications and computer hardware industries.

11. The U.S. trade balance is affected by many other factors as well, including differing monetary policies and export subsidies between the United States and its trading partners.

12. To the extent that national markets are not open to foreign producers (i.e., if public procurement is reserved for domestic producers), these data will understate the export competitiveness of foreign producers.

13. Unlike the previous section that examined data on industry manufacturing value added (domestic content), the value of exports reported in this section reflects the final value of industry shipments exported, not just that resulting from domestic production. Exported shipments will, therefore, often include the value of purchased foreign inputs.

14. Like the United States, national governments usually have strong ties to the aerospace industry in their country, often supporting its development, funding R&D, and serving as a major customer for its products.

15. See OECD (2001) for discussion of classifying economic activities according to degree of "knowledge-intensity."

16. Compared to the extensive data available for the manufacturing industries, national data that track activity in many rapidly growing service sectors are limited in the level of industry disaggregation and types of data collected.

17. The U.S. dollar rose against other major currencies in the late 1990s and continued to rise until early 2002. The sharp rise in the U.S. dollar was a contributing factor in the broad-based decline in exports by U.S. manufacturers during 2000 to 2003. The U.S. export decline was also affected by slower rates of GDP growth experienced by some U.S. trading partners during that time, including the EU and Japan.

18. U.S. trade in software products is not a separate Advanced Technology Program (ATP) category in the official statistics but is included in the ATP category covering information and communications products. For this report, trade in software products is examined separately, creating an 11th category.

19. The U.S. government and U.S. corporations have long advocated the establishment and protection of intellectual property rights. The Office of the U.S. Trade Representative monitors countries with reported violations and reports on the status of intellectual property protection in its annual report, *Foreign Trade Barriers*.

20. Data presented in appendix table 6-7 only go back to 1987, but data held by the Bureau of Economic Analysis indicate that year-to-year increases date back to 1982. See Borga and Mann (2004).

21. An *affiliate* refers to a business enterprise located in one country that is directly or indirectly owned or controlled by an entity in another country. The controlling interest for an incorporated business is 10% or more of its voting stock; for an unincorporated business, it is an interest equal to 10% of voting stock.

22. In addition, data on the destination of multinational corporate sales to foreign affiliates also suggest that market access is an important factor in the firms' decision to locate production abroad. See Borga and Mann (2004).

23. France also has been an important source of technological know-how over the years. In 1996, France was the leading European supplier to U.S. firms. Since then, data for France have been intermittently suppressed to avoid disclosing individual company operations. Data were last published for France in 2003 and showed an increase in U.S. purchases of French technological know-how compared with 2000 or 1996.

24. See chapter 2 for a discussion of international higher education trends and chapter 4 for a discussion of trends in U.S. R&D.

25. See Porter and Roessner (1991) for details on survey and indicator construction; see Roessner, Porter, and Xu (1992) for information on the validity and reliability testing the indicators have undergone.

26. See National Science Board 2002, vol. 1, figure 6-14: 6-17; and vol. 2, appendix table 6-5: A6-32.

27. The Harbison-Myers Skills Index, which measures the percentage of the population attaining secondary and higher education, was used for these education-based assessments. See appendix table 6-9 for complete source reference.

28. See Romer PM (1996). Why, indeed, in America? Theory, history, and the origins of modern economic growth. *American Economic Review* 86(2)(May):202–6; also see Freeman RB (2005). Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?, Working Paper 11457, National Bureau of Economic Research, June 2005, www.nber.org/papers/w11457; and Jacobson K (2005). China and India Are Poised to 'Leapfrog' U.S. in Innovation. *Manufacturing & Technology New* 12(14).

29. Rather than granting property rights to the *inventor* as is the practice in the United States and many other countries, some countries grant property rights to the *applicant*, which may be a corporation or other organization.

30. The number of U.S. patents granted jumped by 32% from 1997 to 1998. Although patent applications had been rising before that, the PTO attributes much of the increase in 1998 to greater administrative efficiency and the hiring of additional patent examiners.

31. U.S. universities and colleges owned about 1.9% of U.S. utility patents granted in 2001. The PTO counts these as being owned by corporations. For further discussion of academic patenting, see chapter 5.

32. Before 1990, data are provided as a total for the period 1963–1980. In U.S. PTO statistical reports, the ownership category breakout is independent of the breakout by country of origin.

33. The Bayh-Dole Act of 1980 (PL 96–517) permitted government grantees and contractors to retain title to inventions resulting from federally supported R&D and encouraged the licensing of such inventions to industry. The Stevenson-Wydler Technology Innovation Agreement of 1980 (PL 96–480) made the transfer of federally owned or originated technology to state and local governments and to the private sector a national policy and the mission of many government laboratories. The act was amended by the Federal Technology Transfer Act of 1986 (PL 99-502) to provide additional incentives for the transfer and commercialization of federally developed technologies. In April 1987, Executive Order 12591 ordered executive departments and agencies to encourage and facilitate collaborations among federal laboratories, state and local governments, universities, and the private sector, particularly small business, to aid technology transfer to the marketplace. In 1996, Congress strengthened private-sector rights to intellectual property resulting from these partnerships. See chapter 4 for a further discussion of technology transfer and other R&D collaborative activities.

34. Although historically, U.S. patents awarded to all companies headquartered in Germany rank that country among the top five countries receiving U.S. patents, no single German company ranks among the top 10.

35. Some of the decline in U.S. patenting by inventors from the leading industrialized nations may be due to movement toward European unification, which has encouraged wider patenting within Europe.

36. As of September 30, 2004, the U.S. Patent and Trademark Office reports that average pendency is 27.6 months for utility, plant, and reissue patent applications. Applications for utility patents account for the overwhelming majority of these requests.

37. The additional expenses associated with applying for a patent in a foreign market may discourage weak foreign applications.

38. Information in this section is based on the U.S. PTO classification system, which divides patents into approximately 400 active classes. With this system, patent activity for U.S. and foreign inventors in recent years can be compared using an activity index. For any year, the activity index is the proportion of corporate patents in a particular class granted to inventors resident in a specific country divided by the proportion of all patents granted to inventors resident in that country. The activity indices are restricted to corporate patents to facilitate comparability between the United States and foreign countries because most U.S. patents granted to foreign inventors are filed by foreign corporations.

39. Trends reported in this section include all patents (i.e., utility, design, and plant patents), although most are utility patents otherwise known as patents for inventions. According to a recent report issued by the U.S. Patent and Trademark Office, biotechnology patents can span eight patent classes and describe subject matter related to bioinformatics, gene therapy, cellular immunology, and recombinant enzymes and proteins to name a few. See U.S. Patent and Trademark Office Technology Profile Report. 2004. Patent examining technology center, groups 1630–1660, biotechnology. Office of Electronic Information Products.

40. One seminal court decision opening the floodgate for biotechnology-related patents is the 1980 Supreme Court decision, *Diamond* v. *Chakrabarty,* which ruled that genetically engineered living organisms could be patented.

41. Patent data cover years 1977–2003.

42. The project is a collaboration among OECD, the National Science Foundation, the EU, the World Intellectual Property Organization, patent offices in the United States and Japan, and the European Patent Office. The database was developed by and is currently housed at OECD.

43. Up until March 2001, only patents granted in the United States were published. Technically, the data set counts those inventions for which patent protection is sought in Europe and Japan and obtained in the United States.

44. Although patents granted in one country do not offer any protection under another country's intellectual property laws.

45. Data presented here are compiled by Thomson Financial Services for the National Venture Capital Association. These data are obtained from a quarterly survey of venture capital practitioners that include independent venture capital firms, institutional venture capital groups, and recognized corporate venture capital groups. Information is at times augmented by data from other public and private sources.

46. Recent reports from the National Venture Capital Association show that new money coming into venture capital funds slowed down during the last quarter of 2000, following several quarters of lackluster returns to investors in venture capital funds. See National Venture Capital Association, "Venture capital fundraising slows in fourth quarter, but hits new record for the year," press release, February 23, 2001.

47. Under the Department of Labor "Prudent Person" standard, "A fiduciary must discharge his or her duties in a prudent fashion." For pension fund managers, the standard emphasizes how prudent investors balance both income and safety as they choose investments. The website www.investorwords.com describes the Prudent Man Rule as the fundamental principle for professional money management stated by Judge Samuel Putnam in 1830 *(Supreme Court of Massachusetts in Harvard College* v. *Armory):* "Those with responsibility to invest money for others should act with prudence, discretion, intelligence, and regard for safety of capital as well as income."

Glossary

Activity index: Proportion of corporate patents in a particular class granted to inventors resident in a specific country divided by the proportion of all patents granted to inventors resident in that country.

Affiliate: A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Gross value-added: Gross output minus the cost of purchased intermediate inputs and supplies.

Intellectual property: Intangible property that is the result of creativity; the most common forms of intellectual property include patents, copyrights, trademarks, and trade secrets.

"Not obvious": One criterion (along with new and useful) on which an invention is judged to determine its patentability.

Triadic patent family: An invention for which patent protection is sought in the United States, Europe, and Japan.

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Chapter 7
Science and Technology: Public Attitudes and Understanding

List of Sidebars

List of Tables

List of Figures

Highlights

Overview

Although Americans express strong support for science and technology (S&T), most are not very well informed about these subjects. The public's lack of knowledge about basic scientific facts and the scientific process can have far-reaching implications.

- Knowledge of basic scientific facts and concepts is necessary not only for an understanding of S&T-related issues but also for good citizenship. Knowing how science works—how ideas are investigated and either accepted or rejected—can help people evaluate the validity of various claims they encounter in daily life.
- Many in the scientific community are concerned that lack of knowledge about S&T may adversely affect the level of government support for research, the number of young people choosing S&T careers, and the public's resistance to miracle cures, get-rich-quick schemes, and other scams.

Information Sources

Television is still the main source of information about S&T, but the Internet is a strong competitor.

- In the United States and other countries, most adults pick up information about S&T primarily from watching television, including educational and nonfiction programs, newscasts and newsmagazines, and even entertainment programs.
- The Internet is having a major impact on how the public gets information about S&T. In 2004, the Internet was the second most popular source of news about S&T, up from fourth place in 2001.
- The number of households with broadband Internet connections has been growing rapidly. People with broadband are much more likely than those with dial-up connections to view the Internet as an important source of information.
- The Internet is the preferred source when people are seeking information about specific scientific issues. In 2004, 52% of National Science Foundation survey respondents named the Internet as the place they would go to learn more about a scientific issue such as global warming or biotechnology, up from 44% in 2001.

The media can affect the public's view of scientific issues.

- Television and other media sometimes miscommunicate science to the public by failing to distinguish between fantasy and reality and by failing to cite scientific evidence when it is needed.
- A study found that the movie *The Day After Tomorrow* influenced individuals' opinions about climate change.

Public Interest in S&T

Evidence about the public's interest in S&T is mixed.

- Surveys found that S&T ranked 10th of 14 categories of news followed most closely by the public in 2004.
- Very few Americans (about 10% of those surveyed) say they are not interested in S&T issues.
- S&T museums are much more popular in the United States than in other countries. The millions of people who visit science museums each year demonstrate interest in science without necessarily being interested in science-related news.

Public Knowledge About S&T

Most people do not think they are well informed about S&T. In fact, Americans generally know little about science, but they may be more knowledgeable than citizens of other countries.

- Many people throughout the world cannot answer simple, science-related questions. Nor do they have an understanding of the scientific process. However, U.S. adults may be somewhat more knowledgeable about science than their counterparts in other countries, especially Russia and China.
- Science knowledge in the United States is not improving. Survey respondents' ability to answer most questions about science has remained essentially unchanged since the 1990s, with one exception: more people now know that antibiotics do not kill viruses. This may be attributable to media coverage of drug-resistant bacteria, an important public health issue.
- Although the U.S. survey has not shown much change over time in the public's level of knowledge about science, the most recent Eurobarometer does show an increase. The change occurred in almost all countries surveyed; Belgium, Germany, Ireland, Luxembourg, and the Netherlands recorded double-digit increases between 1992 and 2005 in the percentage of correct responses to science literacy questions.
- There is considerable variation in science knowledge across countries in Europe.
- Less than half the American population accepts the theory of evolution. Whether and how the theory of evolution is taught in public schools remains one of the most contentious issues in science education.
- Belief in various forms of pseudoscience is common in both the United States and other countries.

Public Attitudes About Science-Related Issues

Most Americans have positive attitudes about the benefits of S&T, but some have reservations, including concerns about moral issues. Support for government funding of research is strong.

- Americans have more positive attitudes about the benefits of S&T than are found in Europe, Russia, and Japan. In recent surveys, 84% of Americans, compared with 52% of Europeans and 40% of Japanese, agreed that the benefits of scientific research outweigh any harmful results.
- A sizeable segment of the U.S. population has some reservations about S&T. For example, in 2004 surveys, more than half of the respondents agreed that "we depend too much on science and not enough on faith," that "scientific research these days doesn't pay enough attention to the moral values of society," and that "scientific research has created as many problems for society as it has solutions." However, agreement with the last two statements declined in recent years.
- In 2004, 83% of Americans surveyed agreed that "even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the federal government." Support is also strong in Europe and Asia.

Recent surveys on topics ranging from the environment to nanotechnology reveal a variety of perceptions and concerns.

- Attitudes toward environmental protection have been shifting in recent years. In 2005, 53% of survey respondents viewed environmental protection as more important than economic growth, and 36% held the opposite view. The percentage choosing the environment rose 6 percentage points between 2003 and 2005, after declining steadily from a peak of 69% in 2000 to an all-time low of 47% in 2003.
- Most Americans know little about genetically modified food and related issues. Although attitudes are divided, opposition to introducing genetically modified food into the U.S. food supply declined between 2001 and 2004. However, the vast majority of Americans (and others) believe that genetically modified food should be labeled.
- Opposition to medical research that uses stem cells from human embryos has declined. In 2004, 36% of those surveyed said they were opposed to this type of research, down from 51% in 2002.
- Most people have never heard of nanotechnology. Americans are somewhat concerned about the risks, but most believe the benefits will outweigh the risks. The biggest concern is loss of privacy from tiny new surveillance devices.

Most people have confidence in the scientific community and a high opinion of science as an occupation.

- Since 2002, more people have expressed confidence in the leadership of the scientific community than in any other profession except the military.
- Scientists share (with doctors) the top spot in the Harris poll of occupations having the most prestige; engineers are about in the middle of this ranking. Most Americans say they would be happy if their son or daughter chose a career in science.

Introduction

Chapter Overview

Most Americans probably do not think about scientific research and technological development on a daily basis. Yet most recognize and appreciate the related benefits. Most Americans also strongly endorse the government's investment in research, whether or not it leads to tangible improvements in health and safety or the economy or to new technologies that make life easier or more enjoyable.

In fact, with few exceptions, science and technology (S&T) enjoy a positive reputation throughout the world. Most people believe that S&T play a key role in raising their standard of living and improving their quality of life. People around the world have been quick to embrace inventions that make living and working conditions better and businesses more profitable, including the latest advancements in communication technologies, such as the Internet, cellular telephones, and increasingly sophisticated types of entertainment delivery systems. Moreover, emerging fields such as nanotechnology seem to be receiving the public's endorsement.

Despite their favorable attitudes, most people do not know a lot about S&T. Many do not seem to have a firm understanding of basic scientific facts and concepts, knowledge that is necessary not only for an understanding of S&T-related issues but also for good citizenship. Even more worrisome is a lack of familiarity with the scientific process. Both scientists and public policymakers are concerned that the public's lack of knowledge about S&T may result in

- Less government support for research[1]
- Fewer young people choosing S&T careers
- Greater public susceptibility to miracle cures, get-rich-quick schemes, and other scams (NIST 2002)

Chapter Organization

This chapter examines aspects of the public's attitudes toward and understanding of S&T. In addition to data collected in surveys sponsored by the National Science Foundation (NSF), the chapter contains extensive information from studies and surveys undertaken by other organizations that track trends in media consumption and changes in public opinion on policy issues related to S&T. (See sidebar, "Data Sources.") One of these sources is an international project designed to measure attitudes toward various technologies in Europe, Canada, and the United States. Preliminary data from the United States and Canada (Canadian Biotechnology Secretariat 2005) are included in this chapter. In addition, for the first time, this chapter includes coverage of similar surveys conducted in Russia and several Asian countries.

The chapter is in three parts. The first part focuses on S&T-related information and interest. It begins with a section on sources of news and information, including a detailed look at the role of the Internet. It then examines several measures of public interest in S&T. (Level of interest indicates both the visibility of the science and engineering community's work and the relative importance accorded S&T by society.) The first part also briefly discusses the public's perception of how well informed it is about science-related issues.

The second part of the chapter covers knowledge of S&T. It explores three indicators of scientific literacy: familiarity with scientific terms and concepts, understanding of the scientific method, and belief in pseudoscience.

The third part examines public attitudes about science-related issues. It includes data on public opinion about S&T in general, support for federal funding of scientific research, views on environmental issues, and public confidence in the science community. It also presents information on how the public perceives the pros and cons of various technologies such as stem cell research, genetic engineering (including genetically modified foods), and the emerging field of nanotechnology.

Data Comparability

The surveys that provided the data included in this chapter were sponsored and conducted by a variety of organizations, for different purposes, using different items in varying order and context. Therefore, their results are not directly comparable. This is particularly true for surveys done in other countries, where language and cultural differences add further complexities. (However, it should be noted that many items included in the NSF Survey of Public Attitudes Toward and Understanding of Science and Technology were replicated—to the greatest extent possible—in all countries covered in this chapter.) Thus, the findings presented in this chapter summarize broad patterns and trends emerging from these diverse sources. Readers will find the specific sources identified throughout the chapter and additional information in the sidebar, "Data Sources."

Information Sources, Interest, and Perceived Knowledge

People get news and information about S&T from a variety of sources. However, television is where most adults throughout the world find out about the latest S&T developments. Although the Internet is not the leading source of news for Americans, it is the only medium that has been gaining viewers in recent years, and it is now the first place people go to get information about specific S&T subjects (figure 7-1; appendix tables 7-1, 7-2, and 7-3).

Although most Americans claim to be at least moderately interested in S&T, few science-related news stories attract much public interest. In addition, few people feel well informed about new scientific discoveries and the use of new inventions and technologies.

This section takes a detailed look at the various sources of news and information about S&T in the United States and other countries, focusing on television as the longstanding

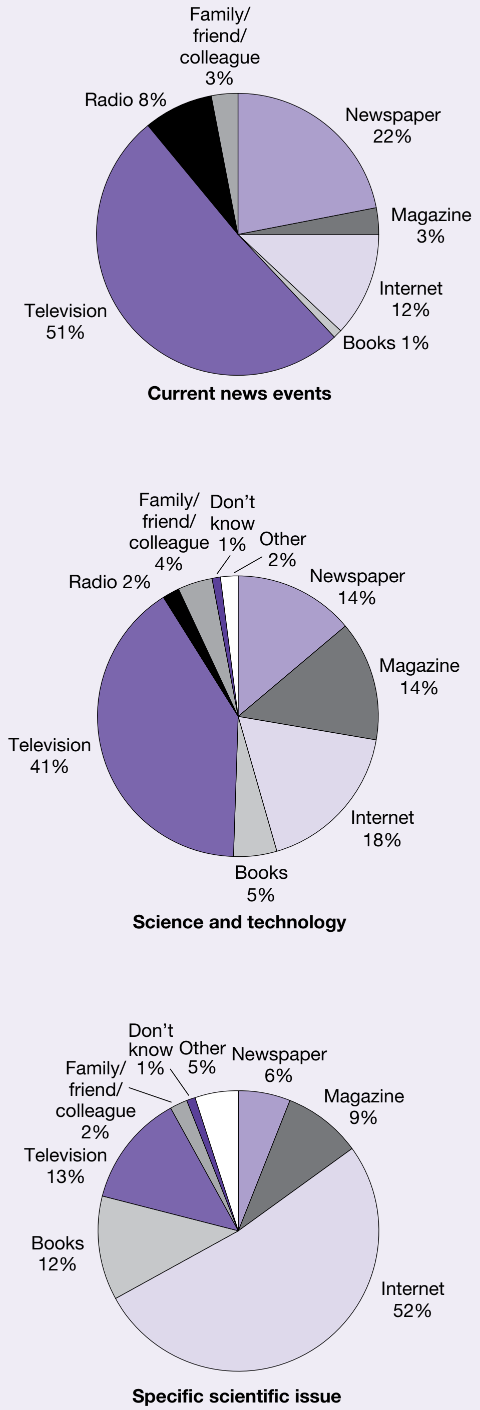
Data Sources

Data from the following surveys are included in this chapter:

Most recent year survey conducted	Sponsoring organization	Title*	Information used in the chapter	Type of survey	Number surveyed and standard error of estimates
2001	National Science Foundation	Survey of Public Attitudes Toward and Understanding of Science and Technology	Various knowledge and attitude items, including public support for basic research, belief in pseudoscience, and interest in science and technology	RDD	n=1,574 ± 2.47%
2004	National Science Foundation	Michigan Survey of Consumer Attitudes	A subset of items collected in the 2001 NSF survey	RDD	n=2,025 ± 2.49%
2005	European Commission	Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology;* Eurobarometer 225/Wave 63.1: *Social Values, Science and Technology*	Various knowledge and attitude items, including public support for basic research and trust in scientists	Face-to-face interviews Multistage, random sampling	n=24,895 ± 1.9%–± 3.1%
2005	Canadian Biotechnology Secretariat	Canada-U.S. Survey on Biotechnology	Attitudes toward technology, including biotechnology and nanotechnology	RDD	Canada: n=2,000 ± 2.19%; United States n=1,200 ± 2.81%
2003	British Council, Russia	*Russian Public Opinion of the Knowledge Economy*	Various knowledge and attitude items	Paper questionnaires	n=2,107
2001	Chinese Ministry of Science and Technology	*China Science and Technology Indicators*	Various knowledge and attitude items	National in scope	n=8,350
2004	Food Policy Institute Rutgers–The State University of New Jersey	Americans and GM Food	Attitudes toward genetically modified food and mad cow disease	RDD	n=1,201 ± 3.0%
2005	The Gallup Organization	Various ongoing surveys	Public attitudes toward the environment, cloning, space exploration, belief in pseudoscience, and Internet use in China	RDD	n=1,000–1,100 ± 3.0%
2002	Harris Interactive	The Harris Poll	Prestige of various occupations, Internet use, and attitudes toward genetically modified food	RDD	n=2,415 ± 2.0%
2001	Japan National Institute of Science and Technology Policy	The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan	Various knowledge and attitude items	Face-to-face interviews Two-stage stratified random sampling	n=2,146
2004	Korea Science Foundation	Survey on Public Attitude of Science and Technology	Various knowledge and attitude items	Face-to-face interviews National, three-stage stratified random sampling	n=1,007 ± 3.1%
2000	Malaysian Science and Technology Information Centre	Public Awareness of Science and Technology	Various knowledge and attitude items	Face-to-face interviews Two stage sampling	n=5,000
2004	North Carolina State University	Public Perceptions About Nanotechnology	Attitudes toward nanotechnology	RDD	n=1,536 ± 2.5%
2004	Pew Initiative on Food and Biotechnology	Various ongoing surveys	Public attitudes toward food biotechnology	RDD	n=1,000 ± 3.1%
2004	Pew Research Center for the People and the Press	Various ongoing surveys	Media consumption and public attitudes toward technology	RDD	n=3,000 ± 3.0%
2005	Research!America	Various ongoing surveys	Public attitudes toward funding health and scientific research	RDD	n=800–1,000 ± 3.5%
2004	National Opinion Research Center	General Social Survey	Public confidence in various institutions and government funding of programs	Face-to-face interviews	n=877 ± 0.05%
2004	USC Annenberg School Center for the Digital Future	Surveying the Digital Future	Public attitudes toward the Internet and Internet use	RDD	n=2,009
2002	Virginia Commonwealth University Center for Public Policy	VCU Life Sciences Survey	Public attitudes toward scientific progress and moral values, stem cell research, and genetic testing	RDD	n=1,004 ± 3.0%

*For ongoing surveys, most recent year is shown.
RDD = random dialing computer-assisted interview survey. All RDD surveys listed above are national in scope.

Figure 7-1
Sources of information in United States: 2004



NOTES: Detail may not add to total because of rounding. Categories with <0.5% response not shown.

SOURCE: University of Michigan, Survey of Consumer Attitudes (2004). See appendix tables 7-1, 7-2, and 7-3.

Science and Engineering Indicators 2006

leading source and the Internet as a powerful competitor. The section also examines indicators of both the public's interest in S&T and how well informed people feel about S&T.

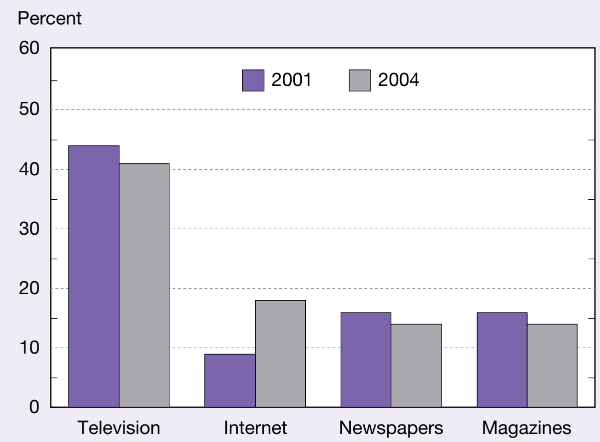
S&T Information Sources: Television Leads Worldwide

For decades now, television has been the top source of news and information in most U.S. households. (See sidebar, "Television and Other Forms of Popular Culture Influence What Adults Know and Think About Science.") The same holds true for other countries. However, the Internet has been gaining ground as a competing source of news and information for an increasing number of people throughout the world.

In the United States, in 2004, about half (51%) of those responding to an NSF-sponsored survey named television as their leading source of news about current events in general, about the same as the number (53%) recorded in 2001. In both years, newspapers and the Internet ranked second and third, respectively. However, the percentage of respondents naming newspapers as their main source of news about current events in general declined from 29% in 2001 to 22% in 2004. At the same time, those citing the Internet increased, from 7% to 12%. In fact, the Internet has been the only news medium to grow in popularity in recent years (Pew Research Center for the People and the Press 2004).

When survey respondents were asked about their leading source of news about S&T, television once again came in first, with 41% naming it in 2004. (The comparable statistic for 2001 was 44%.) The Internet was a distant second (18%), followed by newspapers (14%) and magazines (also 14%).[2] Between 2001 and 2004, the Internet went from being the fourth most popular source of news about S&T to being the second (figure 7-2).

Figure 7-2
Primary source of news about science and technology in United States: 2001 and 2004



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); and University of Michigan, Survey of Consumer Attitudes (2004).

Science and Engineering Indicators 2006

Television and Other Forms of Popular Culture Influence What Adults Know and Think About Science

Information about science is communicated to the U.S. public through several types of television programs. Educational and nonfiction shows promote science and aim to be both informative and entertaining. News programs, including national and local morning and nightly newscasts and newsmagazines, devote segments to science-related subjects and issues. In addition, entertainment programs occasionally include information about science. For example, a February 2005 episode of *The West Wing* featured storylines on stem cell research, Mad Cow Disease, and the field of economics.

A broad range of science-content programs is available on U.S. television, including Public Broadcasting Service (PBS) series (such as *Nova*) and programs for children. The vast majority of U.S. households now have cable or satellite television and therefore have access to the Discovery Channel and a growing array of options made possible by advances in digital technology. These include an increasing number of channels that devote considerable attention to science and technology and health (e.g., Discovery Health, the National Geographic Channel, the History Channel) and niche market channels (e.g., the Research Channel, the University Channel, NASA TV).

Table 7-1 is a comprehensive list of prime-time science programs on television in 2005. None of these 29 shows are on the broadcast networks (ABC, CBS, FOX, NBC, UPN, or WB) and only 3 are on PBS, the networks received by nearly all households.* The other 26 shows are all on the Science Channel, National Geographic, the History Channel, NASA TV, the Discovery Channel, Discovery Kids Network, or History International, where the number of viewers is far smaller than that of the broadcast networks. Therefore, most of the news and information the majority of adults receive about science comes from network news programs; network magazine

(continued on next page)

Table 7-1
Science programs on television: 2005

Program	Program type	Channel
Alan Alda in Scientific American Frontiers	Series science	PBS
Building the Ultimate	Limited series anthology, science	SCIENCE
Close Up	Series nature, science	NGC
Deep Sea Detectives	Series documentary, science	HISTORY
Destination Mars	Series documentary, science	SCIENCE
Discover Magazine	Series science	SCIENCE
DragonFlyTV	Series children, educational, science	PBS
Education File	Series educational, science	NASA
Gallery/History	Series science, history	NASA
ISS Mission Coverage	Series science	NASA
Living Wild	Series nature, science	NGC
Megascience	Series science	SCIENCE
MythBusters	Series documentary, science	DSC
Naked Science	Series documentary, science	NGC
National Geographic	Series anthology, nature, science	PBS
Nova	Series science, nature, anthology	PBS
Paleoworld	Series documentary, science	SCIENCE
Rough Science	Series science	SCIENCE
Science Wonders	Series science	SCIENCE
Solar Science	Series science	SCIENCE
Strange Days at Blake Holsey High	Series children, drama, science,	DCKIDS
Techknowledge	Series science	SCIENCE
The New Detectives: Case Studies in Forensic Science	Series crime, medical, science	DSC
The Planets	Limited series documentary, science	SCIENCE
This Week at NASA Education file	Series educational, science	NASA
Video File	Series news, science	NASA
Voyages	Series anthology, documentary, science	HISI
What the Ancients Knew	Limited series history, science	SCIENCE
Wild Tech	Series science	SCIENCE

DCKIDS = Discovery Kids Network; DSC = The Discovery Channel; HISI = History International; HISTORY = The History Channel; NASA = NASA TV; NGC = National Geographic Channel; PBS = Public Broadcasting Service; SCIENCE = The Science Channel

SOURCE: Rex Rivers, Land of Awes Information Services, Data Direct (Tribune Company), special tabulation.

Science and Engineering Indicators 2006

(continued from previous page)

shows such as *60 Minutes, CBS Sunday Morning,*† and *20/20;* and the occasional network documentary.

Although television newsmagazines can be a leading source of news about science for the public, the regular audience for these shows has been declining since 1993. In that year, more than half (52%) of those surveyed by the Pew Research Center said they regularly watched "newsmagazine shows such as *60 Minutes, 20/20,* or *Dateline.*" In 2004, only 22% gave that response (Pew Research Center for the People and the Press 2004).

Local newscasts contain a relatively large number of segments about health and medicine and spend more time on the weather than any other topic. According to one report, "TV weathercasters are often the most visible representatives of science in U.S. households" (NIST 2002). They have educated the public about jet streams, fronts, barometric pressure, and environmental issues such as global climate change.

Television entertainment programs occasionally dispense information about science to the public. Because shows such as *CSI* (Crime Scene Investigation) reach relatively large audiences, many people may be educated or become aware of science and science-related issues by watching them. At the 2005 AAAS (American Association for the Advancement of Science) annual meeting, a symposium was devoted to "The CSI Effect: Forensic Science in the Public Imagination." According to the forensic scientists who participated in the event, *CSI* has sparked public interest in and respect for how science can be applied to catching criminals. In addition, universities have seen a significant increase in the numbers of students pursuing degrees in forensic sciences (Houck 2005).

Studies have also documented that young adults get much of their news from late night talk shows (Pew Research Center for the People and the Press 2004). Exposure to science takes place when these shows mention the latest scientific breakthroughs and science-related public policy issues (e.g., climate change), when scientists make occasional appearances to talk about their work, and when comedy segments revolve around science-related themes.

Entertainment television can also distort or mischaracterize science, cultivating among frequent viewers reservations about the impact of science on society, while displacing other activities (such as reading newspapers) that are valid ways of learning about science informally (Nisbet et al. 2002). For example, programs such as *Medium* that feature characters who claim to possess psychic abilities can foster or reinforce pseudoscientific beliefs (James Randi Educational Foundation 2005). Some scientists view such programs as harmful because "a misinformed public…is as worrisome as an uninformed public" (Chism 2002). In 2004, Showtime began running a series in which entertainers Penn and Teller debunk pseudoscientific beliefs. Topics covered have included mediums, alien abductions, and "even a relatively mainstream practice like feng shui" (Janzen 2004).

Other forms of popular culture, such as books and movies, also can affect what people know about science and shape their attitudes toward science-related issues. In a national survey, for example, about half of the respondents who had seen the movie *The Day After Tomorrow* said it made them more worried about global warming, although almost as many said it had had no effect on their view. However, national surveys taken before and after the movie's release did not find a significant shift in overall national opinion about global warming. One likely reason is that even very popular movies reach only a fraction of the population (Leiserowitz 2004).

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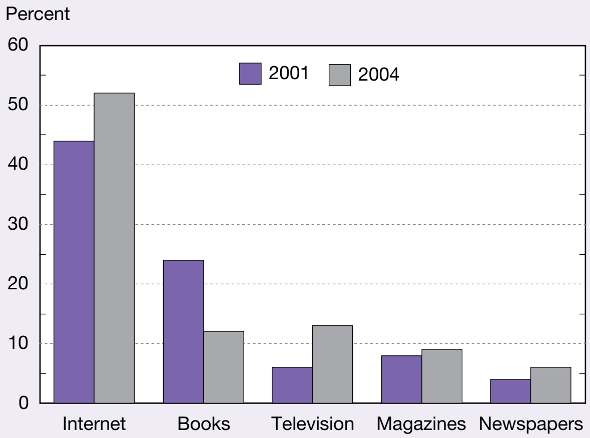
*A recent study found that CBS's coverage of biotechnology was three times as extensive as that of any other network (Kubey and Nucci 2004).

†The long-running series *Sunday Morning* almost always contains at least one segment aimed at informing the public about science. Recent topics have included nanotechnology and the controversy over the number of women who become scientists.

When people get information about science from television, they tend to do so inadvertently. That is, they pick up tidbits about science and science-related issues from watching the news or other programs that are not specifically about science (the exception would be viewers who purposefully seek out science programs such as Nova). In contrast, obtaining science information from the Internet is more likely to be purposive.[3] For example, the number of people naming the Internet as the place they would go to learn more about a scientific issue such as global warming or biotechnology rose from 44% in 2001 to 52% in 2004. Most of the gain apparently came at the expense of books. In 2001, nearly a quarter of those surveyed named books as their main source of information about a specific scientific issue. That percentage was cut in half (12%) in 2004, an indication that print materials, such as encyclopedias and other reference and technical books, are now taking a back seat to the Internet as research tools for the general public.[4] At the same time, the number naming television increased from 6% in 2001 to 13% in 2004. In both 2001 and 2004, magazines and newspapers were identified by less than 10% of those surveyed (figure 7-3).

One reason the Internet is supplanting traditional media such as print encyclopedias is that these sources are available on the Internet, where search engines have replaced thumbing through pages. For example, the *Encyclopedia Britannica* and *Encarta* are accessible online. Buying an online encyclopedia subscription has several advantages over visiting a library or purchasing the volumes. The online subscription is cheaper, more convenient, and less prone to obsolescence, and it requires no storage space. Current issues of major newspapers and newsmagazines are also available

Figure 7-3
Primary source of information about specific scientific issue: 2001 and 2004



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); and University of Michigan, Survey of Consumer Attitudes (2004).

Science and Engineering Indicators 2006

online. Arguably, it is easier to access the *New York Times* or *Washington Post* online than to read stories interspersed with page after page of advertisements.

According to the NSF survey data, people with more education and those with more income are less likely to rely on television as the chief source of both news in general and S&T information and more likely to use the Internet to get news and information. Also, men are more likely than women to rely on the Internet for news and S&T information. It is not surprising to find that reliance on the Internet is higher among these groups, given that they were the first to use the Internet extensively.

Television is also the leading source of news about S&T in other countries. For example, 60% of respondents to the 2001 Eurobarometer ranked television as either their first or second most important source of information on scientific developments, followed by the written press (37%), radio (27%), school or university (22%), scientific journals (20%), and the Internet (17%). In general, these preferences varied little across countries (European Commission 2001).

Similar statistics were also collected in Russia (Gokhberg and Shuvalova 2004). Once again, television was by far the leading source of news and information about S&T. (One reason television is such a dominant news source in Russia is that Internet access is relatively limited there, as in many other countries.)

In 2003, 87% of those surveyed in Russia named television as a source, compared with 82% in 1996. Newspapers and magazines also showed a gain between 1996 and 2003, from 45% to 50%. Radio ranked third (44% in 2003), followed by conversations with colleagues, friends, and family members (29%); advertising (17%); and scientific and popular science journals and books (13%). Only 6% named the Internet, and 2% named museums and S&T exhibitions. In 2003, 5% of Russians responded that they "have no concern about S&T news."

Statistics from several Asian countries show a similar pattern.[5] In Japan, 91% of those surveyed in 2001 said they obtained S&T information by watching television news. Newspaper articles ranked second, at 70%, followed by television documentary programs (53%), articles in magazines and weekly journals (35%), and conversations with friends and family (20%). Only 12% identified the Internet as a current method of obtaining S&T information, and only 2% said they read S&T magazines often. Another 16% said they read S&T magazines occasionally.

In South Korea, half of those surveyed in 2004 named television or radio as their leading means of gathering S&T information, followed by newspapers (21%), the Internet (13%), books and other publications (4%), and magazines (3%).[6]

Television is also the leading source of S&T information in China, with 83% of survey participants providing that response in 2001. Newspapers and magazines were second (52%), followed by "chatting with relatives or colleagues" (20%). Only 2% identified the Internet as a source of S&T information. Men, urban residents, and individuals with high levels of formal education were more likely than others to say they got information about S&T from books, newspapers, and magazines, and from the Internet. (See sidebar, "Internet Use Growing Rapidly in China.")

The Internet: An Increasingly Popular Source of S&T Information

According to an ongoing media consumption study, the Internet has established a foothold during the past decade as an important source of news, although "going online for the news has yet to become part of the daily routine for most Americans, in the same way as watching television news, reading the newspaper, or listening to radio news" (Pew Research Center for the People and the Press 2004).[7] In 2004, nearly three-quarters (73%) of survey respondents had a computer at home (Pew Research Center for the People and the Press 2004), up from about one-third (31%) a decade earlier (table 7-2).[8] According to NSF survey data, 70% of adults had access to the Internet at home in 2004, up from 59% in 2001. More men (74%) than women (66%) were online. In addition, 90% of college graduates had access to the Internet from home in 2004, compared with 65% of those with only a high school education and 29% of those who did not graduate from high school. Also, the higher the family income, the more likely a person was to be online in 2004.[9] (See appendix table 7-4 and sidebar, "Broadband Changes Everything.")

Trends in the Internet as a News Source

The number of people going online for news at least 3 days per week rose dramatically in the late 1990s, from 2% in 1995 to 23% in 2000, and has continued to increase during the early part of this decade, although at a much slower pace

Internet Use Growing Rapidly in China

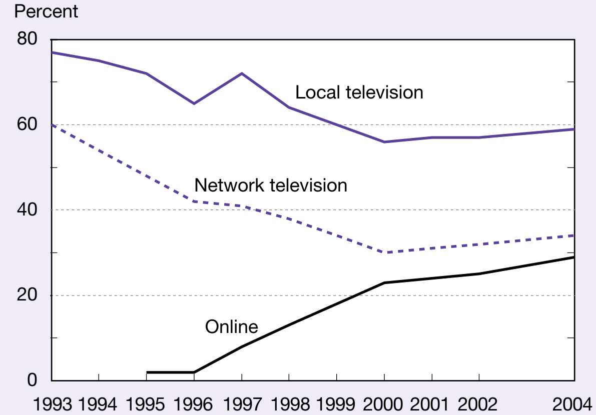
The Gallup Organization has been tracking computer and Internet use in China since 1997 (Burkholder 2005). The latest survey data show that both computer ownership and Internet use have increased substantially in that country in the past few years. By the end of 2004, 13% of Chinese households nationwide had a computer, up from 4% in 1999 and 2% in 1997. In China's 10 largest cities, 47% of households have at least one computer as of late 2004; in Beijing, the figure is 66%. About a quarter (24%) of survey respondents in late 2004 reported that they have regular access to a computer "either at home, at work, at school, or somewhere else"; among young adults (ages 18–24), the figure is 62%.

In addition, 12% of all Chinese citizens age 18 and older reported in 2004 that they have used the Internet, a major gain over the 2% figure recorded in 1999. In 1997, only 10% of Chinese adults had heard of the Internet. Not surprisingly, urban residents were far more likely than rural residents to report using the Internet (28% versus 2%, respectively). Internet use is especially common in the largest cities, such as Beijing (47%) and Shanghai (36%). Young adults (ages 18–24) in urban areas are far more likely to use the Internet than those age 40 and older (74% versus 5%, respectively).

About 7% of Chinese households had in-home broadband service in late 2004; the proportion is much higher in Beijing (38%) and Shanghai (32%). When asked what they used the computer for, the most frequent response was to access news (72%), followed by to obtain reference information (63%) and other general information such as sports and weather (59%).

(Pew Research Center for the People and the Press 2004). In 2004, 29% of those surveyed said that they went online for news at least 3 times per week (figure 7-4). In addition, online newspaper readership has been rising steadily since 2001 (Cole 2004).

Figure 7-4
Use of broadcast versus online news: 1993–2004



NOTE: Online news obtained at least 3 days per week.

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey (2004).

Science and Engineering Indicators 2006

Characteristics of Internet News Users

Internet news audiences tend to be younger, more affluent, and better educated than the population as a whole. They are also more likely to be male, although the gender gap has narrowed in recent years, as has the racial divide. Between 2002 and 2004, the proportion of African Americans going online for news at least 3 days per week increased from 15% to 25%. The increase was similar in the Hispanic community, from 22% in 2002 to 32% in 2004 (Pew Research Center for the People and the Press 2004).

Education has always been the most important determinant of online news use. At least half of college graduates use the Internet for news on a regular basis, compared with less than one-fifth of high school graduates and less than one-tenth of those who did not finish high school. Little growth has occurred in Internet news use among those without a college degree, regardless of age or sex (Pew Research Center for the People and the Press 2004).

Table 7-2
Ownership of home computers: Selected years, 1994–2004

Response	1994	1995	1998	2000	2002	2004
Yes	31	36	43	59	65	73
No	69	64	57	41	35	27

NOTES: Responses to: *Do you have any type of personal computer, including laptops, in your home?* Before 2002, question also said: *These do not include game machines such as Nintendo or Sega*. Before 2000, wording was: *Do you have any type of personal computer, including laptops, such as an IBM PC or a Macintosh, in your home?*

SOURCE: Pew Research Center for the People and the Press, NII/Entertainment Media Survey (March 2005).

Science and Engineering Indicators 2006

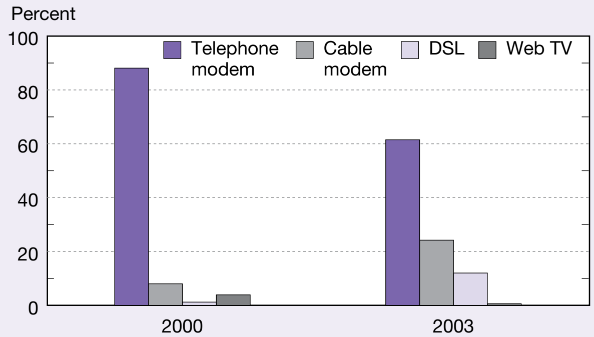
Broadband Changes Everything

The most notable finding of recent surveys on Internet use is the large gain in the number of households with broadband connections. In 2002, less than one-fourth (22%) of adults who went online had broadband. By late 2003, the proportion had grown to 37%. In mid-2004, the statistic was approaching one-half (44%) (Harris Interactive 2004c). Similarly, data from the Pew Research Center show that 49% of those surveyed in 2004 had a high-speed connection from home.

Another survey has been tracking Internet use since 2000 (Cole 2004). The survey has produced statistics documenting the increase in the number of households with broadband connections (figure 7-5).

According to one expert, "broadband changes everything" (Cole 2004). The differences between people with broadband and those with dial-up connections are greater than the differences between those with dial-up connections and those who do not use the Internet at all. How often people log on, how long they stay on, what they do online, and where they log on from are all related to whether or not they have a broadband connection. On average, broadband users are online 17.3 hours a week, compared with 10.6 hours for dial-up users. They do more of everything online, except seeking medical information and participating in distance learning. In particular, broadband users are more likely than telephone modem users to say that the Internet is a very important or extremely important source of information. For young people especially, online media usage is very high (Cole 2004).

Figure 7-5
Households with broadband versus other Internet connections: 2000 and 2003



SOURCE: J. Cole, *Surveying the Digital Future: Year Four: Ten Years, Ten Trends* (2004), http://www.digitalcenter.org/downloads/DigitalFutureReport-Year4-2004.pdf.

Science and Engineering Indicators 2006

Categories of News Sought Online

Weather has been the most popular category of news sought online since 2000, with more than three-fourths (76%) of those surveyed in 2004 saying that they sought that kind of information (table 7-3).[10] Science and health has been the second most popular category in every year of the survey except 1998 (when it led the other groups).[11] The types of science-related information sought online seem to be of a practical, personally relevant nature. People do not seem to be very curious about scientific research or policy-related issues.

In 1996, when data collection on Internet news began, technology was the most popular topic: 64% of those surveyed in 1996 said that they sought news about technology. However, as more people go online for news, technology has slipped in ranking: in 2004, it ranked fifth. Since the 2000 survey, the number of people going online for international and political news has grown. The 2000 and 2004 presidential elections, the events of September 11, 2001, and the subsequent wars in Afghanistan and Iraq generated increased interest in political and international news (Pew Research Center for the People and the Press 2004).

Internet users and nonusers have different news interests. In 2004, Internet users were more likely than nonusers to be interested in news about political figures and events in Washington, international affairs, S&T, and culture and the arts, and they were less likely than nonusers to be interested in news about weather, crime, health, local government, and religion. Among Internet users, 18% said they followed news about S&T very closely, compared with 13% of nonusers (table 7-4).

Public Interest in S&T

Most Americans say they are interested in S&T. When asked in a survey about their interest in S&T issues, very few adults admit to not being interested in these subjects. That was the usual pattern in NSF surveys conducted between 1979 and 2001. Similar surveys conducted in other countries indicate that the overall level of public interest in S&T is less than that in the United States. However, Americans may not be as interested in S&T as they claim. Indicators from other surveys point to relatively little interest in S&T topics and news.

Interest in S&T Around the World

Surveys conducted by NSF and other organizations consistently show that Americans are interested in issues related to S&T. In 2001, about 45% of NSF survey respondents said they were very interested in new scientific discoveries and the use of new inventions and technologies. About the same number said they were moderately interested in these subjects. Only about 10% were not interested at all.[12]

In Europe in 2005, 30% of survey respondents said they were very interested in new scientific discoveries and new inventions and technologies, about half (48%) said they

Table 7-3
Use of Internet as source of news: Selected years, 1996–2004
(Percent)

Type of news	1996	1998	2000	2002	2004
Weather	47	48	66	70	76
Science and health	58	64	63	60	58
International	45	41	45	55	54
Political	46	40	39	50	54
Technology	64	60	59	54	53
Business	53	58	53	48	46
Entertainment	50	45	44	44	46
Sports	46	39	42	47	45
Local	27	28	37	42	45

NOTE: Data reflect respondents who said they go online for news.

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey (2004).

Science and Engineering Indicators 2006

Table 7-4
News followed by American public, by Internet user status: 2004
(Percent)

Type of news	All respondents	Use Internet	Do not use Internet
Weather	53	49	60
Crime	32	29	36
Community	28	27	29
Health	26	23	31
Sports	25	25	23
Washington news	24	26	22
International affairs	24	26	19
Local government	22	20	24
Religion	20	17	26
Science/technology	16	18	13
Entertainment	15	14	15
Business/finance	14	15	13
Consumer news	13	12	14
Culture and arts	10	12	8

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey (2004).

Science and Engineering Indicators 2006

were moderately interested in these subjects, and one-fifth said they were not at all interested. There was considerable variation in interest across countries, and the overall level of interest was down somewhat from 1992, the last time these questions were asked. The reasons cited most often for disinterest in S&T were lack of understanding and lack of concern (European Commission 2005a).

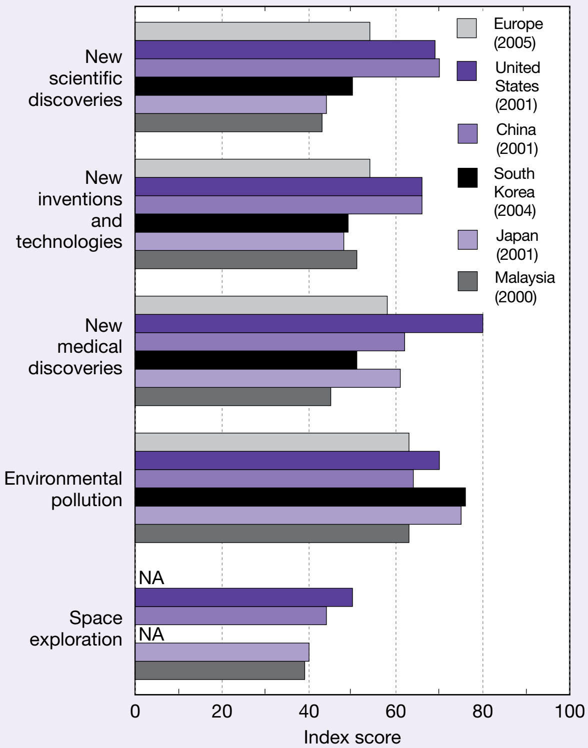
U.S. and European findings coincided in two areas: more men than women expressed an interest in S&T, and respondents were more interested in medicine and the environment than in S&T in general. However, the number of Europeans claiming to be very interested in new medical discoveries and environmental pollution declined significantly between 1992 and 2005 (European Commission 2005a).

Like Americans, Russians are more interested in "achievements in medicine" than in any other issue. In a group of 13 items in a 2003 survey of public interests, scientific discoveries and new inventions and technologies ranked seventh and ninth, respectively, after international affairs, the economy and business, environmental issues, education, and problems of age and life expectancy. However, interest in both issues increased between 1996 and 2003 (Gokhberg and Shuvalova 2004).

Citizens in several Asian countries seem to express less interest than Americans and Europeans in S&T (the Chinese are a notable exception). In 2001, the average levels of U.S. public interest in new scientific discoveries and the use of new inventions and technologies were, on a scale of 0–100, 69 and 66, respectively. The comparable numbers were much lower for Japan, South Korea, and Malaysia. However, the levels for China were about the same as those for the United States (figure 7-6; appendix table 7-5).

Interest in new medical discoveries seems to be much lower in Asian countries than in the West. In the United States in particular, nearly everyone is interested in new medical discoveries. Year after year, more people expressed interest in this subject than in any other. For example, in 2001, about two-thirds of the NSF survey respondents

Figure 7-6
Level of public interest in science and technology issues, by country/region: Most recent year



NA = not available

NOTES: Responses to: *There are a lot of issues in the news, and it is hard to keep up with every area. I'm going to read you a short list of issues, and for each one—as I read it—I would like you to tell me if you are very interested, moderately interested, or not at all interested.* "Don't know" responses not included. All responses converted to 0–100 scale, with 100 for very interested, 50 for moderately interested, and 0 for not interested. In China, values assigned were 100 for great interest, 67 for fair interest, 33 for not much interest, and 0 for not interested. In Malaysia, values assigned were 100 for interested, 67 for moderately interested, 33 for slightly interested, and 0 for not interested. Indices were obtained by adding all the values for each policy issue and computing average. Detail may not add to total because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); Chinese Ministry of Science and Technology, *China Science and Technology Indicators 2002* (2002); Korea Science Foundation, Survey on Public Attitude of Science & Technology 2004 (2004); National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology, The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan (2002); Malaysian Science and Technology Information Centre, Ministry of Science, Technology and the Environment, *The Public Awareness of Science and Technology Malaysia 2000* (2001); and European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology* (2005). See appendix table 7-5.

Science and Engineering Indicators 2006

reported they were "very interested" in new medical discoveries. (None of the other survey items, except local school issues, received such a high percentage of "very interested" responses.)[13] In the U.S. survey, new medical discoveries is the only item that has consistently produced interest index scores in the 80s. In contrast, it yielded much lower scores in the four Asian countries.

Interest in environmental pollution is high in most countries, including the United States, where the index score for this item was 70 in 2001. However, more recent data seem to indicate that interest may have waned during the first part of this decade (see "Environmental Issues" section in this chapter). In both South Korea and Japan, where pollution is an increasingly serious problem, environmental pollution issues attract more public interest than other S&T issues. China also had a relatively high index score for environmental issues. However, in Russia, interest in environmental issues declined between 1996 and 2003 (Gokhberg and Shuvalova 2004).

Despite all the newsworthy events taking place in space during the past few years, interest in issues related to space exploration is relatively low in all of the countries surveyed. The topic ranked at or near the bottom in the United States, Europe (in 2001), Russia, China, and Japan.

Attention to S&T News

Despite the American public's professed interest in S&T issues, there is reason to believe that interest may not be as strong as the NSF survey data indicate. Since 1986, the Pew Research Center for the People and the Press has maintained a news interest index. For a story to be included in the list of top news items, at least 1% of those surveyed had to say that they were following the story "very closely." Relatively few S&T-related stories have made the list. (See sidebar, "Few Science-Related News Stories Attract Public Interest.")

A Pew Research Center survey also shows that weather is by far the most popular type of news followed by most Americans.[14] The other types of news tracked most closely by Americans in 2004 were crime, community affairs, health, and sports.[15] S&T ranked tenth, lower than all other categories except entertainment, business and finance, consumer news, and culture and arts. Only 16% of those surveyed said that they followed news about S&T very closely. (See table 7-6.) However, S&T ranked higher (fifth) among college graduates, after weather, international affairs, national political news, and health. In contrast, the top categories among those who did not graduate from college were weather, crime, community, health, and sports.

Men and adults ages 30–64 were more likely than others to say that they followed S&T news very closely. The breakdown by race and ethnicity is similar to that for all respondents, with one exception: Asian Americans were disproportionately more likely than others to say that they followed S&T news very closely (Pew Research Center for the People and the Press 2004).

Visits to Museums, Zoos, and Libraries

Interest in news about S&T is only part of the story. The millions of people who visit science museums every year are also demonstrating interest in science without necessarily being interested in science news.

Surveys show that S&T museums are more popular in the United States than in other countries. In 2001, 30% of NSF survey respondents said they had visited such a museum in

Few Science-Related News Stories Attract Public Interest

For nearly two decades, the Pew Research Center for the People and the Press has been tracking news stories that attract public interest. Of the approximately 1,100 most closely followed news stories of 1986–2004, not many had anything to do with science and/or technology. And, of the few that did, most were about weather and other types of natural disasters (such as earthquakes) and health-related subjects—not about scientific breakthroughs and technological advances. It should be noted, however, that an engineering/technology story actually does top the list. In July 1986, 80% of those surveyed said they were closely following news about the explosion of the space shuttle Challenger, not a natural disaster, but a manmade one. Similarly, the loss of the space shuttle Columbia was one of the most closely followed news stories of 2003.

Table 7-5 lists the most closely followed S&T-related stories of 2000–2004 (Pew Research Center for the People and the Press 2005). Weather and health-related news dominate the list. In fact, hurricane news was the leading science-related news story in both 2002 and 2003.

In addition to the relatively small number of S&T news stories on the Pew list, interest in S&T news may have declined after 2001: only 4 stories were added to the list in 2002, 6 in 2003, and 4 in 2004 (3 of those occurred in late 2003), compared with 10 in 2000 and 12 in 2001.

Table 7-5
Science/technology-related news stories attracting most public interest: 2000–04

Subject	Public interest	Date question asked
Hurricane Isabel	47	Sep-03
Reports of anthrax in United States[a]	47	Nov-01
Space shuttle Columbia disaster	46	Feb-03
Firestone tire recall	42	Jan-01
Winter weather in Northeast and Midwest	42	Jan-01
Flu outbreak and shortage of vaccine	41	Dec-03
Reports of anthrax in United States[a]	41	Nov-01
SARS spread from Asia	39	May-03
Hurricanes in Louisiana and Gulf of Mexico	38	Oct-02
Cases of West Nile virus	34	Sep-02
Bush decision on stem cell research	1	Aug-01
Mad Cow Disease in Washington State	29	Jan-04
Federal ruling on Microsoft	28	Jun-00
SARS spread from Asia	28	Jun-03
Food and Drug Administration's decision on RU-486	26	Oct-00
Missing Los Alamos computer files	25	Jun-00
Outbreak of foot-mouth in Europe	22	Mar-01
Midwest floods	20	Apr-01
Droughts in United States	19	Apr-02
Landing of spacecraft on Mars	19	Jan-04
Reports on AIDS in Africa	19	Jul-00
Worldwide AIDS epidemic	19	Aug-01
Hackers attacking websites	18	Feb-00
Mad Cow Disease in Europe	18	Aug-01
AOL–Time Warner merger	17	Jan-00
Earthquake in Iran	16	Jan-04
Government's plan for Microsoft	16	May-00
Mapping human genetic code	16	Jul-00
Earthquake in India	15	Feb-01
Missile defense system	15	May-01
Oil spill off coast of Spain	15	Dec-02
Reports of cloned baby by religious cult	14	Jan-03
Court ruling in Microsoft case	13	Apr-00
Ricin found in Senate office building	12	Feb-04
Floods in Mozambique	10	Mar-00
United Nations' special session on HIV/AIDS	6	Jul-01

[a]Two separate surveys in November 2001 by the Pew Research Center asked about reports of anthrax.

NOTE: Data reflect respondents who said they followed story very closely.

SOURCE: Pew Research Center for the People and the Press, News Interest Index, Public Attentiveness to News Stories: 1986–2004 (2005).

Science and Engineering Indicators 2006

Table 7-6
News followed very closely by American public: Selected years, 1996–2004
(Percent)

Type of news	1996	1998	2000	2002	2004
Weather	NA	NA	NA	NA	53
Crime	41	36	30	30	32
Community	35	34	26	31	28
Health	34	34	29	26	26
Sports	26	27	27	25	25
Washington news	16	19	17	21	24
International affairs	16	16	14	21	24
Local government	24	23	20	22	22
Religion	17	18	21	19	20
Science and technology	20	22	18	17	16
Entertainment	15	16	15	14	15
Business and finance	13	17	14	15	14
Consumer news	14	15	12	12	13
Culture and arts	9	12	10	9	10

NA = not available

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey (2004).

Science and Engineering Indicators 2006

the last 12 months, compared with 16% of Europeans (in 2005), 13% of Japanese, 14% of Chinese, and 1% of Russians (2003).

Although the rate of S&T museum attendance in Europe seems to be about half that in the United States, the 2005 rate for Europe was about 50 percent higher than that recorded in 2001 (European Commission 2005a). When Europeans who had not visited an S&T museum were asked their reasons, about one-third said they “don’t understand” S&T, and an approximately equal number said they “did not care” about S&T (European Commission 2005a). Within Europe, Sweden, Norway, Switzerland, Luxembourg, and Iceland have the highest rates of S&T museum attendance (appendix table 7-6).

S&T museums are not the only public attractions that are less popular in other countries than in the United States. More than half (58%) of Americans reported that they had visited a zoo or an aquarium during the past 12 months, compared with 43% of the Japanese respondents, 32% of Chinese, 27% of Europeans, and 9% of Russians.

Americans also go to libraries more often than the citizens of other countries and are more likely than Europeans (other than citizens of Iceland, Denmark, the Netherlands, Sweden, Switzerland, Norway, and Finland) to visit an art gallery. Finally, only 14% of the Americans surveyed said they had not visited any of the establishments included in the survey, compared with 4 of 10 Europeans (41%) and 7 of 10 Russians (71%) (European Commission 2005a; Gokhberg and Shuvalova 2004).

Feeling Well Informed About S&T Issues

Despite the public’s expression of interest in S&T, few people feel well informed about these subjects. In 2004, only about 15% of NSF survey respondents described themselves as very well informed about new scientific discoveries and the use of new inventions and technologies. About one-third of those surveyed considered themselves poorly informed about these topics (appendix table 7-7).[16]

Among the issues included in the survey, Americans feel the most informed about local school issues and the economy and business conditions. In 2004, the index scores for these two topics (on a scale of 0–100) were 56 and 51, respectively. Five items (new medical discoveries, environmental pollution, military and defense policy, new scientific discoveries, and the use of new inventions and technologies) had index scores between 40 and 46. Space exploration had the second lowest index score (36) in 2004 (appendix table 7-8).

For 8 of the 10 issues included in the NSF survey, men were more likely than women to feel well informed. Among the science-related issues, the widest gender gap (14 points) was for space exploration; the gap for the use of new inventions and technologies, new scientific discoveries, and environmental pollution was 10, 5, and 3 points, respectively. In contrast, women were more likely than men to feel well informed about new medical discoveries (appendix table 7-9).

With few exceptions, the NSF survey data show a strong, positive relationship between education (both level of formal education and number of math and science courses completed) and feeling well informed about public policy issues. This is particularly true for four of the five science-related issues in the survey (the relationship between education and feeling well informed about new medical discoveries was not as strong as that for the other four issues). In contrast, the relationship between family income and feeling well informed about science-related public policy issues is either much weaker (than that for education) or nonexistent (appendix table 7-9).

Survey data from several Asian countries, Europe, and the United States indicate that, compared with the citizens of Japan, Malaysia, and South Korea, Americans and Europeans consistently feel better informed about science-related

issues, with one exception: environmental pollution. However, it is difficult to draw definitive conclusions from these data because the citizens of other countries may have different reference points for describing their level of knowledge.

Analysis of data from the United States, Europe, and four Asian countries (China, Japan, South Korea, and Malaysia) revealed similar relationships between interest in S&T and feeling informed. In all of these countries, the level of feeling informed about S&T is considerably lower than the level of professed interest in S&T issues, although the level of feeling informed about a specific issue is positively related to the level of interest in the same issue (Park 2005).

Public Knowledge About S&T

U.S. middle and high school students may not do as well in math and science as their counterparts in some other countries (see chapter 1, "Elementary and Secondary Education"). U.S. *adults,* however, seem to be slightly or somewhat more knowledgeable about science than their counterparts in other countries.

It is important to have some knowledge of basic scientific facts, concepts, and vocabulary. Those who possess such knowledge are able to follow science news and participate in public discourse on science-related issues. Having appreciation for the scientific process may be even more important. Knowing how science works, i.e., understanding how ideas are investigated and either accepted or rejected, is valuable not only in keeping up with important science-related issues and participating meaningfully in the political process, but also in evaluating and assessing the validity of various types of claims people encounter on a daily basis (including those that are pseudoscientific) (Maienschein 1999).

Surveys conducted in the United States and other countries reveal that most citizens do not have a firm grasp of basic scientific facts and concepts, nor do they have an understanding of the scientific process. In addition, belief in pseudoscience seems to be widespread, not only in the United States but in other countries as well. This section explores these three indicators of scientific literacy. (Scientific literacy is defined here as knowing basic facts and concepts about science and having an understanding of how science works.)[17]

Understanding Scientific Terms and Concepts

International Patterns and Trends

A substantial number of people throughout the world appear to be unable to answer simple, science-related questions (figure 7-7; appendix table 7-10). Many did not know the correct answers to several (mostly) true/false questions designed to test their basic knowledge of science.

U.S. data do not show much change over time in the public's level of knowledge about science. In contrast, the most recent European data do show an increase. Belgium, Germany, Ireland, Luxembourg, and the Netherlands recorded double-digit increases in the percentage of correct responses between 1992 and 2005, and most other European countries also recorded gains. There is considerable variation in science knowledge across countries in Europe.[18]

Knowledge scores were especially low in China and Russia. For example, in China, less than half the respondents answered "true" to the statements "the center of the Earth is very hot" and "the continents on which we live have been moving their location for millions of years and will continue to move in the future."[19] In contrast, substantial majorities of the respondents in most other countries answered these questions correctly (the question on the center of the earth was not asked in Russia).[20]

On two questions, U.S. survey participants did considerably better than their counterparts in other countries:

- More than 70% of Americans correctly answered "false" to the statement "all radioactivity is manmade." In the other countries, the percentage of correct responses was considerably lower.
- Only in the United States, Europe, and South Korea did a majority correctly answer true to the statement "it is the father's gene that decides whether the baby is a boy or a girl." The percentage of correct responses in other countries ranged from 46% for Malaysia to 22% for Russia. In addition, the number of Europeans who answered this question correctly increased significantly between 2001 and 2005.

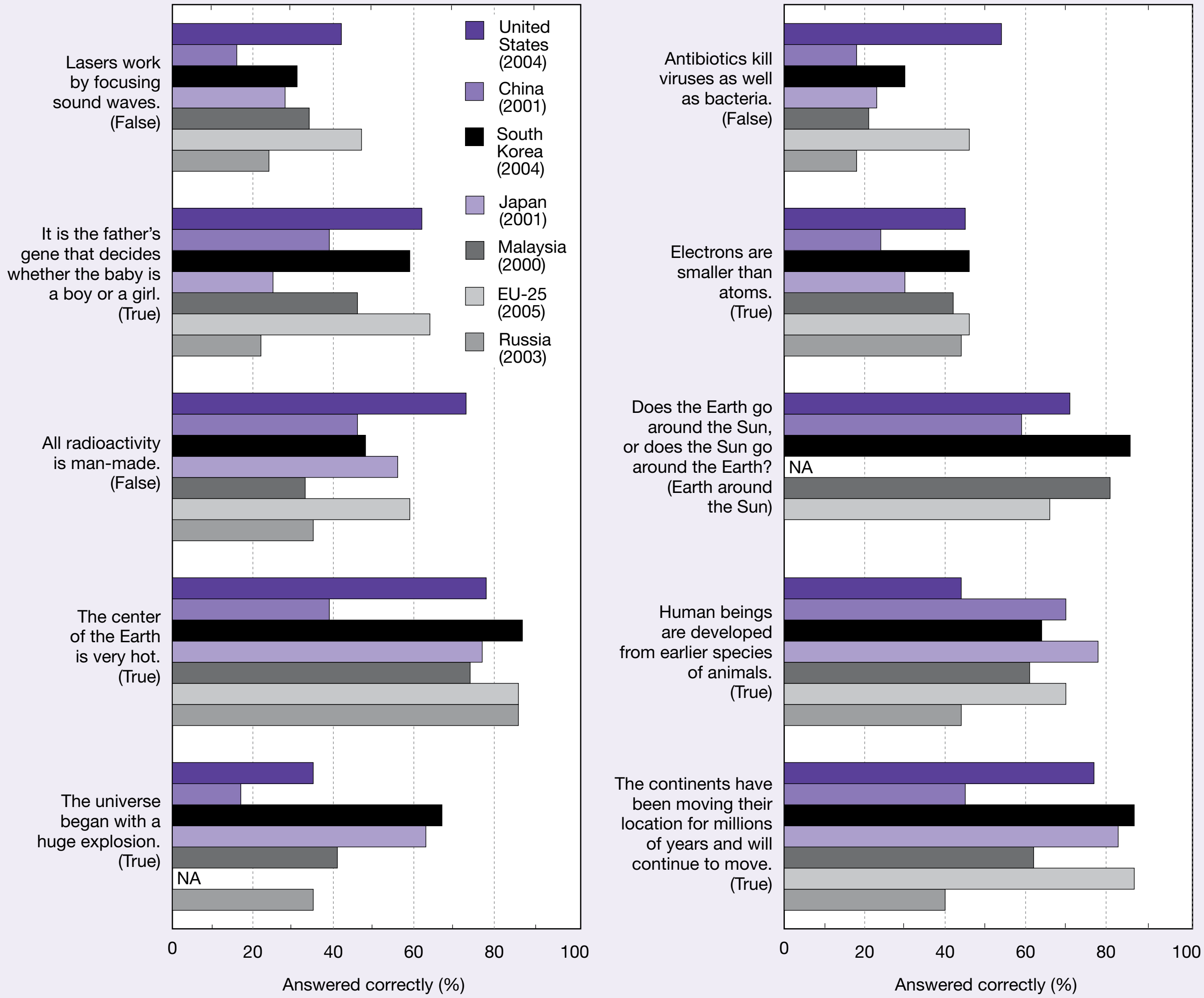
Less than half the respondents in each country knew that "lasers [do not] work by focusing sound waves." In contrast, most people seem to know that the Earth goes around the Sun (and not vice versa).

One question in particular shows a notable increase in the percentage of correct responses in both the United States and Europe: more people now know that antibiotics do not kill viruses. In 2001, for the first time, a majority (51%) of U.S. respondents answered this question correctly, up from 40% in 1995. In the United States, correct responses increased to 54% in 2004. In Europe, 46% of respondents answered the question correctly in 2005, compared with 40% in 2001 and only 27% in 1992.

The U.S. survey is the only one in which at least half the participants answered the question about antibiotics and viruses correctly. After Europe, the next highest percentage of correct responses was in South Korea (30%), followed by Japan (23%) and Malaysia (21%). Less than one in five Russian and Chinese respondents (18%) knew that antibiotics do not kill viruses.

The promising trend in knowledge about antibiotics and viruses in the United States and Europe suggests that a public health campaign to educate the public about the increasing resistance of bacteria to antibiotics has been working. This problem has been the subject of widespread media coverage, and when stories mention that the main culprit is the overprescribing of antibiotics, they typically note the fact that antibiotics are ineffective in killing viruses. In addition, parents of young children, especially those prone to ear infections,

Figure 7-7
Correct answers to specific science literacy questions, by country/region: Most recent year



EU = European Union; NA = not available

SOURCES: University of Michigan, Survey of Consumer Attitudes (2004); Chinese Ministry of Science and Technology, Public scientific literacy and attitudes towards S&T, *China Science and Technology Indicators 2002* (2002); Korea Science Foundation, Survey on Public Attitude of Science & Technology 2004 (2004); National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology, The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan (2002); Malaysian Science and Technology Information Centre, Ministry of Science, Technology and the Environment, *The Public Awareness of Science and Technology Malaysia 2000* (2001); L. Gokhberg and O. Shuvalova, *Russian Public Opinion of the Knowledge Economy: Science, Innovation, Information Technology and Education as Drivers of Economic Growth and Quality of Life,* British Council, Russia (2004); and European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology* (2005).

Science and Engineering Indicators 2006

have been warned by their pediatricians about this problem. However, the message still has not reached a large segment of the population throughout the world.

Americans apparently are also becoming more familiar with the terminology of genetics. In a 2001 NSF survey, 45% of respondents were able to define DNA. The percentage of correct responses to this survey question increased in the late 1990s, a trend that probably reflected heavy media coverage of DNA use in forensics and medical research. More recently, a 2003 Harris poll found that 60% of adults in the United States selected the correct answer when asked "what is DNA?" (the genetic code for living cells), and two-thirds chose the right answer when asked "what does DNA stand for?" (deoxyribonucleic acid) (kSERO Corporation, Inc. 2003). As mentioned earlier in the chapter, a popular television entertainment show such as *CSI* increases public understanding of DNA (see sidebar, "Television and Other Forms of Popular Culture Influence What Adults Know and Think about Science.")

In the United States, knowledge about science is positively related to level of formal schooling, income level, and number of science and math courses taken. In addition, younger respondents and those without minor children at home were more likely than others to have answered the questions correctly. Finally, men seem to be more knowledgeable about science than women: in 2004, men scored an average of 65%, compared with 55% for women (appendix tables 7-11 and 7-12).

Evolution and the "Big Bang"

Americans were less likely than residents of other countries to answer "true" to the following scientific knowledge questions: "human beings, as we know them today, developed from earlier species of animals" and "the universe began with a huge explosion." In the United States, 44% of the respondents in an NSF-sponsored survey answered "true" to the first question in 2004, about the same level recorded in every year (except one) that the question has been asked. In contrast, 78% of Japanese respondents answered "true," as did 70% of the Chinese and European respondents and more than 60% of the South Korean and Malaysian respondents. Only in Russia did less than half (44%) of respondents answer "true." Similarly, Americans were less likely than other survey respondents (except the Chinese) to answer "true" to the "big bang" question.

U.S. responses to questions about evolution and the big bang appear to reflect more than unfamiliarity with basic elements of science. The 2004 Michigan Survey of Consumer Attitudes administered two different versions of these questions to different groups of respondents. Some were asked questions that tested knowledge about the natural world ("human beings, as we know them today, developed from earlier species of animals" and "the universe began with a big explosion"). Others were asked questions that tested knowledge about what a scientific theory asserts or a group of scientists believes ("according to the theory of evolution, human beings, as we know them today, developed from earlier species of animals" and "according to astronomers, the universe began with a big explosion"). Respondents were much more likely to answer correctly if the question was framed as about scientific theories or beliefs rather than as about the natural world. When the question about evolution was prefaced by "according to the theory of evolution," 74% marked true; only 44% marked true when it was not. Similarly, 62% agreed with the prefaced question about the big bang, but only 35% agreed when the prefatory phrase was omitted. These differences probably indicate that many Americans hold religious beliefs that cause them to be skeptical of established scientific ideas, even when they have some basic familiarity with those ideas.

Surveys conducted by the Gallup Organization provide similar evidence. An ongoing Gallup survey, conducted most recently in 2004, found that only about a third of Americans agreed that Darwin's theory of evolution has been well supported by evidence (Newport 2004).[21] The same percentage agreed with the alternative statement that Darwin's theory was not supported by the evidence, and an additional 29% said they didn't know enough to say. Data from 2001 were similar. Those agreeing with the first statement were more likely than others to be men, well educated (65% of those with postgraduate education and 52% of those with a bachelor's degree), and live in the West (47%) or East (42%).

In response to another group of questions on evolution asked by Gallup in 2004, about half (51%) of those surveyed agreed with either of two statements compatible with evolution: that human beings developed over millions of years either with or without God's guidance in the process. However, 45% agreed with a third statement, that "God created human beings pretty much in their present form at one time within the last 10,000 years or so." These views on the origin of human beings have remained virtually unchanged (in six surveys) since the questions were first asked in 1982 (Newport 2004).

During most of the 20th century, probably the most contentious issue related to the teaching of science has been whether and how evolution is to be taught in U.S. public school classrooms.[22, 23] The controversy has continued in the new millennium, erupting in quite a few states, including Georgia and Pennsylvania, and making front-page headlines in major newspapers.[24] A survey conducted in 2005 revealed that Americans have been paying fairly close attention to newspaper and television news coverage about teaching alternatives to evolution (Nisbet and Nisbet 2005). Contention about this issue also surfaced in England in 2001 and in the Netherlands in 2005. (See sidebar, "More Than a Century After Darwin, Evolution Still Under Attack in Science Classrooms")

Understanding the Scientific Process

NSF has used three survey items to assess "public understanding of the nature of scientific inquiry," i.e., how well people understand aspects of the scientific process. Understanding how science works is a major indicator of scientific literacy. Based on their responses to the three inquiry items, many Americans appear not to have a firm grasp of the nature of the scientific process. The same is true of Europeans.

In 2001, both the NSF survey and the Eurobarometer asked respondents questions designed to test their knowledge of two important aspects of scientific literacy: how an experiment is conducted and their understanding of probability.[25] Only 43% of Americans and 37% of Europeans answered the experiment question correctly. Both groups did better with probability: 57% of Americans and 69% of Europeans answered that question correctly. In 2004, 46% of Americans answered the experiment question correctly, and 64% gave a correct answer to the probability questions (appendix table 7-13). NSF survey respondents were also asked to explain in their own words what it means to study something scientifically. In 2004, only 23% of respondents gave a response that indicated they knew what it meant.[26]

More Than a Century After Darwin, Evolution Still Under Attack in Science Classrooms

In 1999, the Kansas State Board of Education decided to delete evolution from the state's science standards. The action received widespread press coverage and sparked an outcry in the science community. Most of the public also disagreed with the decision, which was reversed after board members who had voted for the change were defeated in the next election.

Thus began another round of attacks on the teaching of evolution in public school classrooms. Similar eruptions have been occurring since the landmark 1925 Scopes "monkey" trial. Although Tennessee teacher John Scopes was convicted, science ended up being the true victor, according to the history books and thanks to the play *Inherit the Wind.* The next milestone occurred in 1987 when the Supreme Court struck down a Louisiana law that prohibited the teaching of evolution unless equal time was given to creationism.

The National Center for Science Education (NCSE) tracks attacks on the teaching of evolution in the United States and around the world. In general, the recent controversies have come from two directions: a push to introduce "intelligent design" in science classrooms as a viable alternative to evolution* and efforts to add evolution disclaimers to science textbooks. Recently, legislatures or school boards in about 20 states have considered allowing the teaching of alternatives to evolution in science classrooms. Controversies making national headlines include the following:

- In October 2004, the Dover, Pennsylvania, school district became the first in the nation to require that ninth-graders be told about intelligent design in biology class. The decision triggered a lawsuit. The parents of several students are suing the school board; the American Civil Liberties Union and Americans United for the Separation of Church and State are representing them. The trial is scheduled for September 2005.
- Six years after the initial controversy, Kansas is once again taking up the issue. This time, the state education board is considering adding intelligent design to its science standards. Representatives of the scientific community boycotted hearings on the subject, held in May 2005, because "participating in them would only strengthen the idea in some minds that there was a serious debate in science about the power of the theory of evolution" (Dean 2005). The final vote on the Kansas science standards is also scheduled for September 2005.
- In 2002, the school board in Cobb County, Georgia, decided that every biology textbook in the state would have a sticker declaring that "evolution is a theory, not a fact, regarding the origin of living things." A lawsuit was filed by parents of the students, and a trial was held in late 2004. In January 2005, the judge in the case ruled the evolution disclaimer unconstitutional and ordered the stickers removed. The school district is appealing the decision. Currently, Alabama is the only state requiring evolution disclaimer stickers on biology textbooks.

In addition to the way science is taught (or not taught) in classrooms,† battles over other issues have erupted in other places in recent years:

- In several cities, IMAX theaters have declined to screen films such as *Cosmic Voyage, Galapagos,* and *Volcanoes of the Deep Sea* because of community opposition to the films' treatment of evolution as fact (Dean 2005).
- Several science organizations protested the sale of a book promoting creationism, *Grand Canyon: A Different View at the Grand Canyon,* at the National Park Service bookstore. The National Park Service is reviewing the issue.
- The Smithsonian Institution screened the film *The Privileged Planet* in June 2005, but not before drawing criticism from a variety of science organizations because the authors of the book on which the film is based are affiliated with a pro-intelligent-design think tank. After the protests, the museum withdrew its cosponsorship and returned the organization's donation because it "determined that the content of the film is not consistent with the mission of the Smithsonian Institution's scientific research."
- In June 2005, the Park and Recreation Board of Tulsa, Oklahoma, voted to approve a display depicting the Biblical account of creation at the city's zoo. The decision was reversed a month later (NCSE 2005).

This kind of controversy is almost absent in other industrialized nations. However, that may be changing. For example, since 2002, the teaching of creationism at a small group of privately financed state schools in northeast England has triggered a considerable amount of debate in Parliament (Pincock 2005).

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*The theory of intelligent design holds that life is too complex to have happened by chance and that, therefore, some sort of intelligent designer must be responsible. Critics claim that this theory is simply a more sophisticated form of creationism (which the courts have said may not be taught in public schools). They argue that intelligent design theory has nothing to do with science because its assertions are not falsifiable: they cannot be tested or observed and cannot undergo experimentation. In contrast, "[evolution] has been directly observed in operation not only in the laboratory but also in the field. Where there is still room for argument and discussion is in the precise contributions of different mechanisms to evolutionary change. In this vibrant debate, intelligent design offers no meaningful contribution." According to Eugenie C. Scott, president of the National Center for Science Education, "There aren't any alternative scientific theories to evolution." In October 2002, the American Association for the Advancement of Science Board of Directors passed a resolution on intelligent design that "calls upon its members to assist those engaged in overseeing science education policy to understand the nature of science, the content of contemporary evolutionary theory and the inappropriateness of 'intelligent design theory' as a subject matter for science education."

†Although they are using teaching guides and textbooks that meet the approval of biologists, some teachers avoid mentioning evolution in their classrooms because their superintendents or principals discourage them from discussing it or because of opposition in the communities in which they teach. This approach can take the form of assigning the material on evolution to be read, but not discussing it in class (Dean 2005)

Although 39% of Americans surveyed in 2004 correctly answered all three questions about the nature of scientific inquiry, 61% did not.[27] This lack of understanding may explain why a substantial portion of the population believes in various forms of pseudoscience.

Belief in Pseudoscience

Although S&T are held in high esteem throughout the modern world, pseudoscientific beliefs continue to thrive. Such beliefs coexist alongside society's professed respect for science and the scientific process.

A recent study of 20 years of survey data collected by NSF concluded that "many Americans accept pseudoscientific beliefs," such as astrology, lucky numbers, the existence of unidentified flying objects (UFOs), extrasensory perception (ESP), and magnetic therapy (Losh et al. 2003). Such beliefs indicate a lack of understanding of how science works and how evidence is investigated and subsequently determined to be either valid or not. Scientists, educators, and others are concerned that people have not acquired the critical thinking skills they need to distinguish fact from fiction. The science community and those whose job it is to communicate information about science to the public have been particularly concerned about the public's susceptibility to unproven claims that could adversely affect their health, safety, and pocketbooks (NIST 2002). (See sidebar, "Sense About Science.")

Pseudoscience has been defined as "claims presented so that they appear [to be] scientific even though they lack supporting evidence and plausibility" (Shermer 1997, p. 33).[28] In contrast, science is "a set of methods designed to describe and interpret observed and inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation" (Shermer 1997, p. 17).

Belief in pseudoscience increased significantly during the 1990s and into the early part of this decade (Newport and Strausberg 2001) and then fell somewhat between 2001 and 2005 (figure 7-8). The largest declines were in the number of people who believe in ESP, clairvoyance, ghosts, mentally communicating with the dead, and channeling. Nevertheless, about three-fourths of Americans hold at least one pseudoscientific belief; i.e., they believed in at least 1 of the 10 survey items (similar to the percentage recorded in 2001).[29] In addition, 22% believed in five or more of the items, 32% believed in four, and 57% believed in two. However, only 1% believed in all 10 (Moore 2005b).

Belief in pseudoscience is widespread. For example, at least a quarter of the U.S. population believes in astrology, i.e., that the position of the stars and planets can affect people's lives. Although two-thirds (66%) of those queried in 2004 said that astrology is "not at all scientific," about one-third considered it at least "sort of scientific" (appendix table 7-14).[30]

Belief in astrology may be more prevalent in Europe. In 2001, 53% of Europeans surveyed thought astrology is "rather scientific" and only a minority (39%) said it is not at all scientific. In the 2005 survey, Europeans were asked whether or not they considered certain subjects to be scientific, using a 5-point scale (with higher values indicating that a subject is more scientific). About 4 out of 10 (41%) of those surveyed gave responses of 4 or 5 for astrology, the same as the score for economics. However, when the survey used the word "horoscopes" instead of astrology, only 13% gave a response of 4 or 5. Disciplines most likely to be considered scientific by Europeans were medicine (89%), physics (83%), biology (75%), mathematics (72%), astronomy (70%), and psychology (53%). History (34%) and homeopathy (33%) were at the bottom of the list (European Commission 2005a). Comparable U.S. data on the various disciplines do not exist.

Europeans were more likely than Americans to agree that "some numbers are particularly lucky for some people." The percentages in Europe were 37% (2005) and 32% (2001).[31]

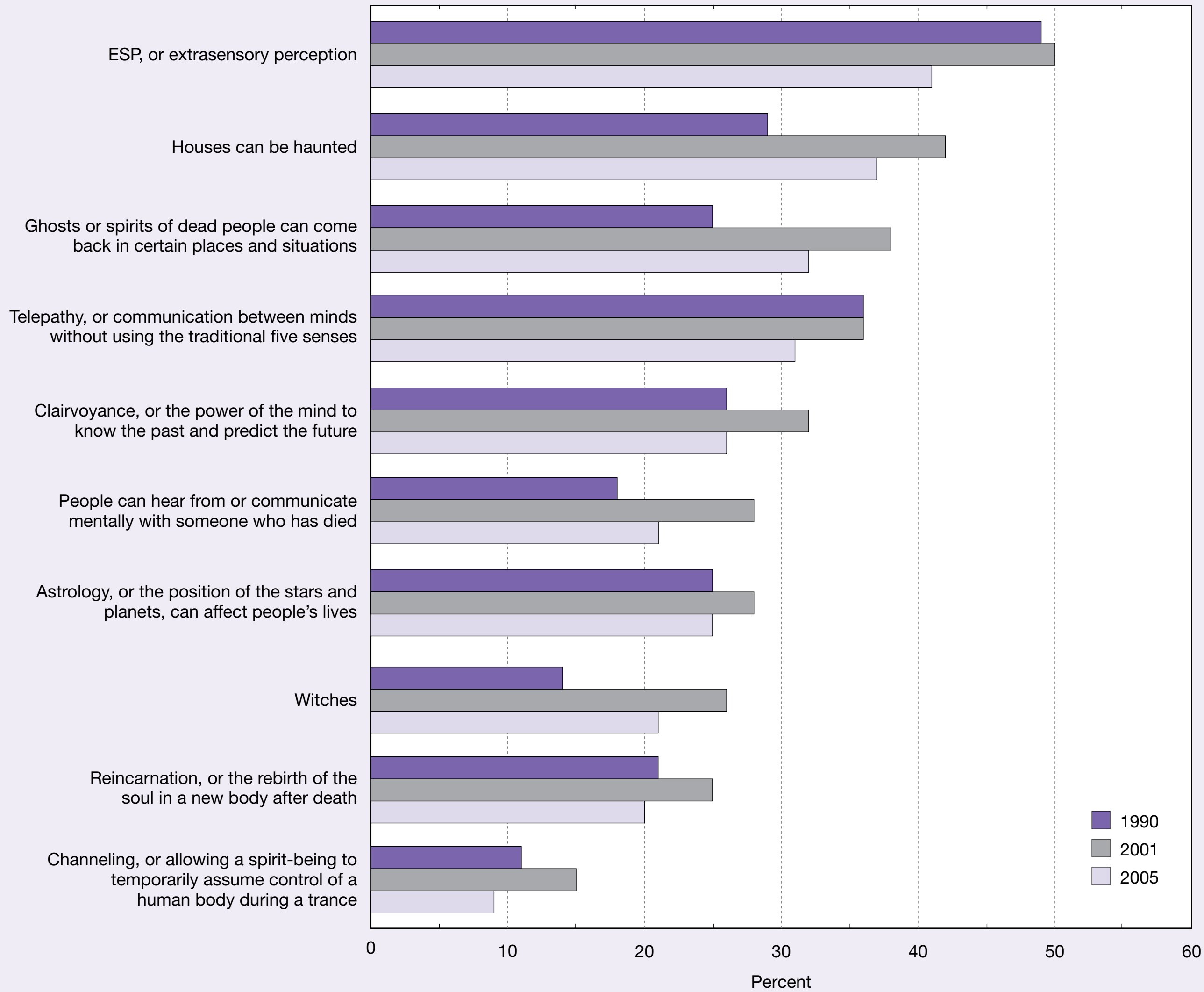
In the United States, skepticism about astrology is strongly related to level of education: in 2004, 81% of college graduates said that astrology is "not at all scientific," compared with 51% of those with less than a high school education and 62% of those who had completed high school but not college. In Europe, however, respondents with college degrees were just as likely as others to claim that astrology is scientific.

In the United States, belief in astrology is also related to level of income (which, in turn, is related to education). Those in higher income brackets were less likely than others to say that astrology is either very or sort of scientific.

Sense About Science

A new group, Sense About Science, was recently formed in the United Kingdom. Its goal is to help scientists and their institutions educate the press and the public about the importance of peer review. Recent scares—such as the possibility that radiation from mobile phones poses health risks, that the MMR (measles, mumps, and rubella) vaccine can cause autism, and that acrylamide in fried foods can cause cancer—could be put into perspective if the press and the public understood how the scientific process is used to distinguish between claims that are valid and those that are not. A poll commissioned in 2004 by the Science Media Centre and the journal *Nature* and conducted by the London-based market-research company MORI revealed that almost three-fourths of the UK public does not know what peer review is. Sense About Science plans to work with research and educational bodies to encourage teaching about peer review in schools and universities (Sense About Science 2004).

Figure 7-8
Belief in paranormal phenomena: 1990, 2001, and 2005



SOURCE: D.W. Moore, Three in four Americans believe in paranormal, *Gallup Poll News Service* (16 June 2005), http://www.gallup.com/poll/content/default.aspx?ci=16915.

Science and Engineering Indicators 2006

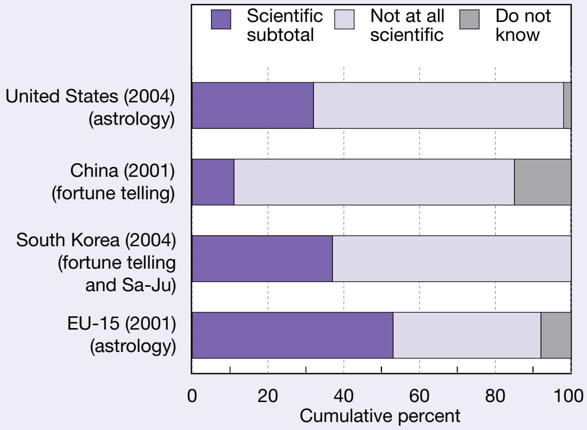
Like astrology in the United States and Europe, fortune telling is common in China and South Korea. However, only 1% of Chinese survey respondents said fortune telling is very scientific and 10% thought it is "a bit" scientific. In contrast, 74% answered either "not at all scientific" or "not very scientific." A similar item on a South Korean survey showed a larger percentage (37%) of respondents answering either "very scientific" or "sort of scientific" (figure 7-9; appendix table 7-15).

Surveys conducted by NSF and other organizations suggest that at least half of the U.S. public believes in the existence of ESP (CBS News 2002), and a sizable minority believes in UFOs and that aliens have landed on Earth. In the 2001 NSF survey, 60% of respondents agreed that "some people possess psychic powers or ESP," and 30% agreed that "some of the unidentified flying objects that have been reported are really space vehicles from other civilizations." Similarly, one-third of the Chinese respondents (33%) believed in the existence of aliens.

Public Attitudes About Science-Related Issues

Attitudes toward science in the United States are considerably more favorable than those in Europe and Japan, although similar to those in other Asian countries such as China and South Korea. Despite some disparity in attitudes toward science, Americans and the citizens of other countries strongly support government funding of basic research. Recently, the public has grappled with controversial developments such as

Figure 7-9
Public assessment of astrology or fortune telling, by country/region: 2001 or 2004



EU = European Union

NOTES: Responses to: *Would you say that astrology is very scientific, sort of scientific, or not at all scientific?* For United States, China, and South Korea, "scientific subtotal" is a sum of "very scientific" and "sort of scientific."

SOURCES: University of Michigan, Survey of Consumer Attitudes (2004); Chinese Ministry of Science and Technology, *China Science and Technology Indicators 2002* (2002); Korea Science Foundation, Survey on Public Attitude of Science & Technology 2004 (2004); European Commission, Research Directorate-General, Eurobarometer 55.2: *Europeans, Science and Technology* (2001).

Science and Engineering Indicators 2006

cloning and embryonic stem cell research (the vast majority of Americans oppose cloning, but attitudes about embryonic stem cell research are mixed). Genetically modified foods continue to generate public concern around the world, especially in Europe. In addition, scientists have been keeping a watchful eye on public opinion regarding the emerging field of nanotechnology, which some fear may prompt unwarranted or excessive concerns about safety (Cobb and Macoubrie 2004). Regardless of their attitudes about these and other science-related issues, Americans' confidence in the science community has remained high for several decades.

This section takes an in-depth look at public attitudes about S&T in general, high-profile issues that have tended to generate controversy, and science as a profession. It presents survey data from a variety of sources in the United States and other countries.

S&T in General

In general, Americans have highly favorable attitudes about S&T. In the Virginia Commonwealth University (VCU) 2004 Life Sciences Survey, 90% of respondents agreed that developments in science have helped make society better, and 92% agreed that "scientific research is essential for improving the quality of human lives." These two statistics were higher in 2004 than they have ever been (VCU Center for Public Policy 2004).

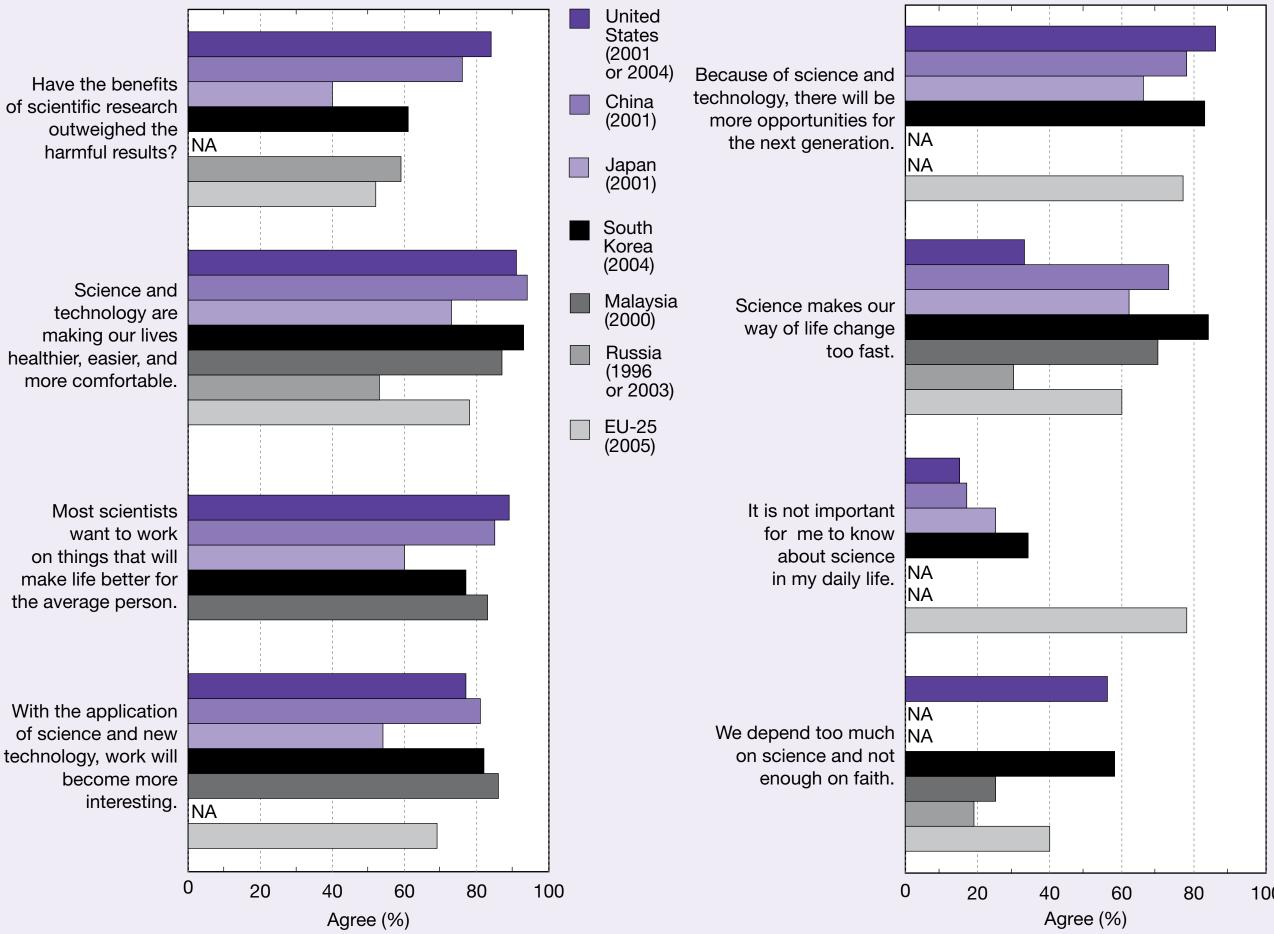
Attitudes toward S&T are also highly favorable in Europe. Nearly 9 out of 10 of those surveyed agreed that "developments in S&T have improved the quality of life for [their] generation," and nearly 8 out of 10 said that S&T "will improve the quality of life of future generations" (European Commission 2005b).

Americans seem to have more positive attitudes about the benefits of S&T than are found in Europe, Russia, and Japan; however, attitudes in China and South Korea are similar to those in the United States, if not more favorable (figure 7-10; appendix table 7-16). These attitudes are reflected in levels of agreement with various statements in surveys conducted most recently in 2004 (United States and South Korea), 2001 (China, Europe, and Japan), 2000 (Malaysia), or 2003 (Russia):

- **"Science and technology are making our lives healthier, easier, and more comfortable."** Among Americans surveyed, 91% of Americans agreed with the statement. The Chinese and South Korean statistics were similar to the U.S. findings, but lower percentages were recorded in Japan and Europe. In Russia, only half of those surveyed agreed with the statement.
- **"With the application of science and new technology, work will become more interesting."** About three-fourths of Americans agreed with the statement in 2004, as did somewhat greater proportions of Malaysians, South Koreans, and Chinese. Once again, the level of agreement was lower in Europe and considerably lower in Japan.
- **"Because of science and technology, there will be more opportunities for the next generation."** Among Americans, 86% agreed. Percentages for the other surveys ranged from 83% (South Korea) to 66% (Japan).
- **"The benefits of scientific research outweigh the harmful results."**[32] In the United States, 84% of survey respondents agreed with the statement in 2004.[33] The level of agreement was also high in China and South Korea but was lower in Europe, where only about half agreed. In the United States, 13% of respondents disagreed with the statement, about the same percentage recorded for Europe.[34] Among Russians surveyed in 2003, 59% agreed that the benefits of scientific research outweigh the harmful results, a larger proportion than found in Europe or in Japan (40% in 2001). The Russian percentage was, however, lower than it had been in some past years (e.g., 73% in 1999, 70% in 1997), although about the same as it was in 1996 (57%).

Despite Americans' highly favorable views about the benefits of S&T, a sizeable segment of the population has some reservations. In the 2004 VCU Life Sciences Survey, 61% of respondents agreed that "scientific research these days doesn't pay enough attention to the moral values of society." However, that percentage has been declining steadily and dropped 12 percentage points between 2001 and 2004. Agreement that "scientific research has created as many problems for society as it has solutions" also declined, from

Figure 7-10
Attitudes toward science and technology, by country/region: Most recent year



EU = European Union; NA = not available

NOTES: U.S. responses to “Most scientists want to work on things…” are from 2001 survey. U.S. responses for other questions are from 2004 survey. Russian responses to “Science and technology are making our lives healthier…” and “We depend too much…” are from 1996 survey. Responses to “Have the benefits…” and “Science makes our way of life change…” are from 2003.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); University of Michigan, Survey of Consumer Attitudes (2004); Chinese Ministry of Science and Technology, *China Science and Technology Indicators 2002* (2002); Korea Science Foundation, Survey on Public Attitude of Science & Technology 2004 (2004); National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology, The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan (2002); Malaysian Science and Technology Information Centre, Ministry of Science, Technology and the Environment, *The Public Awareness of Science and Technology Malaysia 2000* (2001); L. Gokhberg and O. Shuvalova, *Russian Public Opinion of the Knowledge Economy: Science, Innovation, Information Technology and Education as Drivers of Economic Growth and Quality of Life,* British Council, Russia (2004); and European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology* (2005).

Science and Engineering Indicators 2006

59% in 2002 to 51% in 2004. In the 2004 Life Sciences Survey, those who said that “religious beliefs provide…guidance in [their] day-to-day living” were considerably more likely than others to support both statements (VCU Center for Public Policy 2004).

Findings from the NSF survey and other surveys also reveal some reservations about S&T in the United States and other countries. For example, Americans were more likely than the citizens of most other countries to agree with the statement “we depend too much on science and not enough on faith.” In the United States, 56% of respondents agreed in 2004. The percentage of agreement was similar in South Korea and Malaysia but considerably lower in Europe and Russia.

Another survey item revealed less reservation about science in the United States than in other countries. One-third of Americans agreed that “science makes our way of life change too fast.” Although the Russian response was similar, surveys in other countries all recorded much higher levels of agreement.

Government Funding of Scientific Research

All indicators point to widespread public support for government funding of basic research in the United States and elsewhere. This has been the case since at least the mid-1980s.

In 2004, 83% of NSF survey respondents agreed with the following statement: "Even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the federal government."[35] The stability of this measure of public support for basic research is noteworthy. The level of agreement has been around 80% since 1985. In addition, a consistently small percentage of respondents have held the opposite view. In 2004, 17% disagreed with the statement; only 2% strongly disagreed with it (appendix table 7-18).

The level of agreement about the desirability of government funding for research is similarly high in other world regions. Among Europeans surveyed, 76% favor government investment in basic research, and the level of agreement was similar or even higher in South Korea (91%), China (90%), Malaysia (82%), and Japan (80%)[36] (figure 7-11; appendix table 7-19).

Figure 7-11
Support for government funding of basic research, by country/region: Most recent year

EU = European Union

NOTE: Responses to: *Even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the Federal Government. Do you strongly agree, agree, disagree, or strongly disagree?*

SOURCES: University of Michigan, Survey of Consumer Attitudes (2004); Chinese Ministry of Science and Technology, *China Science and Technology Indicators 2002* (2002); Korea Science Foundation, Survey on Public Attitude of Science & Technology 2004 (2004); National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology, The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan (2002); Malaysian Science and Technology Information Centre (MASTIC), Ministry of Science, Technology and the Environment, *The Public Awareness of Science and Technology Malaysia 2000* (2001); L. Gokhberg and O. Shuvalova, *Russian Public Opinion of the Knowledge Economy: Science, Innovation, Information Technology and Education as Drivers of Economic Growth and Quality of Life,* British Council, Russia (2004); and European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology (*2005). See appendix table 7-19.

Science and Engineering Indicators 2006

Although there is strong evidence that the American public supports the government's investment in basic research, few Americans can name the two agencies that provide most of the federal funds for this type of research. In a recent survey, only 5% identified the National Institutes of Health (NIH) as the "government agency that funds most of the medical research paid for by taxpayers in this country,"[37] and only 3% named NSF as "the government agency that funds most of the basic research and education programming in the sciences, mathematics, and engineering in this country." In the same survey, 68% could name the Food and Drug Administration (FDA) as the "government agency that conducts the review and approval of new drugs and devices before they can be put on the market in this country," and 32% were able to name the Centers for Disease Control and Prevention (CDC) as the "government agency whose primary mission is disease prevention and health promotion in this country" (Research!America 2005). Between 2001 and 2004, the number of people who could name NIH, NSF, or the FDA remained about the same, but the number who could identify the CDC increased from 24% to 32%.

In 2004, 13% of General Social Survey (GSS) respondents thought the government was spending too much on scientific research; 40% thought the government was not spending enough—an increase over the 34–37% levels recorded between 1988 and 2002.[38] In another survey, 57% thought it was very important "in terms of job creation and incomes" for the government to invest in scientific research, and an additional 36% thought it was somewhat important (Research!America 2005).

To put the response on scientific research in perspective, it helps to look at the percentage who thought the government was not spending enough in other program areas: improving health care (79%) and education (74%), reducing pollution (64%), improving national defense (39%), and exploring space (15%). The percentage favoring increased spending went up in all categories (except improving education) between 2002 and 2004 (appendix table 7-20).

The loss of the Columbia space shuttle in early 2003 apparently had little, if any, impact on public support for the U.S. space program. Public attitudes about manned space flight were strikingly similar to those recorded in 1986 after the loss of the space shuttle Challenger.[39]

Support for increased government spending on research is more common in Europe than in the United States. When asked about the statement "my government should spend more money on scientific research and less on other things," 57% of Eurobarometer respondents agreed. Italy, Spain, France, and Turkey had the highest rates of agreement, and the Netherlands, Finland, and Malta the lowest (European Commission 2005a).

Environmental Issues

Concern about the quality of the environment has not changed much since 2002, according to the Gallup Organization's Earth Day survey, conducted in March of each year.

In 2005, 35% of those surveyed said they "worried a great deal" about the quality of the environment, 30% said they worried "a fair amount," and 34% had little or no worry. However, the percentage of Americans who said they worried a great deal or a fair amount was lower in 2005 (and the 2 previous years) than in 2001 (Saad 2005).

Environment Compared With Other Concerns

The environment also ranks fairly low, in terms of worry, among various problems facing the country. Among 12 problems included in the survey in 2005, the quality of the environment ranked 9th. More people said they worried a great deal about the availability and affordability of health care (60%), Social Security (48%), crime and violence (46%), drug use (42%), the possibility of future terrorist attacks in the United States (41%), the availability and affordability of energy (39%), the economy (38%), and hunger and homelessness (37%) (Blizzard 2005).

Only 1% of those surveyed in 2005 named the environment when asked "what do you think is the most important problem facing this country today?"[40] Although the environment does not register as a serious current problem, the public considers it one of the most important problems the country will face in 25 years. But even by that long-term measure, concern about the environment has declined. Until 2002, the environment was the most frequently mentioned problem in response to the 25-year outlook question. Since 2002, more people have named other problems. Nearly a quarter (23%) of those surveyed in 2005 chose Social Security, followed by the economy in general, at a distant 9%. Only 6% named the environment (the same percentage chose health care), down from 14% and 11% in 2000 and 2001, respectively (Saad 2005).

Global Warming

Although Americans seem to accept climate change, or global warming, as a real phenomenon, most do not seem to have a great deal of concern about it.[41] In addition, in 2005, only 16% of Americans said they understood the issue of global warming "very well," about half (54%) understood it "fairly well," and the rest answered either "not very well" (24%) or "not at all" (6%). These percentages are almost identical to those recorded in each of the four previous annual surveys (Saad 2005).

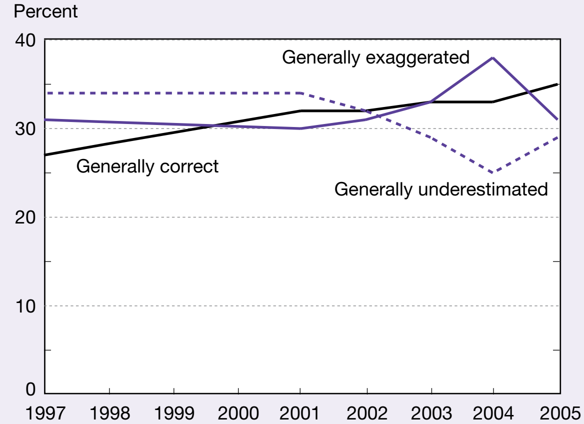
In 2005, 31% of those surveyed said that news reports on global warming generally exaggerated the problem, down from 38% of those surveyed the previous year. The number who believe that the press has been underestimating the problem was 35% in 2005, about the same as the percentages in the two previous survey cycles (but up from 27% in 1997). In 2005, 29% thought that news coverage of global warming was generally correct (the same percentage as 2003 but up from 25% in 2004) (Saad 2004, 2005a) (figure 7-12).

Whatever their view about the seriousness of global warming, more than half (54%) of Americans surveyed in 2005 think its effects have already begun, and others expect to see effects within a few years (5%) or within their lifetime (10%). Only 9% said the potential effects of global warming would never happen. Once again, these percentages changed little between 2001 and 2005. In addition, most Americans (61%) believe that human activities, more than natural causes, are responsible for increases in the Earth's temperature over the last century.

In 2005, 42% of Americans thought that the United States should agree to abide by the provisions of the Kyoto agreement on global warming; 23% said it should not, and 35% had no opinion. These statistics were virtually unchanged from the previous year (Moore 2004).

Although Americans seem to be aware of the issue and believe press reports, they are less concerned about global warming than other environmental hazards. On a list of 10 types of environmental issues, "damage to Earth's ozone layer" and the "'greenhouse effect' or global warming" ranked eighth and ninth, respectively, in 2004 (table 7-7). In addition, after increasing from 24% in 1997 to 40% in 2000, the number of people who worry a great deal about global warming declined to 26% in 2004. In fact, 9 of the 10 items on the list had similar declines between 2000 and 2004, with "maintenance of the nation's supply of fresh water for household needs" the only exception. Figure 7-13 shows the decline in the public's worry about four environmental problems (global warming, air pollution, acid rain, and damage to the ozone layer) from 2000 to 2004 (Saad 2004).

Figure 7-12
Perceptions about news coverage of global warming: 1997–2005



NOTE: Responses to: *Thinking about what is said in the news, in your view is the seriousness of global warming generally exaggerated, generally correct, or is it generally underestimated?*

SOURCE: L. Saad, Public's environmental outlook grows more negative, *Gallup Poll News Service* (21 April 2005), http://www.gallup.com/poll/content/?ci=15961&pg=1.

Science and Engineering Indicators 2006

Table 7-7
Environmental concerns of American public: Selected years, 1997–2004
(Percent)

Issue	1997	1999	2000	2001	2002	2003	2004
Pollution of drinking water	NA	68	72	64	57	54	53
Pollution of rivers, lakes, and reservoirs	NA	61	66	58	53	51	48
Contamination of soil and water by toxic waste	NA	63	64	58	53	51	48
Maintenance of nation's supply of fresh water for household needs	NA	NA	42	35	50	49	47
Air pollution	42	52	59	48	45	42	39
Damage to Earth's ozone layer	33	44	49	47	38	35	33
Loss of tropical rain forests	NA	49	51	44	38	39	35
Extinction of plant and animal species	NA	NA	45	43	35	34	36
Greenhouse effect or global warming	24	34	40	33	29	28	26
Acid rain	NA	29	34	28	25	24	20

NA = not available

NOTE: Data reflect respondents who said they worry a great deal about issue.

SOURCE: L. Saad, Global warming on public's back burner, *Gallup Poll News Service* (20 April 2004), http://www.gallup.com/poll/content/?ci=11398&pg=1.

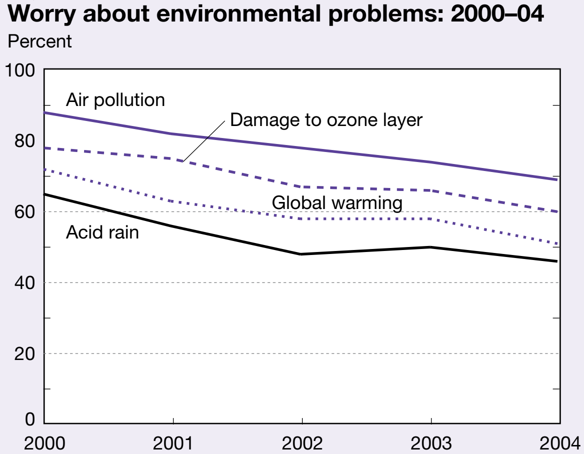
Science and Engineering Indicators 2006

Trust in Institutions

Americans place the most trust in local and national environmental organizations to protect the quality of the environment. However, the level of trust in national environmental groups in 2005 was down from that recorded in 2000 (Carlson 2005b).

About a quarter of those surveyed said they trusted national and local environmental organizations "a great deal." The comparable numbers for federal environmental agencies like the EPA and state environmental agencies were 22% and 16%, respectively. Politicians and private industry fared less well, with the percentage of "great deal" responses ranging from 15% for the Democratic Party and small businesses to 7% for large corporations. (The U.S. Congress [11%] and the Republican Party [7%] fell in between those groups.)

Figure 7-13
Worry about environmental problems: 2000–04



NOTES: Responses to: *I'm going to read you a list of environmental problems. As I read each one, please tell me if you personally worry about this problem a great deal, a fair amount, only a little, or not at all.* Percentages represent those who said either a "great deal" or "fair amount."

SOURCE: L. Saad, Global warming on public's back burner, *Gallup Poll News Service* (20 April 2004), http://www.gallup.com/poll/content/?ci=11398&pg=1.

Science and Engineering Indicators 2006

Government Environmental Policy

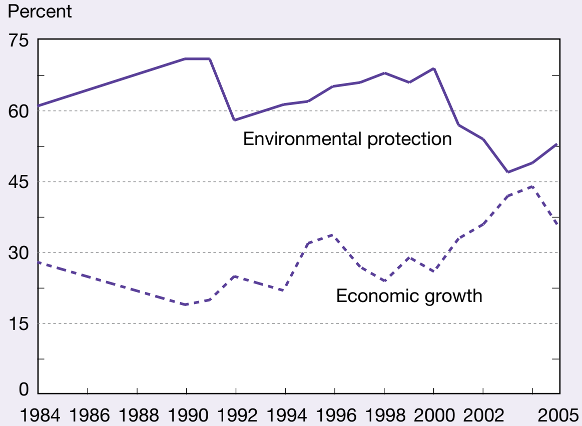
In 2005, a majority of Americans (58%) chose the "too little" response to the question, "do you think the U.S. government is doing too much, too little, or about the right amount in terms of protecting the environment?" Only 5% said "too much." These numbers resulted in the highest ratio of "too little" to "too much" since 1992, when 68% said the government was doing too little. That percentage fell continuously after 1992 until it reached a low point of 51% in 2003 (Dunlap 2005).

When survey respondents were asked in 2005 to choose between two statements about tradeoffs between environmental protection and economic growth, "protection of the environment should be given priority, even at the risk of curbing economic growth" or "economic growth should be given priority, even if the environment suffers to some extent," 53% chose the former, and 36% the latter. The percentage choosing the environment rose 6 percentage points between 2003 and 2005, after declining steadily from a peak of 69% in 2000 to an all-time low of 47% in 2003 (Carlson 2005a). Similarly, the percentage favoring economic growth over the environment in 2005 was the lowest it has been since 2002 (Carlson 2005a) (figure 7-14).[42]

In 2005, about half of the respondents (53%) opposed opening up the Alaskan Arctic Wildlife Refuge for oil exploration; 42% were in favor of it, up from 35% in 2002. Polls on this subject often produce inconsistent results, because of question wording and the general public's unfamiliarity with the issue (Moore 2005a).

In 2005, a slight majority (54%) of Americans favored using nuclear energy to provide electricity, about the same

Figure 7-14
Public priorities for environmental protection versus economic growth: 1984–2005



NOTE: Responses to: *With which one of these statements about the environment and the economy do you most agree—protection of the environment should be given priority, even at the risk of curbing economic growth (or) economic growth should be given priority, even if the environment suffers to some extent?*

SOURCE: D.K. Carlson, Public priorities: environment vs. economic growth. *Gallup Poll News Service* (12 April 2005), http://www.gallup.com/poll/content?ci=15820&pg=1.

Science and Engineering Indicators 2006

as the percentage recorded a year earlier, but a slight increase over the 2001 level. However, most Americans (63%) were opposed to the construction of a nuclear energy facility where they live. Men were more likely than women to favor nuclear energy and the construction of a plant in their community (Carlson 2005c).

Attitudes Toward Technology

Americans welcome new consumer products that are based on the latest technologies. Nowhere is that more obvious than in the burgeoning market for an array of devices that enhance and expand audio and video communication capabilities. About three-fourths of the population had a home computer and/or a digital video disc (DVD) player in 2004, and nearly as many (68%) had a cell phone. In addition, almost 15% of those surveyed in 2004 said they owned a personal digital assistant (PDA) and/or had a digital video recorder (DVR) or TiVo (a digital video recording set-top device for home televisions). As mentioned earlier in this chapter, the number of households with broadband Internet connections has grown tremendously in recent years, and the vast majority of Americans also subscribe to cable or have satellite service (Pew Research Center for the People and the Press 2004). Table 7-8 shows Americans' increasing acquisition of high-technology products between 1996 and 2004.[43]

An overwhelming number of Americans have favorable views of new technological developments in general. In response to the question, "on the whole, have developments in new technology helped make society better or not," 88% answered "better," a statistic that has been roughly the same since 2001, the first year the question was asked (VCU Center for Public Policy 2004).

Surveys conducted in the United States and Canada in 2005 show that respondents share a positive view of technology in general (69% and 65%, respectively), but differ somewhat in their perception of some specific technologies (Canadian Biotechnology Secretariat 2005). In both countries, men hold a more favorable view than women, and the level of agreement rises with respondents' income level; this is true for technology in general and for most specific technology fields. The

Table 7-8
Americans' acquisition of high-technology products: Selected years, 1996–2004
(Percent)

Variable	1996	1998	2000	2002	2004
Use a computer	58[a]	61	68	71	73
Have home computer	36	43	59	65	73
Go online	1	36	54	62	66
Subscribe to cable	69	67	67	66	64
Subscribe to satellite	NA	NA	NA	NA	25
Have a…					
VCR	85[b]	NA	NA	NA	92
DVD player	NA	NA	16	44	76
Cell phone	24[a]	NA	53	64	68
Palm Pilot	NA	NA	5	11	14
DVR/TiVo	NA	NA	NA	3	13

NA = not available

[a]June 1995.
[b]February 1994.

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey (2004).

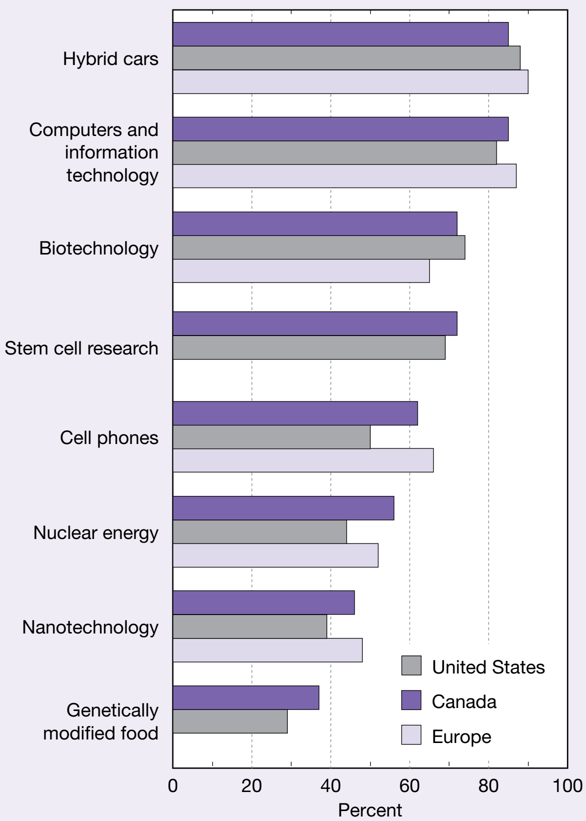
Science and Engineering Indicators 2006

same surveys also revealed considerable public support for research in the relatively new fields of biotechnology and nanotechnology, as well as confidence in the scientists who conduct the research. (See sidebar, "Americans and Canadians Share Optimistic Attitudes Toward Science and Those Who Practice It.")

Large majorities in the United States, Canada, and Europe believe that certain technologies, such as hybrid cars and computers and information technology, will "improve our way of life in the next 20 years,"[44] with not much difference between the three surveys. On the other hand, successively smaller percentages of respondents in all three (but fewer in Canada than in the United States and Europe) hold that view of cell phones, nuclear energy, and nanotechnology (figure 7-15). In addition, 40% of Americans and 52% of Canadians viewed genetically modified food as likely to "make things worse," and 28% of Americans and 39% of Canadians thought the same of nuclear energy.

In 2005, 72% of Americans thought that biotechnology would "improve our way of life in the next 20 years." This was a considerable gain over the 51% who expressed that view in 2000. In addition, the proportion who thought that biotechnology would "make things worse" in the next 20 years fell from 29% in 2000 to 13% in 2005. The pattern was similar in Europe, where the proportion of survey respondents who were optimistic about biotechnology increased from 38% in 1999 to 65% in 2005, while the proportion who were pessimistic dropped from 31% to 19% (figure 7-16).

Figure 7-15
Impact of new technologies in United States, Canada, and Europe: 2005



NOTES: Responses to: *I am going to read you a list of areas in which new technologies are currently developing. For each of these areas, do you think it will improve our way of life in the next twenty years, it will have no effect, or it will make things worse?* (In Europe, the question was worded: *For each of these, do you think it will have a positive, a negative, or no effect on our way of life in the next 20 years?*) Data are percent of responders who believe things will improve or have a positive effect.

SOURCE: Canadian Biotechnology Secretariat, Canada-U.S. Survey on Biotechnology (2005); and European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: *Social Values, Science and Technology* (2005).

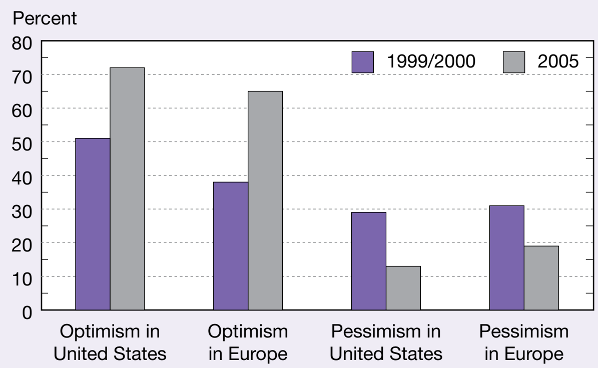
Science and Engineering Indicators 2006

Biotechnology and Medical Research

The introduction of new technologies based on genetic engineering has generated controversy during the past decade. From a nationwide recall of taco shells containing genetically modified corn not approved for human consumption to scientists promising to clone humans in the not-too-distant future, people around the world have been trying to determine whether the potential benefits of biotechnology outweigh the risks.

Most people admit to being ill informed about biotechnology. In 2003, 2004, and 2005, only 1 out of 10 Americans

Figure 7-16
Attitudes toward biotechnology in United States and Europe: 1999/2000 and 2005



NOTES: Responses to: *Science and technology change the way we live. I am going to read out a list of areas in which new technologies are currently developing. For each of these areas, do you think it will improve our way of life in the next 20 years, will have no effect, or will make things worse?* (In 2005, the question in Europe was worded: *For each of these, do you think it will have a positive, a negative or no effect on our way of life in the next 20 years?*) Percentages are for respondents who said that biotechnology will improve our way of life in the next 20 years (optimism) and for those who said that biotechnology will make things worse (pessimism). European surveys conducted in 1999 (EU-15) and 2005 (EU-25); U.S. surveys conducted in 2000 and 2005.

SOURCES: T.A. Ten Eyck, G. Gaskell, and J. Jackson, Seeds, food and trade wars: Public opinion and policy responses in the US and Europe, *Journal of Commercial Biotechnology* 10:258–67 (2004), Canadian Biotechnology Secretariat, Canada-U.S. Survey on Biotechnology (2005); and European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: *Social Values, Science and Technology* (2005).

Science and Engineering Indicators 2006

Americans and Canadians Share Optimistic Attitudes Toward Science and Those Who Practice It

In early 2005, the Canadian Biotechnology Secretariat conducted surveys in both Canada and the United States to see how the public views research in the relatively new frontiers of biotechnology and nanotechnology. The results indicate that the citizens of both countries have considerable confidence in the scientific community and its work. For example, only about 15% of those surveyed in both countries seem to have apprehensions about research in the two fields. However, although trust in the scientific community was high, government authorities in both countries did not fare as well.

The views of Americans and Canadians were very similar, but American attitudes were somewhat more favorable. For example, Americans were more likely than Canadians to strongly agree with the following statements:

- "If the best available scientific evidence says that a particular use of biotechnology—or nanotechnology—is safe, it should be allowed."
- "Biotechnology research represents the next frontier of human endeavor, a frontier that will lead to significant quality of life benefits for all." (However, when "nanotechnology" replaced "biotechnology" in this statement, American and Canadian opinions converged.)

Approximately equal (and relatively small) percentages of respondents in the two countries (12% in the United States and 16% in Canada) disagreed with the first statement. About 15% of respondents in both countries disagreed with the second statement, with regard to both biotechnology and nanotechnology.

Roughly equal numbers of Americans and Canadians (about 9 out of 10), agreed that "although there may be some unknown risks, technologies like biotechnology—and nanotechnology—are an inevitable part of the future, so all we can do is make sure that [their] uses are as safe as possible."

Americans and Canadians also hold similar views about whether decisions concerning biotechnology and nanotechnology should be based on moral and ethical considerations or mainly on scientific evidence of risk and benefit. In both countries, more respondents chose scientific evidence over moral and ethical considerations, but the margin was not large: 16 percentage points in Canada and 19 in the United States.*

In addition to optimism about biotechnology and nanotechnology, Americans and Canadians seem to have a great deal of confidence in the people responsible for research. A considerable majority (about 70%) of respondents in both countries believe that decisions about biotechnology and nanotechnology should be based mainly on the views and advice of experts, not on the views of the average citizen. Canadians have slightly less confidence than Americans in the experts.†

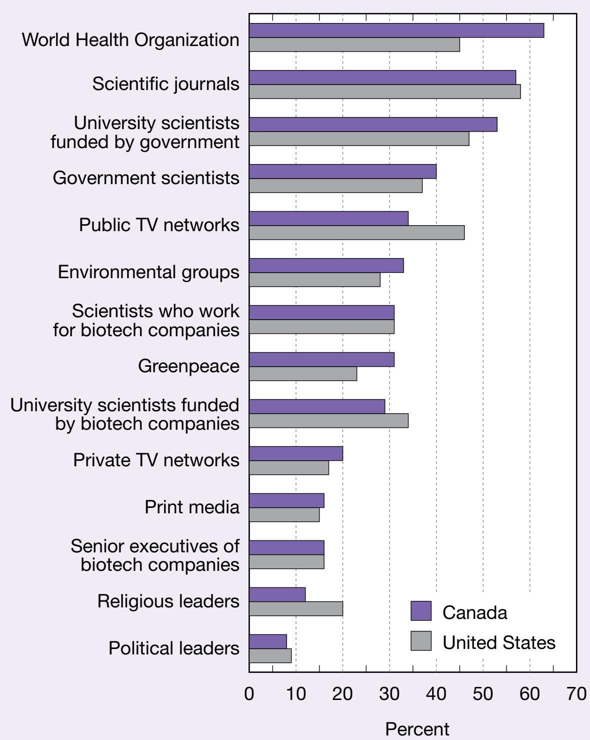
Americans were more likely than Canadians to choose the statement, "I believe that biotechnology research has been carried out in consideration of my interests, values, and beliefs" (57% versus 49%) instead of the alternative, "I believe that these types of technologies have not been developed in consideration of my interests, values, and beliefs." However, about half of those in both countries chose the first response when nanotechnology was substituted for biotechnology in the question.

A clear majority in both countries (55%–58%) said they trusted those in authority to ensure that biotechnology or nanotechnology research will follow strict ethical guidelines. However, 40% said they did not trust those in authority to do so. Moreover, 55% of Americans and 65% of Canadians said that their governments did not do enough to study and monitor the impact of biotechnology and nanotechnology products.

Both Americans and Canadians were asked to rate their trust in various institutions that could provide information about biotechnology‡ (figure 7-17). Near or at the top of the list in both countries were scientific journals and university scientists funded by the government. The

(continued on next page)

Figure 7-17
Credibility of sources of information on biotechnology: 2005



NOTES: Responses to: *For each of the following, if you were to hear information from them regarding biotechnology, how much would you trust that information to be credible, using a scale of 1–5, where 1 is not at all credible and 5 is extremely credible?* Percentages represent those who said 4 or 5.

SOURCE: Canadian Biotechnology Secretariat, Canada-U.S. Survey on Biotechnology (2005).

Science and Engineering Indicators 2006

(continued from previous page)

World Health Organization and government scientists were also in the top five. Scientists who work for biotechnology companies held a middle ranking in both countries. Among the least trusted were political leaders, senior executives of biotechnology companies, the print media, and private television networks. Although there were more similarities than differences in the level of trust accorded the various institutions in the two countries, there were a few exceptions:

- Canadians have more trust than Americans in the World Health Organization.
- Canadians are more likely than Americans to trust environmental groups and Greenpeace.
- University scientists funded by biotechnology companies enjoy more trust in the United States than in Canada.
- Americans are more likely than Canadians to trust religious leaders and public television.

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*A majority of Europeans (53%) said that decisions about S&T should be based primarily on an analysis of the risks and benefits involved. However, one-third of those surveyed thought that such decisions should be based on the moral and ethical issues involved (European Commission 2005b).

†In Europe, two-thirds of those surveyed said that decisions about science and technology should be based primarily on the advice of experts; in contrast, about a quarter of the respondents said that such decisions should be based on "the general public's views of risks and benefits" (European Commission 2005b).

‡The question was: *For each of the following, if you were to hear information from them regarding biotechnology, how much would you trust that information to be credible, using a scale of 1–5 where 1 is not at all credible and 5 is extremely credible.*

described themselves as being "very familiar" with biotechnology. In 2005, 56% thought they were somewhat familiar with it, 25% described themselves as "not very familiar," and 9% said "not at all familiar." Canadians were slightly less likely than Americans to consider themselves familiar with biotechnology (Canadian Biotechnology Secretariat 2005).[45]

When asked whether they have a positive, neutral, or negative reaction to the word biotechnology, Americans and Canadians had similar reactions. In the United States, 38% of those surveyed in 2005 said they had a positive reaction. The comparable numbers for 2004 and 2003 were 41% and 36%, respectively. The percentages were similar for Canada (Canadian Biotechnology Secretariat 2005).

In 2005, 19% of Americans said that they strongly supported "the use of products and processes that involve biotechnology." About half (52%) chose the "support" category. The remainder said they opposed biotechnology (16%) or strongly opposed it (6%). These numbers did not change between 2003 and 2005. In contrast, the number of Canadians saying they supported biotechnology increased from 51% in 2003 to 67% in 2005, and the number opposing it dropped from 37% to 28% during the same period, causing the Canadian numbers to more closely resemble those for the United States in 2005 (Canadian Biotechnology Secretariat 2005).

Americans and Canadians also held similar views of biotechnology's potential in the field of medicine. In 2005, more than 8 out of 10 respondents in each country agreed that biotechnology would be one of the most important sources of health treatments and cures in the 21st century (Canadian Biotechnology Secretariat 2005).

Americans find genetic modification of plants far more acceptable than genetic modification of animals. When asked to rate on a 10-point scale how "comfortable" they are with genetic modification of different types of life forms, respondents were most comfortable with the modification of plants (5.94 average rating), followed by microbes (4.14), animals used for food (3.73), insects (3.56), and animals used for other purposes (2.29). The survey participants were least comfortable with the genetic modification of humans (1.35). When asked specifically about genetic modification of animals, more than half (57%) of those surveyed said they opposed it; only one-third (32%) favored it. These percentages remained virtually unchanged between 2003 and 2004 (Pew Initiative on Food and Biotechnology 2004).

From a list of several possible uses for biotechnology, survey participants were most likely to support "to produce more affordable pharmaceutical drugs by using plants." More than half (54%) of those surveyed said this was a very good reason to use biotechnology. Nearly as many (52%) supported "to produce less expensive food to reduce hunger around the world" (Pew Initiative on Food and Biotechnology 2004).

Genetically Modified Food

Issues that people perceive as a possible threat to their health and safety—and that of their children—are bound to draw attention and generate controversy (see sidebar, "Are Americans Afraid of Getting Mad Cow Disease?). The persistent public concern about genetically modified (GM) food, in the United States and elsewhere in the world, is a clear example.

The first products genetically altered using biotechnology started appearing on store shelves about a decade ago. Since then, concern about their safety has stirred worldwide controversy. For example, in 2003, the European Union voted to require labeling on foods containing GM ingredients. The promised benefits of GM food—increased productivity, longer shelf life, and reduced reliance on chemical pesticides—have been offset by perceived health and environmental risks and a perceived assault on consumers' right to choose what they eat.[46]

Several major surveys that measure public opinion on GM food have been undertaken in the United States in recent years. Their findings, which are similar, are summarized below.

Are Americans Afraid of Getting Mad Cow Disease?

Most Americans have not changed their beef-eating habits because of Mad Cow Disease. In a survey conducted in January 2004, about one-fifth of those queried said they had reduced their beef consumption, and 4% said they had stopped eating beef altogether (Hallman, Schilling, and Turvey 2004).

The survey also showed that about 9 out of 10 Americans had heard of Mad Cow Disease, and nearly that many were aware of the case discovered in the United States in December 2003. However, the level of knowledge about the disease was not high. For example, only a little more than half (56%) correctly answered false to the statement, "cooking beef thoroughly will reduce the chance of getting sick from beef contaminated with mad cow disease."

About two-thirds of those surveyed thought that the nation's beef supply was safe; a somewhat higher percentage thought the beef in their local stores was safe. In addition, most expressed confidence in the government and farmers for the way they handled the case discovered in December 2003. On a scale of 1–10, with 10 the highest level of confidence, the median score for both the government and farmers was 8.

Few respondents (6%) claimed to be very worried about getting the disease. However, 7 out of 10 thought it likely that another case of it would be found in the United States.

Awareness and Knowledge

Not only are most Americans unfamiliar with GM food issues, their level of awareness has declined and their level of knowledge has not increased in recent years. In a recent survey, only 32% of respondents reported that they heard some or a great deal about genetically modified foods in 2004, a 12-point decline since 2001.[47] The public is largely dependent on the media to inform them about GM food, and when the subject receives little press coverage, their level of awareness declines (Pew Initiative on Food and Biotechnology 2004).[48]

Most people admit to not knowing much about GM food. The majority of survey respondents in the United States and Canada said they had read, seen, or heard only a little or nothing about issues involving GM food, and nearly half (47%) of Americans and more than half (59%) of Canadians said they had never discussed GM food with anyone before the survey interview (Canadian Biotechnology Secretariat 2005).

In addition, most Americans were unaware that GM ingredients have been in the food supply for some time. Only about half (48%) knew that GM food was currently available on their grocery store shelves, and only about a third (31%) said they had consumed it.[49] When asked to rate their own knowledge of GM food, about half (48%) chose the "very little" category. Another 16% said that they knew "nothing at all." Thirty percent claimed to know "a fair amount" and 5% thought they knew a great deal about GM food (Hallman et al. 2004).

In 2004, survey respondents were also asked a dozen quiz-type questions designed to test their knowledge of textbook genetics and basic facts about GM food. More than half of the respondents (58%) answered less than half of the questions correctly, and only three respondents (less than 1%) answered every question correctly.[50] Respondents' self-reported level of knowledge about GM food was only moderately related to their performance on the quiz (Hallman et al. 2004).

Attitudes

"Approval and disapproval of GM products has not changed much over the past three years" (Hallman et al. 2004). As stated earlier, Americans are more disapproving of animal-based than plant-based genetic modification. In a Food Policy Institute survey, 27% said they approved of the use of genetic modification to create plant-based food products, and 16% said the same about animal-based GM food products; 23% disapproved of plant-based GM food products, and 43% disapproved of animal-based GM products (Hallman et al. 2004).

In Europe, the most recent Eurobarometer revealed "a large diversity in public opinion at the national level on the use of genetically modified organisms for meat products or crops" (European Commission 2005b).[51]

Perceived Benefits and Risks

In judging the extent to which GM food might benefit society, on a scale of 1 to 5, 41% of Americans chose 3 (moderate benefit). About a third (31%) assigned higher scores (substantial benefits), and about a quarter (26%) gave lower scores. Almost equal numbers of Americans gave the exact same scores in response to the opposite question about how much risk GM food might pose for society. Canadians were less likely than Americans to believe in the benefits of GM foods and more likely to assign risk to them. Americans were also more likely than Canadians to think that GM food is morally and ethically acceptable. For example, 43% of Americans gave a rating of 5 (29%) or 4 (14%) in response to this question, compared with 32% of Canadians (Canadian Biotechnology Secretariat 2005).

In the most recent Pew Initiative survey, 30% of respondents agreed that GM foods are "basically safe" and 27% thought they were "basically unsafe." However, opposition to "introducing genetically modified foods into the U.S. food supply" declined from 58% in 2001 to 47% in 2004. Attitudes about the safety of GM food improved considerably when the survey participants were told that they were already consuming foods developed through biotechnology (Pew Initiative on Food and Biotechnology 2004).

In another survey conducted in 2004, 43% of Americans thought that the risks of GM foods outweighed the benefits

(38% took the opposite view), a slight decline from the 48%-to-38% split recorded in 2000 (Harris Interactive 2004b). Survey respondents recognized both advantages and disadvantages. On the plus side, 71% of respondents in 2004 (up from 66% in 2000) believed that agricultural production would increase because of GM plants and crops, and 47% (up from 42% in 2000) believed that GM crops "will make food less expensive than it would be otherwise." On the negative side, a majority (54%) in 2004 thought GM crops "will upset the balance of nature and upset the environment" (Harris Interactive 2004b).[52]

Government Regulation

Along with health and environmental concerns, labeling of GM food products is a related biotechnology issue that has received considerable attention in recent years. However, Americans appear to know very little about this topic. In 2004, most survey respondents (68%) did not know that the federal government does not require food labels to specify that a product contains GM ingredients. In addition, 88% did not know that GM crops are not tested for human safety, and 77% did not know that they are not tested for environmental safety (Hallman et al. 2004).[53]

A recent survey found a high level of confidence in the government's ability to properly regulate GM food, with three-fifths (61%) of those surveyed assigning scores of 5 or 4 (on a 5-point scale) in describing their level of confidence in the safety and regulatory approval systems of the U.S. government. Only 3% assigned a score of less than 3. Canadians expressed slightly less confidence in their government regulatory approval system (Canadian Biotechnology Secretariat 2005).

In another survey conducted in 2004, 8% of Americans who reported hearing about regulations for GM foods thought there is "too much" regulation, 19% said there is the right amount, and 40% said there is "too little." (down 5 percentage points from 2003). Among those surveyed, 85% thought regulators should ensure that GM foods are safe before they come to market, and 81% believed the FDA should approve the safety of GM foods before they come to market, even if there would be "substantial delays" (Pew Initiative on Food and Biotechnology 2004).

Labeling

Nine out of 10 Americans support the labeling of GM food and GM ingredients in processed foods (Pew Initiative on Food and Biotechnology 2004). Although the same overwhelming support for labeling was found in a 2002 survey, only half of the respondents (53%) said they would actually take the time to look for foods labeled as not being genetically modified, and less than half (45%) said they were willing to pay more for foods that had not been genetically modified (Hallman et al. 2002).

Public Trust in Scientists and Others

In the United States, scientists are considered more trustworthy than any other group involved in biotechnology issues such as GM foods. In a recent survey, scientists received more votes of confidence than medical professionals, consumer advocacy organizations, environmental organizations, universities, and farmers. Ranked lowest in trustworthiness were the federal government, media sources, industry, and (in last place) grocery stores. However, because scientists are likely to be employed by groups on the list, these data have been interpreted to indicate that survey respondents probably distinguish between scientists and the organizations that may employ them (Lang 2004) and seem to deem scientists more trustworthy than the organizations (Hallman, Hebden, and Cuite, 2004).

Another recent survey also revealed confidence in the scientists involved in biotechnology research. When asked how confident they were that GM food research is in safe hands, two-thirds of respondents in both the United States and Canada assigned a rating of 4 or 5 (on a 5-point scale, 5 being the highest rating) (Canadian Biotechnology Secretariat 2005). (For more about the views of Americans and Canadians on biotechnology research, see sidebar "Americans and Canadians Share Optimistic Attitudes Toward Science and Those Who Practice It.")[54]

Human Cloning and Stem Cell Research

Americans overwhelmingly oppose human cloning but are more divided on the subject of medical research that uses stem cells from human embryos. Support for the latter has fluctuated, but in 2004, 53% of the public expressed support for embryonic stem cell research, whereas 36% were opposed.

Human Cloning

All recent U.S. surveys that measure public opinion on human cloning have yielded similar findings: about 4 out of 5 Americans say they are opposed, and most of those say they are strongly opposed. In one survey, 66% of respondents said they were strongly opposed to human cloning, 17% were somewhat opposed, and only 13% said they favored it (VCU Center for Public Policy 2004). In another survey, 77% answered "no" to the question, "do you think that research into reproductive cloning should be allowed." In contrast, 66% said that they thought therapeutic cloning should be allowed (Research!America 2005).

Opposition to human cloning seems to be based on moral objections, not safety concerns. Moreover, public opinion on this subject has held steadfast. In annual surveys conducted between 2001 and 2004, about 9 out of 10 respondents said that cloning humans was morally wrong (Lyons 2004a).

Cloning animals evoked a lesser degree of moral objection. In 2004, 64% of those surveyed found it morally objectionable, compared with 32% who did not. Like the statistics for human cloning, these numbers have held fairly constant since 2001 (Lyons 2004a).

People may have difficulty differentiating between human reproductive cloning and human therapeutic cloning.[55] (Therapeutic cloning refers to the use of cloning technology in medical research to develop new treatments for diseases.) In 2004, only 8% of respondents described themselves as

having a "very clear" understanding of the difference between human reproductive cloning and human therapeutic cloning; 26% were "somewhat clear," 34% were "not very clear," and 30% were "not at all clear." These statistics were almost identical to those in the previous year's survey. (VCU Center for Public Policy 2004).

Opposition to therapeutic cloning is not quite as strong as opposition to human cloning in general: 38% of respondents in the 2004 VCU survey were strongly opposed to therapeutic cloning, 18% were somewhat opposed, 16% strongly favored it, and 26% somewhat favored it. College graduates were somewhat less opposed than others.

According to the most recent Eurobarometer, "Europeans seem somewhat prepared to accept cloning animals and cloning human stem cells from embryos (in exceptional circumstances or under strict control) for the sake of human health." About a third (31%) of those surveyed answered "never" when asked if they approve "cloning animals such as monkeys or pigs for research into human diseases. Opposition was highest in Switzerland, Luxembourg, and the United Kingdom, and lowest in Spain, Belgium, Hungary, and Estonia. Less than a fourth (22%) of respondents gave the "never" response when asked about "cloning human stem cells from embryos to make cells and organs that can be transplanted into people with diseases." However, a majority (59%) of Europeans are opposed to "cloning human beings so that couples can have a baby even when one partner has a genetic disease." The highest levels of opposition were in Switzerland, Luxembourg, Iceland, and France (European Commission 2005b).

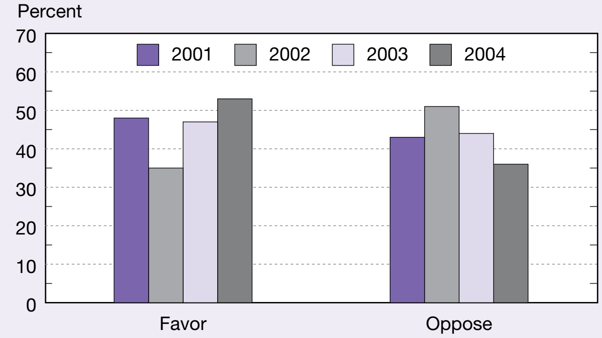
Stem Cell Research

Controversy over the federal government's role in funding embryonic stem cell research became a 2004 presidential campaign issue. In addition, several states have begun (or are considering) funding such research on their own. Four states—California, Connecticut, Illinois, and New Jersey—have allocated taxpayer funds. By far, the largest initiative is in California, where voters in 2004 approved spending $3 billion to establish the California Institute of Regenerative Medicine. California plans to spend $300 million annually during the next decade to support stem cell research.

Public opinion on stem cell research is more evenly divided than that on human cloning. However, the most recent data show an increase in public support for embryonic stem cell research between 2002 and 2004:

- After falling from 48% in 2001 to 35% in 2002, the percentage of survey respondents favoring medical research that uses stem cells from human embryos rose to 47% in 2003 and 53% in 2004 (figure 7-18). The percentage strongly favoring this type of research showed a similar pattern, doubling from 12% in 2002 to 24% in 2004. At the same time, opposition declined from 51% in 2002 to 36% in 2004, and strong opposition declined from 29% to 22% (VCU Center for Public Policy 2004).

Figure 7-18
Public attitudes toward stem cell research: 2001–04



NOTE: Responses to: *On the whole, how much do you favor or oppose medical research that uses stem cells from human embryos?*

SOURCE: Virginia Commonwealth University (VCU), Center for Public Policy, Public Opinion on Science and Biotechnology: Increasing opposition to cloning, but greater support for embryonic stem cell research, VCU Life Sciences Survey (2004).

Science and Engineering Indicators 2006

- The percentage of respondents who said that "conducting stem cell research [is more important than] not destroying the potential life of human embryos involved in this research" increased from 43% in March 2002 to 52% in August 2004 to 56% in December 2004 (Pew Research Center for the People and the Press 2005).[56]

Other surveys have explored various dimensions of Americans' opinion about embryonic stem cell research, including morality, government restrictions on funding, correlations with religious beliefs and political conservatism, and comparative views of men and women.[57] These surveys show:

- The percentage of respondents who believe that embryonic stem cell research is morally acceptable increased from 52% in 2002 to 60% in 2005. Among those surveyed, 11% thought there should be no restrictions on this type of research, 42% thought current restrictions should be eased, 24% chose "keep current restrictions," and 19% were opposed to all funding (Saad 2005).
- Religious beliefs play a major role in shaping opinions on this issue. In 2004, 77% of survey respondents who said that religion was not important to them favored stem cell research, compared with 38% of those who said that religion provides a great deal of guidance for them (VCU Center for Public Policy 2004).[58]
- Those who identified themselves as political conservatives were more likely than others to oppose stem cell research. For example, 44% of self-defined conservatives thought that conducting stem cell research was more important than reservations about destroying the potential life of human embryos, compared with 61% of moderates, and 77% of liberals (Pew Research Center for the People and the Press 2005).

- Finally, men were more likely than women (47% versus 39%) to say that conducting stem cell research was more important than reservations about destroying the potential life of human embryos. Support for this type of research also varied by age, education, and income, with younger adults, those with more formal education, and those with higher family incomes more likely than others to indicate support for stem cell research (Pew Research Center for the People and the Press 2005).

Surveys in the United States and Canada found that attitudes about stem cell research were remarkably similar in the two countries. (See sidebar, "Americans' and Canadians' Attitudes Toward Stem Cell Research Are Not That Different.")

Americans' and Canadians' Attitudes Toward Stem Cell Research Are Not That Different

According to a study conducted in early 2005, Canadians are more likely than Americans to approve of embryonic stem cell research, but the difference is not large. Canadians also expressed slightly more confidence in their country's safety and regulatory approval systems governing stem cell research and in the scientists responsible for conducting such research. (Canadian Biotechnology Secretariat 2005). However, Americans were more likely than Canadians to think they were very or somewhat familiar with the issue; say they had read, seen, or heard about issues involving stem cell research; and say they had discussed the subject with others.

Survey respondents in the United States and Canada had almost identical assessments of the benefits and risks of stem cell research: they thought the benefits are greater than the risks. On a scale of 1 (none) to 5 (substantial), two-thirds of respondents in both countries assigned scores of 4 or 5 for benefits, and only about one-fifth assigned 4 or 5 for risks. In both countries, more respondents scored risk as 3 (moderate) than any other score: 32% of U.S. respondents and 39% of Canadians. About half of the respondents in each country scored stem cell research as 4 or 5 for moral acceptability; 18% of Americans and 13% of Canadians deemed it "morally questionable" or "morally unacceptable."

Nanotechnology

Nanotechnology refers to the emerging technology of making extremely small components measured in nanometers (a nanometer is one-billionth of a meter). Though a relatively new area of research, nanotechnology is already having a major impact in many fields, including medicine, electronics, and chemistry, and it is already an important driver of innovation in manufacturing.

The science and policy communities are paying close attention to public reaction to nanotechnology-related issues. The media have recently begun to report on possible dangers and risks (e.g., that nanoparticles may be detrimental to human health), focusing attention on the adequacy of government regulation and oversight of this emerging field. Scientists fear that, as happened in Europe and elsewhere when GM foods were introduced, public opinion about nanotechnology could turn negative, potentially slowing research (Brown 2004).

Several surveys designed to gauge public opinion about nanotechnology have been undertaken recently. Findings from these surveys, summarized below, indicate that most of the public has never heard of nanotechnology, most think the benefits outweigh the risks, and views about government funding of nanotechnology research are mixed.

Awareness

In one recent study, more than half of Americans surveyed said they were not very familiar (23%) or not at all familiar (35%) with nanotechnology. A similar percentage (59%) said they had not read, seen, or heard about issues involving nanotechnology research, and 73% said they had never discussed nanotechnology research with anyone. Responses were similar in Canada (Canadian Biotechnology Secretariat 2005).

In another survey, more than 80% of those polled said they had heard "little" or "nothing" about nanotechnology (Cobb and Macoubrie 2004). In a third study, about a quarter of the respondents said they had never heard of nanotechnology—even after the interviewer provided an explanation. Only 16% said they felt somewhat informed about nanotechnology and its economic impact (Scheufele 2005). In addition, 80% of Americans were unable to name a single leading nanotechnology company (Small Times 2004).

Perceived Benefits and Risks

Although nanotechnology may have numerous unknown social, economic, and environmental consequences, and although most Americans do not know much about it (Cobb and Macoubrie 2004), the majority hold generally positive views of it. When asked to rate nanotechnology's potential benefit to society on a scale of 1 to 5 (where 1 is no benefit and 5 is substantial benefit), nearly 9 out of 10 respondents (87%) assigned scores of 5 (32%), 4 (18%), or 3 (37%). Scores were even higher when respondents were asked about nanotechnology's economic benefits. More than 8 out of 10 assigned scores of 5 (42%) or 4 (42%). Canadians' responses to these questions were similar (Canadian Biotechnology Secretariat 2005).[59]

When given a list of five options specifying benefits from nanotechnology, a majority (57%) of survey respondents selected "new and better ways to detect and treat human diseases" as the most important, followed by "new and better ways to clean up the environment" (16%), "increased national

security and defense capabilities" (12%), and ways to "improve human physical and metal abilities" (11%). Only 4% chose "cheaper, longer-lasting consumer products" as the most important benefit (Cobb and Macoubrie 2004).

When Americans and Canadians were asked to rate the risk nanotechnology may "pose for our society" on a scale of 1 (lowest) to 5 (highest), about half (49%) of the American respondents chose 3, only 14% picked 4 or 5, and about 30% chose 1 or 2. The Canadian response was almost identical (Canadian Biotechnology Secretariat 2005).

In choosing which of five potential risks was the most important to avoid, more respondents (32%) picked "losing personal privacy to tiny new surveillance devices" than any other choice. Other respondents chose "a nanotechnology inspired arms race" (24%), "breathing nano-sized particles that accumulate in your body" (19%), "economic disruption caused by the loss of traditional jobs" (14%), and "uncontrollable spread of self-replicating nano-robots" (12%) (Cobb and Macoubrie 2004).[60]

Ethics and Morality

In general, although many Americans are unfamiliar with nanotechnology, most Americans believe it to be morally and ethically acceptable. On a scale of 1 to 5, 36% of those surveyed scored it 5 and 18% scored it 4, the highest levels of moral and ethical acceptability. Only 8% had the greatest reservations, scoring it 1 or 2. Canadians were somewhat more likely than Americans to question nanotechnology's moral and ethical acceptability (Canadian Biotechnology Secretariat 2005).

Government Regulation

Most Americans and Canadians also expressed confidence in the ability of their country's safety and regulatory approval systems to monitor developments in nanotechnology. About 7 out of 10 survey participants in both countries gave their governments scores of 4 or 5 (the highest levels of confidence), and another quarter of each group were moderately confident in their country's safety and regulatory approval systems (Canadian Biotechnology Secretariat 2005).

Survey participants in the United States and Canada were asked to choose one of five statements that best captured their views about nanotechnology. In the United States, 43% chose "I approve of nanotechnology, as long as the usual levels of government regulation and control are in place," compared with 35% of Canadians. The percentages were essentially reversed for the statement "I approve of nanotechnology if it is more tightly controlled and regulated," selected by 35% of Americans and 44% of Canadians. Less than 15% in each country chose "I do not approve of nanotechnology except under very special circumstances," and only 5% of Americans and 4% of Canadians said they did "not approve of nanotechnology under any circumstances" (Canadian Biotechnology Secretariat 2005).

Confidence in Scientists and Others

Both Americans and Canadians also have a high level of confidence in the scientists who are involved in nanotechnology research. Eight out of 10 (79%) of the respondents in each country indicated that nanotechnology "is in safe hands" by assigning the scientists scores of 4 and 5; another 16% in each country gave them a score of 3 (Canadian Biotechnology Secretariat 2005).

However, most Americans seem to be distrustful of business leaders in the nanotechnology industry and their ability and willingness to minimize potential risks to humans. Six out of 10 (60%) of those surveyed said they had "not much trust" in nanotechnology business leaders, less than 5% said they had "a lot" of trust, and 35% said they had "some" trust. The respondents who were less trusting were also more likely to think nanotechnology's risks were greater than its benefits (Cobb and Macoubrie 2004).

Government Funding of Research

Various surveys have produced mixed findings about public support for government funding of nanotechnology research, as summarized below:

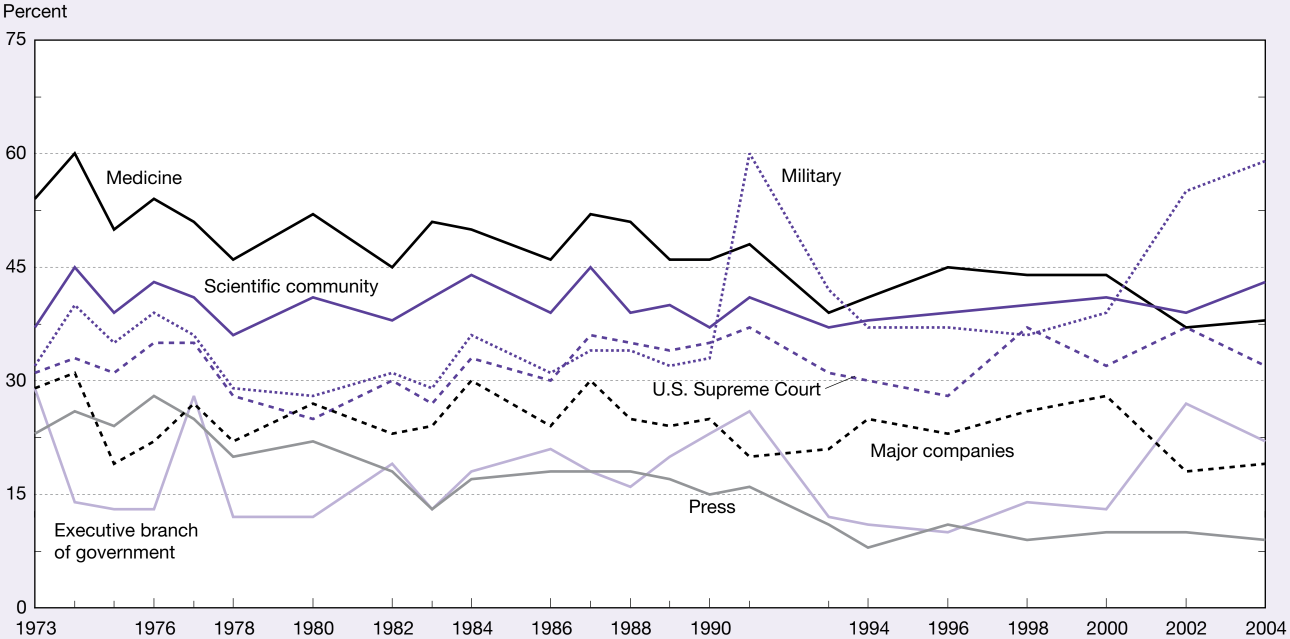
- In one survey, 42% favored increased funding for nanotechnology research, and 58% opposed it (Scheufele 2005).[61]
- In another survey, 31% of Americans and 38% of Canadians said their government should be "actively involved" in nanotechnology research, about 45% in each country said "moderately involved," and 20% of Americans and 14% of Canadians said "not involved" (Canadian Biotechnology Secretariat 2005).
- A third survey found that 60% of respondents agreed the government should increase current funding levels for nanotechnology research; 60% also agreed it is very important for state governments to get involved in nanoscience research funding (GolinHarris 2004).

Confidence in the Leadership of the Science Community

Since 2002, more people have expressed confidence in the leadership of the scientific community than in any other profession except the military. Public confidence in the leadership of various professional communities has been tracked for nearly three decades. Participants in the General Social Survey (GSS) are asked whether they have a "great deal of confidence, only some confidence, or hardly any confidence at all" in the leadership of various professional communities (Davis, Smith, and Marsden 2005). In 2004, 43% said they had a great deal of confidence in the leadership of the scientific community, marking the second time in the history of the survey (the first was in 2002) that greater confidence was expressed in science than in medicine (figure 7-19; appendix table 7-21).[62]

In 2002 and 2004, the science community might have topped the GSS confidence rankings had events not prompted

Figure 7-19
Public expressing confidence in leadership, by institution type: 1973–2004



SOURCE: J.A. Davis, T.W. Smith, and P.V. Marsden, *General Social Survey 1972–2004 Cumulative Codebook,* University of Chicago, National Opinion Research Center (2005).

Science and Engineering Indicators 2006

public focus on the military. In 2000, only 39% of the respondents said they had a great deal of confidence in the military; the number rose to 55% in 2002 and 59% in 2004. The events of September 11, 2001, and the subsequent wars in Afghanistan and Iraq are likely contributors to the increase in public confidence in the military. A similar trend was seen in the early 1990s, when confidence in the military rose from 33% in 1990 to 60% in 1991 (at the time of the Gulf War); confidence in the military then dropped to 42% in 1993.

Most of the institutions measured in the GSS saw an increase in the public's confidence in their leadership between 2002 and 2004. This was particularly true for banks and financial institutions and organized religion. Exceptions were the U.S. Supreme Court (which saw a drop in confidence from 37% to 32% between 2002 and 2004), and the executive branch of the federal government (27% in 2004, after an unprecedented increase for that institution from 13% in 2000 to 27% in 2002).

The science community has ranked second or third in the GSS public confidence survey in every year since 1973. Although the vote of confidence for the science community has fluctuated somewhat over the years, it has hovered around 40%. In contrast, the medical profession, which has ranked first in most years, has seen its vote of confidence, once as high as 60% (in 1974), gradually erode. Public confidence in the medical profession was 37% in 2002 (a low) and 38% in 2004; it ranked third in both years.

The public's confidence in the leadership of the press (9% in 2004) and television (10%) was the lowest of all institutions. These ratings have changed little in the past 10 years.

Europeans also express a lot of confidence in scientists. When asked if scientists who work at universities or in industry (doing research or developing new products) have a positive or a negative effect on society, the overwhelming majority of respondents (more than 8 out of 10) said they had a positive effect (European Commission 2005b).[63] However, about three-fifths of Europeans agreed with the following statements: "Because of their knowledge, scientists have a power that makes them dangerous" and "Scientists put too little effort into informing the public about their work" (European Commission 2005a).

Science Occupations

Most people do not encounter scientists in their daily lives. When asked if they personally knew any scientists, 82% of Americans surveyed said no (Research!America 2005).[64] In the United States and several Asian countries, surveys asked participants whether they agreed with the statement "most scientists want to work on things that will make life better for the average person." In the United States, 89% agreed with the statement in 2001, as did 85% of Chinese and 83% of Malaysian respondents. The level of agreement was lower in South Korea (77%) and Japan (60%).

Perceptions of science occupations can be assessed by examining the prestige that the public associates with them. In an August 2004 Harris poll (Harris Interactive 2004a), doctors and scientists received the highest prestige rankings out of 22 occupations. In fact, these were the only occupations seen by more than half of adults (52%) as having very great prestige. However, the 2004 number for scientists was down from that recorded in 2003 (57%), when scientist led all other occupations for the first time, with doctor ranking second at 52%. In 2004, fireman and teacher tied for third (48%), followed by military officer (47%), nurse (44%), police officer (40%), priest/minister/clergyman (32%), and member of Congress (31%) (table 7-9).

The engineering profession generally falls in the middle of the prestige rankings. In 2004, engineering ranked 10th among the 22 occupations in the survey, with 29% of the public saying it had very great prestige—about the same level as 2003, but down from 34% in 2002 and 36% in 2001.

Some notable changes have taken place during the 27 years of Harris Interactive polls about the prestige of different professions and occupations. Among the 11 occupations included in the survey since it began in 1977, only teachers saw an improvement in their rating, from 29% in 1977 to 48% in 2004. In contrast, the rating for scientists fell 14 points, from 66% to 52%, and ratings for doctors and lawyers fell 9 and 18 points, respectively.

The public's perception of science occupations can be measured in other ways. When asked how they would feel if their son or daughter wanted to become a scientist, 80% of Americans responding to the 2001 NSF survey said they would be happy with that decision (18% said they would not care and 2% said they would be unhappy). Responses were the same for both sons and daughters.[65] In contrast, in South Korea, only 54% of those surveyed in 2004 said they would feel happy if their son wanted a career in science; 57% said the same about a daughter. In Russia, only 32% of those surveyed in 2003 said they would want their son or daughter to become a researcher (down from 41% in 1995). In contrast, the Chinese rated science second highest (after medicine) as the occupation they would most like for their children (figure 7-20).

Table 7-9
Prestige of various occupations: Selected years, 1977–2004
(Percent)

Occupation	1977	1982	1992	1997	1998	2000	2001	2002	2003	2004
Scientist	66	59	57	51	55	56	53	51	57	52
Doctor	61	55	50	52	61	61	61	50	52	52
Teacher	29	28	41	49	53	53	54	47	49	48
Military officer	NA	22	32	29	34	42	40	47	46	47
Police officer	NA	NA	34	36	41	38	37	40	42	40
Priest/minister/clergyman	41	42	38	45	46	45	43	36	38	32
Member of Congress	NA	NA	24	23	25	33	24	27	30	31
Engineer	34	30	37	32	34	32	36	34	28	29
Athlete	26	20	18	21	20	21	22	21	17	21
Architect	NA	NA	NA	NA	26	26	28	27	24	20
Business executive	18	16	19	16	18	15	12	18	18	19
Lawyer	36	30	25	19	23	21	18	15	17	17
Entertainer	18	16	17	18	19	21	20	19	17	16
Union leader	NA	NA	12	14	16	16	17	14	15	16
Banker	17	17	17	15	18	15	16	15	14	15
Journalist	17	16	15	15	15	16	18	19	15	14
Accountant	NA	13	14	18	17	14	15	13	15	10

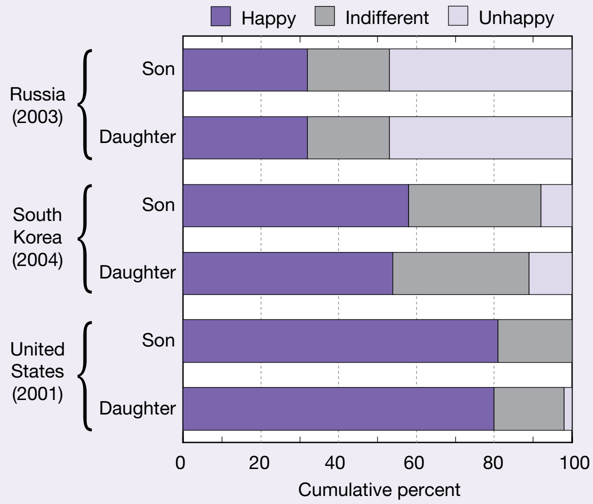
NA = not available

NOTE: Data based on "very great prestige" responses to: *I am going to read off a number of different occupations. For each, would you tell me if you feel it is an occupation of very great prestige, considerable prestige, some prestige, or hardly any prestige at all?*

SOURCE: Doctors, scientists, firemen, teachers and military officers top list as "most prestigious occupations," *The Harris Poll* 65, Harris Interactive (15 September 2004).

Science and Engineering Indicators 2006

Figure 7-20
Attitude toward science career for son or daughter: 2001, 2003, or 2004



NOTES: Responses to: *If you had a daughter, how would you feel if she wanted to be a scientist—would you feel happy, unhappy, or would you not care one way or the other?* and: *If you had a son, how would you feel if he wanted to be a scientist—would you feel happy, unhappy, or would you not care one way or the other?* Russian question slightly different: *Do you want your son/daughter to become a researcher?* Some respondents did not provide information about highest level of education. Detail may not add to total because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); South Korea Science Foundation, Survey on Public Attitude of Science & Technology 2004 (2004); and L. Gokhberg and O. Shuvalova, *Russian Public Opinion of the Knowledge Economy: Science, Innovation, Information Technology and Education,* British Council, Russia (2004).

Science and Engineering Indicators 2006

Conclusion

Americans and the citizens of other countries continue to get most of their information about the latest developments in S&T from watching television. However, the Internet has made inroads and is the leading source of information on specific scientific issues. Although Americans continue to rely most heavily on other, traditional sources of news and information, the Internet is the only news medium with an expanding audience.

Most Americans recognize and appreciate the benefits of S&T. The public is also highly supportive of the government's role in funding basic research. By most measures, American attitudes about S&T are considerably more positive than those in Europe and Japan, but about the same as those in South Korea and Malaysia.

In the United States and other countries, however, residents do not know much about S&T. In addition, their level of knowledge and understanding of scientific terms and concepts has not changed appreciably in the past few years. Perhaps more importantly, most Americans do not understand the scientific process and therefore may lack a valuable tool for assessing the validity of various claims they encounter in daily life. On a related note, evidence suggests that belief in pseudoscience is relatively widespread.

Although Americans generally have very positive attitudes about S&T and high regard for scientists, some harbor reservations about S&T, and many (70% of those surveyed) believe that scientific research does not pay enough attention to moral values. Although Americans are overwhelmingly supportive of medical applications of biotechnology, they are strongly opposed to human cloning. They are more evenly divided about genetically modified food and embryonic stem cell research. Support for the latter, however, has increased recently. Researchers are just beginning to track public attitudes toward and understanding of the emerging field of nanotechnology.

Notes

1. A recent unpublished analysis of the results of nearly 200 surveys conducted in 40 countries between 1988 and 2003 concluded that, other things being equal, the more people know about science, the more likely they are to have favorable attitudes toward it (Allum et al. 2005).

2. In a recent survey, 67% of respondents said that they "would like to see more information in newspapers, magazines, or on television about scientific and medical research," 25% said "about the same amount," and 5% said "less information" (Research!America 2005).

3. However, with increasing fragmentation of television audiences, it seems likely that exposures to science-relevant information from both media are increasingly intentional, even if those exposures are not always for a specific purpose.

4. In a survey on Americans' attitudes toward genetically modified food, most (88%) said that they had never looked for information about the subject. However, when "asked to speculate where they would turn for information about genetically modified food if they were so inclined…57% said they would search the Internet for information;…10% said they would go to the library for information" (Hallman et al. 2004).

5. In this chapter, all data for Asia (unless otherwise specified) were collected by the following: the Chinese Ministry of Science and Technology; the Korea Science Foundation; the Malaysian Science and Technology Information Centre (MASTIC) of the Ministry of Science, Technology and the Environment; and the National Institute of Science and Technology Policy of the Ministry of Education, Culture, Sports, Science and Technology in Japan. For more information, see sidebar, "Data Sources."

6. Among Asians surveyed, South Koreans were most likely to say information on the Internet is reliable and accurate, and Japanese citizens were least likely to say that (Cole 2004).

7. For example, when people were queried about their news habits on a typical day ("yesterday"), only about a quarter (24%) said they got news online, whereas 60%

watched the news on television, 42% read a daily newspaper, and 40% listened to the news on a radio. In addition, the survey revealed that people spend far less time per day obtaining news online than getting news from other sources (Pew Research Center for the People and the Press 2004).

8. In the Pew Research Center survey, 8% of those with a home computer did not have access to the Internet.

9. A study of data collected with the NSF surveys revealed that the most important predictor of home computer ownership was labor force participation (Losh 2004).

10. In the Pew Research Center survey, those respondents who reported that they go online for news were then asked if they looked for particular types of news online.

11. According to Harris Interactive polls, the most popular categories of online news are weather (sought by 60% of respondents in 2004), national news (56%), international news (44%), and local news (36%). (S&T was not among the choices given the respondents.) The Harris polls also found that the number of people who went online often or very often to obtain information about health or diseases rose from 15 to 21% between December 2003 and December 2004 (Harris Interactive 2004d).

Another survey conducted in 2004 found that 58% of respondents had used the Internet to look for information on specific diseases, 33% had looked for information on nutrition, and 32% had looked up information on prescription drugs. In 2004, most Americans thought that health information on the Internet was either strongly helpful (31%) or somewhat helpful (38%) and either very useful (23%) or somewhat useful (42%). Only 19% thought it was harmful, and 21% thought it was not useful (Research!America 2005).

12. Other surveys had similar findings (VCU Center for Public Policy 2004). When asked about their interest in scientific discoveries, only 10% of respondents said they were “not much interested,” and only 5% said they were “not at all” interested; 42% said they had “a lot” of interest, and 42% reported “some” interest. (These numbers have changed little since 2001.)

13. The VCU surveys also show a high level of interest in new medical discoveries (VCU Center for Public Policy 2004). In the 2004 survey, 46% of respondents answered “a lot” when asked how much they were personally interested in new medical discoveries; 44% answered “some”; 7%, “not much”; and 2%, “not at all.” (These numbers also have shown little variation since 2001.)

14. The Pew Research Center question was: “Now I’m going to read you a list of different types of news. Please tell me how closely you follow this type of news either in the newspaper, on television, or on radio…very closely, somewhat closely, not very closely, or not at all closely?” Note that the question did not include online news consumption.

15. Although the number of Americans who follow hard news—especially international news—has increased in recent years, interest in most news topics has remained stable (Pew Research Center for the People and the Press 2004).

16. An examination of the NSF data revealed a positive relationship between feeling well informed about S&T and providing correct answers to science literacy questions; however, the relationship was statistically weak (Losh et al. 2003).

17. Researchers have concluded that fewer than one-fifth of Americans meet a minimal standard of civic scientific literacy (Miller, Pardo, and Niwa 1997).

18. In Europe, residents of Sweden, the Czech Republic, Finland, the Netherlands, Norway, Denmark, and Slovenia have the highest rates of scientific knowledge, and Portugal, Malta, Latvia, Bulgaria, Cyprus and Turkey the lowest. Also, in Europe, men, persons between the ages of 15 and 54, those with more years of formal schooling, and those who do not attend religious services are more likely than others to provide correct responses to questions designed to test their knowledge of science (European Commission 2005a).

19. In China, only 1.4% of the population possessed basic scientific literacy in 2001. The percentage was higher among men (1.7%) and urban residents (3.1%) (Chinese Ministry of Science and Technology 2002).

20. In its own international comparison of scientific literacy, Japan ranked itself 10th of 14 countries included in the report (National Institute of Science and Technology Policy 2002).

21. A recent analysis of public opinion concerning evolution suggests that “many members of the public underestimate the scientific evidence in support of evolution and overestimate the evidence supporting intelligent design” (Nisbet and Nisbet 2005).

22. The cover of the November 2004 issue of *National Geographic Magazine* asked *“Was Darwin Wrong?”* The 33-page article concluded that “[t]he evidence for evolution is overwhelming.”

23. The National Science Board issued a statement on the subject in August 1999 (National Science Board 1999).

24. In a 2005 CBS/*New York Times* poll, 57% of those surveyed favored teaching creationism along with evolution in public schools, down from 65% 4 months earlier. In the same 2005 poll, 35% favored teaching creationism instead of evolution in public schools, down from 37% in the previous survey. About half of those surveyed in both 2004 and 2005 opposed teaching creationism instead of evolution.

25. The question pertaining to experimental evaluation was: “Now, please think of this situation. Two scientists want to know if a certain drug is effective in treating high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure, and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience lower blood pressure levels. Which is the better way to test this drug? Why is it better to test the drug this way?”

The text of the probability question in 2004 was: “Now think about this situation. A doctor tells a couple that their ‘genetic makeup’ means that they’ve got one in four chances

of having a child with an inherited illness. Does this mean that if their first child has the illness, the next three will not? Does this mean that each of the couple's children will have the same risk of suffering from the illness?"

26. Correct explanations of scientific study include responses describing it as theory testing, experimentation, or rigorous, systematic comparison.

27. Similar to questions about scientific facts and concepts, younger respondents, those with more formal education and higher incomes, and those without minor children at home were more likely than others to give correct responses to questions about the scientific process (appendix table 7-13).

28. According to one group studying such phenomena, pseudoscientific topics include yogi flying, therapeutic touch, astrology, fire walking, voodoo magical thinking, alternative medicine, channeling, Carlos hoax, psychic hotlines and detectives, near-death experiences, unidentified flying objects and alien abductions, the Bermuda Triangle, homeopathy, faith healing, and reincarnation (Committee for the Scientific Investigation of Claims of the Paranormal 2003).

29. Those 10 items were extrasensory perception (ESP), that houses can be haunted, ghosts/that spirits of dead people can come back in certain places/situations, telepathy/communication between minds without using traditional senses, clairvoyance/the power of the mind to know the past and predict the future, astrology/that the position of the stars and planets can affect people's lives, that people can communicate mentally with someone who has died, witches, reincarnation/the rebirth of the soul in a new body after death, and channeling/allowing a "spirit-being" to temporarily assume control of a body.

30. In the 2001 NSF survey, 56% of those surveyed agreed that astrology is "not at all scientific," 9% said it is "very scientific," and 31% thought it "sort of scientific." The difference between the 2001 and 2004 data may be attributable to differences in questionnaire design in the 2 years.

31. Countries with the highest levels of agreement were Italy, Latvia, the Czech Republic, Ireland, and Austria. The "least convinced" were in the Netherlands, Luxembourg, and Finland (European Commission 2005a).

32. The question wording was: "Have the benefits of scientific research outweighed the harmful results?"

33. In the United States, agreement with this statement is positively related to education and level of family income (appendix table 7-17).

34. Norway had the highest level of agreement with this statement (74%), followed by Poland (65%), Hungary (63%), Lithuania (63%), and Portugal (60%). The Netherlands (39%) and Slovenia (40%) had the lowest agreement rates, and Finland had the highest disagreement rate (30%) (European Commission 2005a).

35. Another survey found similar (79%) support for government funding of scientific research in 2004 (Research! America 2005).

36. In addition, 83% of Europeans agreed that "basic scientific research is essential for the development of new technologies" (European Commission 2001).

37. According to an annual survey commissioned by the Association of American Medical Colleges, 41% of congressional staff surveyed said that they did not know how and where the NIH budget supports medical research. In another survey of voters conducted by the same organization, 40% said they had never heard of NIH; 31% said they had a favorable opinion of the agency. Many voters (47%) and congressional staffers (35%) erroneously believed that most medical research is carried out by private industry (McInturff and Harrington 2004).

38. In Russia, 76% of those surveyed in 2003 thought that "funds allocated by the government for support of scientific research" were not sufficient, up from 65% recorded in 1997. In 2003, 9% said that such funds were "fairly sufficient," 1% said "more than sufficient," and 14% said they did not know (Gokhberg and Shuvalova 2004).

39. According to a survey conducted in mid-2005, about three-fourths of Americans favor continuing the manned space shuttle program. Surprisingly, support for the shuttle program was even greater immediately after the loss of the Challenger in 1986 (80%) and the Columbia in 2003 (82%). Although a large majority of Americans support the program, and most give NASA's overall performance high marks, support for space exploration declines when respondents are reminded of the expense. In 2005, 58% of those surveyed opposed allocating government funds for a manned trip to Mars, slightly higher than the percentages recorded in 1999 and 1969 (Newport 2005).

40. In recent years, few survey respondents (less than 5%) have mentioned the environment when asked to name the most important problem facing the country today. The story was quite different in the 1970s, after the first Earth Day celebration, when significantly higher percentages of survey participants mentioned the environment (Saad 2005).

41. The Gallup researchers concluded that the "global warming disaster movie—*The Day After Tomorrow*—[which] was the No. 6 top-grossing movie of the year…doesn't appear to have stirred up a great deal of alarm among Americans about global warming" (Saad 2005).

42. In Europe, 89% of those surveyed agreed that "we have a duty to protect nature, even if this means limiting human progress." About half (51%) agreed that "exploiting nature may be unavoidable if humankind is to progress," and 43% agreed that "we have a right to exploit nature for the sake of human well being" (European Commission 2005b).

43. In Europe, half of those surveyed agreed that "many high-tech products are just gadgets," indicating "negative opinion on technological developments linked to the economy." At least 60% of the citizens of Sweden, Norway, Germany, Cyprus, and Luxembourg agreed with the statement (European Commission 2005a).

44. In Europe, the 2005 question was worded "for each of these, do you think it will have a positive, a negative or no effect on our way of life in the next 20 years?"

45. In another series of surveys in the United States, almost half of those queried had heard or read "nothing at all" about genetic engineering or biotechnology; a little over a quarter had heard or read "not much." In addition, nearly two-thirds of those surveyed in 2004 reported that they had never discussed biotechnology, genetic engineering, or genetic modification with anyone (Hallman et al. 2004).

46. Fears that have prompted consumers' concerns include the possible development of food allergies resulting from unknown gene combinations, increased resistance to antibiotics through ingestion of food with antibiotic-resistant genes, and potential toxicity from foods modified to produce pesticides.

47. In a 2005 survey, 12% of Americans described themselves as being very familiar with GM food, 54% said they were somewhat familiar with it, 21% said not very, and 13% said that they were not at all familiar with it; statistics for Canadians were similar (Canadian Biotechnology Secretariat 2005).

48. In January 2001, shortly after widespread media coverage of the Starlink incident (the discovery of unapproved GM corn in the food supply), 44% of those surveyed said they had heard some or a great deal about GM foods. Subsequently, without a similar story making frontpage headlines in more recent years, the level of awareness fell. In 2004, only 32% said they had heard some or a great deal about GM foods (Pew Initiative on Food and Biotechnology 2004). In addition, most Americans were unable to recall news stories about GM food (Hallman et al. 2004).

49. Those who claimed to be aware that GM foods were available in their supermarkets were asked to estimate how many years the products have been available to consumers. The median guess—10 years—was accurate. However, many were confused about which products contained GM ingredients (Hallman et al 2004).

50. For most of the questions, about half of the respondents chose the "unsure" option. For example, 40% of respondents correctly answered "false" to the statement "ordinary tomatoes do not contain genes while GM tomatoes do." However, 51% said they were unsure.

51. More than half (54%) of Europeans surveyed answered "never" in response to a question asking if they approve "growing meat from cell cultures so that we don't have to slaughter farm animals." However, fewer respondents gave the same response to two other items: "developing genetically modified crops to increase the variety of regionally grown foods" (37%) and "developing genetically modified bacteria that could clean up the environment after environmental catastrophes" (19%) (European Commission 2005b).

52. In the Pew Initiative study, those who felt positively toward GM food cited higher yields, food lasting longer, and benefits to developing countries as the major advantages. Those who were concerned were more likely to say that it was wrong to tamper with nature and were more likely to worry about long-term effects on health (Pew Initiative on Food and Biotechnology 2004).

53. In another survey conducted in 2004, 83% of respondents said they knew "not too much" or "nothing at all" about the federal regulation of GM foods. These numbers were virtually unchanged from the previous years (Pew Initiative on Food and Biotechnology 2004).

54. The 2005 Eurobarometer asked several questions about public perceptions of the relationship between policymakers and the field of science. About three-fourths of Europeans surveyed believed that politicians should rely more on the advice of expert scientists. Only about a third agreed that "research conducted by industry is well controlled and regulated" and that "there should be no limit to what science is allowed to investigate on." In addition, half of those surveyed agreed with two different statements: "if a new technology poses a risk that is not fully understood, the development of this technology should be stopped even if it offers clear benefits"; and "if we attach too much importance to risks that are not yet fully understood, we will miss out on technological progress" (European Commission 2005a).

55. The questions used in the Gallup surveys did not differentiate between reproductive and therapeutic cloning (Lyons 2004a). According to the author, the results of an earlier (2002) survey (that asked about both reproductive and other types of cloning) "strongly suggest that respondents are thinking about cloning that results in the creation of a human being when they are simply asked for their views on 'human cloning.' The 2002 poll found higher support for more limited types of cloning, including 59% for cloning organs to be used in medical transplants and 51% for cloning human cells from adults to use in medical research."

56. In the same survey, the percentage of respondents who said they had heard a lot about the issue of stem cell research increased from 27% in March 2002 to 47% in December 2004. Those who said they had heard a lot were more likely than others to say they supported stem cell research (Pew Research Center for the People and the Press 2005).

57. Other surveys provide comparisons with Canadian and British public opinion on embryonic stem cell research. In 2004, 54% of Americans said that embryonic stem cell research was morally acceptable, compared with 61% of Canadians and 57% of the residents of Great Britain. In all three countries, those who said that religion was very important in their daily lives were less likely to believe that stem cell research was morally acceptable than were those who said religion was "fairly important" or "not very important" in their daily lives (Lyons 2004b). For more comparisons between Americans and Canadians on this issue, see sidebar

"Americans' and Canadians' Attitudes Toward Stem Cell Research Are Not That Different."

58. An analysis of the VCU data found that religion might act as a "perceptual screen" on this issue. According to the analysis, for most Americans, the more they reported hearing, reading, or seeing about the issue, the greater their support for embryonic stem cell research. However, among highly religious Americans, regardless of how much more they reported hearing, reading, or seeing about stem cell research, their opinions remained relatively unchanged, which suggests that very religious people may only pay attention to arguments about the issue that confirm their initial reservations (Nisbet 2005).

59. In another survey, about the same number of respondents said that nanotechnology would produce more benefits than risks (40%) and that risks and benefits would be about equal (38%). Only 22% predicted that risks would outweigh benefits (Cobb and Macoubrie 2004). Another researcher found that survey respondents who were aware of nanotechnology held significantly more optimistic views of its potential benefits than those who were not aware of it, but no relationship between factual knowledge about nanotechnology and optimism about its benefits (Scheufele 2005.).

60. The "nano-robot" response is a scenario from *Prey,* a novel by Michael Crichton.

61. Those who were aware of nanotechnology were more likely than others to express support for it. However, factual knowledge about nanotechnology does not seem to have a significant effect on attitudes toward nanotechnology in general, support for increased funding, or risk/benefit perceptions. Nearly half (49%) of the respondents who were aware of nanotechnology said they supported increased financial support for research, compared with only 22% of the unaware group (Scheufele 2005).

62. In China and South Korea, scientists are accorded the highest level of prestige, and medical doctors are ranked second in both countries. In Russia, scientists ranked eighth in terms of the most respected occupations, after lawyer, businessman, politician, programmer, skilled worker, doctor, and teacher. Engineering ranked fourteenth, lower than journalist, artist/actor/writer, tradesman, farmer, and soldier.

63. When the Eurobarometer survey asked "for each of these different people and groups involved in science and technology, do you think that what they do has a positive or a negative effect on society," the following percentages of positive responses were obtained: scientists in university (88%), television and radio reporting on science and technology (86%), consumer organizations testing new products (86%), scientists in industry doing research (85%), newspapers and magazines reporting on science and technology (83%), industry developing new products (81%), environmental groups campaigning on issues related to science and technology (80%), citizens who get involved in debates about science and technology (78%), public authorities assessing the risks that may come from new technologies (78%), animal rights groups campaigning about the treatment of animals (77%), the European Commission regulating science and technology for all European Union countries (75%), and public authorities regulating science and technology (73%) (European Commission 2005b).

64. The 18% who said they did know a scientist were then asked what fields those scientists worked in. Biotechnology/medical/pharmaceutical got the highest number of responses (22%), followed by biology/anatomy/genetics/microbiology (14%), chemistry (11%), physics/nuclear physics (11%), environmental science (5%), and engineering/rocket science (5%); 31% responded "other fields" (Research!America 2005).

65. In Europe, three-fourths of those surveyed agreed that "girls and young women should be further encouraged to take up studies and careers in science"; only 7% held the opposite viewpoint. The highest rates of agreement were in Malta, Ireland, Portugal, Sweden, Cyprus, Poland, Iceland, and Norway, and the lowest were in Latvia and the Czech Republic (European Commission 2005b).

Glossary

Pseudoscience: "Claims presented so that they appear [to be] scientific even though they lack supporting evidence and plausibility" (Shermer 1997, p. 33).

Science: "A set of methods designed to describe and interpret observed and inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation" (Shermer 1997, p. 17).

Scientific literacy: Knowing basic facts and concepts about science and having an understanding of how science works.

Therapeutic cloning: Use of cloning technology in medical research to develop new treatments for diseases; differentiated from human reproductive cloning.

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Chapter 8
State Indicators

Elementary/Secondary Education

Higher Education

Workforce

Financial Research and Development Inputs

R&D Outputs

Science and Technology in the Economy

List of Tables

List of Figures

Introduction

Chapter Overview

In response to increasing interest in both the policy and research communities about the role of science and technology (S&T) in state and regional economic development, a new experimental chapter devoted to the subject was introduced in the 2004 edition of *Science and Engineering Indicators*. This chapter has been expanded in the 2006 edition from the original 24 state indicators to 42.

The chapter focuses on the performance of individual states, the District of Columbia, and Puerto Rico. Although data for Puerto Rico are reported whenever available, they frequently were collected by a different source, making it unclear whether the methodology used for data collection and analysis is comparable with that used for the states. For this reason, Puerto Rico was neither ranked with the states nor assigned a quartile value that could be displayed on the maps. Including data for U.S. territories and protectorates, such as American Samoa, Guam, Northern Mariana Islands, and Virgin Islands, was considered; however, data for these areas were available only on a sporadic basis and for fewer than one-quarter of the indicators, so they were not included.

These indicators are designed to present information about various aspects of state S&T infrastructure and to stimulate discussion about appropriate uses of state-level S&T indicators. The data used to calculate the indicators were gathered from both public and private sources. Whenever possible, data covering a 10-year span are provided to identify meaningful trends. However, because consistent data were not always available for the 10-year period, data for certain indicators are given only for the years in which comparisons are appropriate.

Ready access to accurate and timely information is an important tool for formulating effective S&T policies at the state level. By studying the programs and performance of their peers, state policymakers may be able to better assess and enhance their own programs and performance. The tables are intended to give the user a convenient listing of some of the quantitative data that may be relevant to technology-based economic development. In addition to describing the behavior of an indicator, the "Findings" section frequently presents an interpretation of the behavior's relevance and meaning. The interpretation is sometimes speculative, with the objective of motivating further thought and discussion.

Types of Indicators

Forty-two indicators are included in this chapter and grouped into the following areas:

- Elementary and secondary education
- Higher education
- Workforce
- Financial research and development inputs
- Research and development outputs
- S&T in the economy

The first two areas address state educational attainment. In this edition of *Indicators*, emphasis has been increased on the science and mathematics skills students develop at the elementary and middle school levels. Student achievement is expressed in terms of performance, which refers to the average state score on a standardized test, and proficiency, which is expressed as the percentage of students who have achieved at least the expected level of competence on the standardized test. Other indicators in educational attainment focus on state spending, student costs, and undergraduate and graduate degrees in science and engineering.

Workforce indicators focus on the level of S&E training in the employed labor force. These indicators reflect the higher education level of the labor force and the degree of specialization in S&E disciplines and occupations.

Financial indicators address the sources and level of funding for R&D. They show how much R&D is being performed relative to the size of a state's business base. Comparison of these indicators illustrates the extent to which R&D is conducted by industrial or academic performers.

The final two sections provide measures of outputs. The first focuses on the work products of the academic community and includes the production of new doctorate holders, the publication of academic articles, and patent activity both from the academic community and from all sources in the state.

The second section of output indicators examines the robustness of a region's S&T activity. These indicators include venture capital activity, Small Business Innovation Research awards, and high-technology business activity. Although data that adequately address both the quantity and quality of R&D results are difficult to find, these indicators offer a reasonable information base.

Data Sources and Considerations

Raw data for each indicator are presented in the tables. The first entry in each table represents the average value for the states. For most indicators, the state average was calculated by summing the values for the 50 states and the District of Columbia for both the numerator and the denominator and then dividing the two. Any alternate approach is indicated in the notes at the bottom of the table.

The values for most indicators are expressed as ratios or percentages to remove the effect of state size and facilitate comparison between large and small states or heavily and sparsely populated states. For example, an indicator of higher education achievement is not defined as the absolute number of degrees conferred in a state because sparsely populated states are neither likely to have nor need as extensive a higher education system as states with larger populations. Instead, the indicator is defined as the number of degrees per number of residents in the college-age cohort, which measures the intensity of educational services relative to the size of the resident population.

No official list of high-technology industries or sanctioned methodology to identify the most technology-intensive industries exists in the United States. The definition used here was developed by the U.S. Department of Commerce's Technology Administration in concert with the U.S. Department of Labor's Bureau of Labor Statistics. See "Technical Note: Defining High-Technology Industries."

Key Elements for Indicators

Six key elements are provided for each indicator. The first element is a map that is color-coded to show in which quartile each state placed on that indicator for the latest year that data are available. This helps the reader quickly grasp geographic trends. The sample map below shows the outline of each state. On the indicator maps, the darkest color indicates states ranking in the first or highest quartile, and white indicates states ranking in the fourth or lowest quartile. Cross-hatching indicates states for which no data are available.

The second element is a quartiles table. States are listed alphabetically by quartile. The range of indicator values for that quartile is shown at the top of the column. Ties at quartile breaks were resolved by moving the tied states into one quartile. All of the indicators are broad measures, and several rely on sample estimates that have a margin of error. Small differences in state values generally carry little useful information.

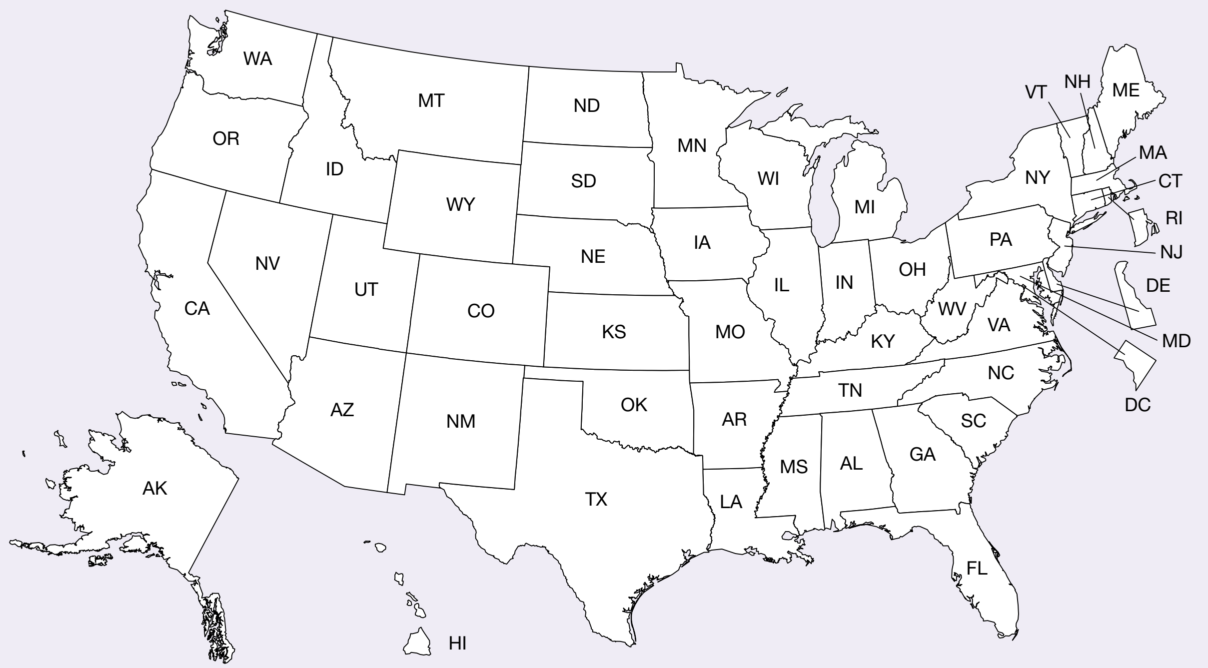
The third element, at the bottom of the map box, is a short citation for the data source. The full citation appears under the table on the facing page.

The fourth element, in a shaded box on the lower left side of the page, is a summary of findings that includes the national average and comments on trends and patterns for the particular indicator. Although most of the findings are directly related to the data, some represent interpretations that are meant to stimulate further investigation and discussion.

The fifth element, on the lower right side of the page, is a description of the indicator, a brief note about the nature of the data, and other information pertaining to the data.

The final element is the data table that appears on the facing page. Up to 3 years of data and the calculated values of the indicator are presented for each state, the District of Columbia, and Puerto Rico. Puerto Rico is included in the data table only when data are available.

U.S. Map and List of Abbreviations



AK........ Alaska
AL........ Alabama
AR........ Arkansas
AZ........ Arizona
CA........ California
CO....... Colorado
CT........ Connecticut
DC....... District of Columbia
DE........ Delaware
FL........ Florida
GA....... Georgia

HI.........Hawaii
IA.........Iowa
ID.........Idaho
IL..........Illinois
IN.........Indiana
KS........Kansas
KY........Kentucky
LA........Louisiana
MA.......Massachusetts
MD.......Maryland

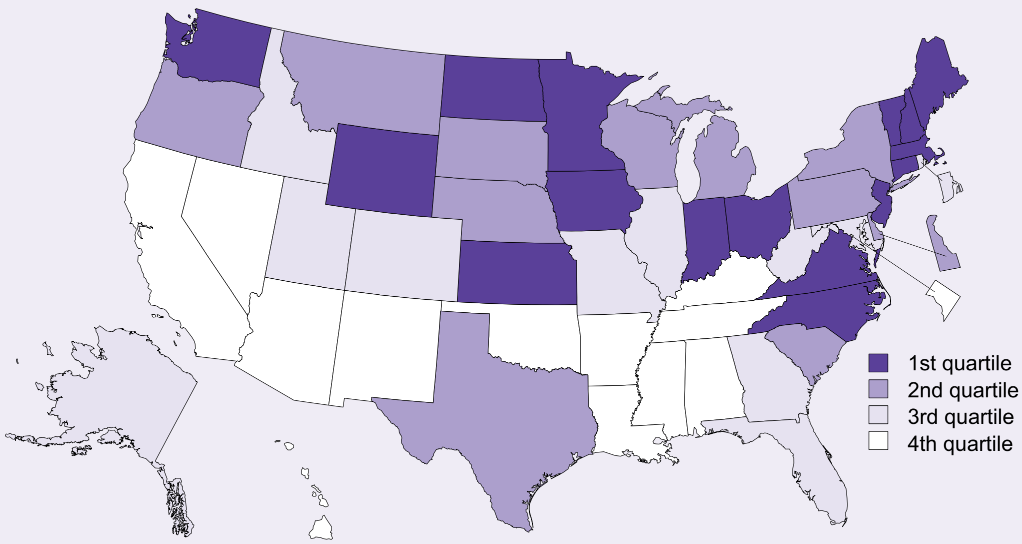
ME........Maine
MI.........Michigan
MN........Minnesota
MO.......Missouri
MS........Mississippi
MT........Montana
NC........North Carolina
ND........North Dakota
NE.........Nebraska
NH........New Hampshire

NJ.........New Jersey
NM.......New Mexico
NV........Nevada
NY........New York
OH........Ohio
OK........Oklahoma
OR........Oregon
PA.........Pennsylvania
RI..........Rhode Island
SC........South Carolina

SD........South Dakota
TN........Tennessee
TX.........Texas
UT........Utah
VA.........Virginia
VT.........Vermont
WA........Washington
WI.........Wisconsin
WV........West Virginia
WY.......Wyoming

Fourth Grade Mathematics Performance

Figure 8-1
Fourth grade mathematics performance: 2003



1st quartile (243–238)	2nd quartile (237–236)	3rd quartile (235–230)	4th quartile (229–205)
Connecticut	Delaware	Alaska	Alabama
Indiana	Michigan	Colorado	Arizona
Iowa	Montana	Florida	Arkansas
Kansas	Nebraska	Georgia	California
Maine	New York	Idaho	District of Columbia
Massachusetts	Oregon	Illinois	Hawaii
Minnesota	Pennsylvania	Maryland	Kentucky
New Hampshire	South Carolina	Missouri	Louisiana
New Jersey	South Dakota	Rhode Island	Mississippi
North Carolina	Texas	Utah	Nevada
North Dakota	Wisconsin	West Virginia	New Mexico
Ohio			Oklahoma
Vermont			Tennessee
Virginia			
Washington			
Wyoming			

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-1.

Findings

- Nationwide, fourth grade students in public schools showed improvement in mathematics mastery as average scale scores for testing with accommodations rose from 222 in 1996 and 224 in 2000 to 234 in 2003.
- Within the limits of statistical significance, 24 states exceeded the 2003 national average mathematics score, 11 had average scores, and 15 fell below the national average.
- All states for which 2000 and 2003 mathematics scores were obtained showed increases in 2003 when the results of testing with accommodations were compared.
- Gains in scores between 2000 and 2003 were detected throughout the entire student sample at all levels of performance.

Mathematics achievement at the fourth grade level lays the foundation for future mathematics education. The National Assessment of Educational Progress (NAEP) is a federally authorized ongoing assessment of student performance in various subjects on a state and national scale. All 50 states and the District of Columbia participated in the 2003 assessment of fourth grade achievement in mathematics. This indicator reports the average score in mathematics for fourth grade students in public schools across each state.

National and state results are reported for only public school students. Beginning in 2002, NAEP obtained the national sample by aggregating the samples from each state rather than by selecting an independent national sample. In 1996, NAEP started permitting students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, small-group testing). National data with and without accommodations were published beginning in 1996, but state-level data with accommodations were not published until 2000. In math, only accommodations-permitted data are available at the state level for 2003. These data are not comparable with data from students who were not permitted accommodations.

Student performance is described in terms of average scores on a scale from 0 to 500.

Table 8-1
Fourth grade mathematics performance, by state: 1996, 2000, and 2003
(Score)

State	1996[a]	2000[a]	2000	2003
National average	222	226	224	234
Alabama	212	218	217	223
Alaska	224	NA	NA	233
Arizona	218	219	219	229
Arkansas	216	217	216	229
California	209	214	213	227
Colorado	226	NA	NA	235
Connecticut	232	234	234	241
Delaware	215	NA	NA	236
District of Columbia	187	193	192	205
Florida	216	NA	NA	234
Georgia	215	220	219	230
Hawaii	215	216	216	227
Idaho	NA	227	224	235
Illinois	NA	225	223	233
Indiana	229	234	233	238
Iowa	229	233	231	238
Kansas	NA	232	232	242
Kentucky	220	221	219	229
Louisiana	209	218	218	226
Maine	232	231	230	238
Maryland	221	222	222	233
Massachusetts	229	235	233	242
Michigan	226	231	229	236
Minnesota	232	235	234	242
Mississippi	208	211	211	223
Missouri	225	229	228	235
Montana	228	230	228	236
Nebraska	228	226	225	236
Nevada	218	220	220	228
New Hampshire	NA	NA	NA	243
New Jersey	227	NA	NA	239
New Mexico	214	214	213	223
New York	223	227	225	236
North Carolina	224	232	230	242
North Dakota	231	231	230	238
Ohio	NA	231	230	238
Oklahoma	NA	225	224	229
Oregon	223	227	224	236
Pennsylvania	226	NA	NA	236
Rhode Island	220	225	224	230
South Carolina	213	220	220	236
South Dakota	NA	NA	NA	237
Tennessee	219	220	220	228
Texas	229	233	231	237
Utah	227	227	227	235
Vermont	225	232	232	242
Virginia	223	230	230	239
Washington	225	NA	NA	238
West Virginia	223	225	223	231
Wisconsin	231	NA	NA	237
Wyoming	223	229	229	241

NA = not available

[a]Accommodations not permitted.

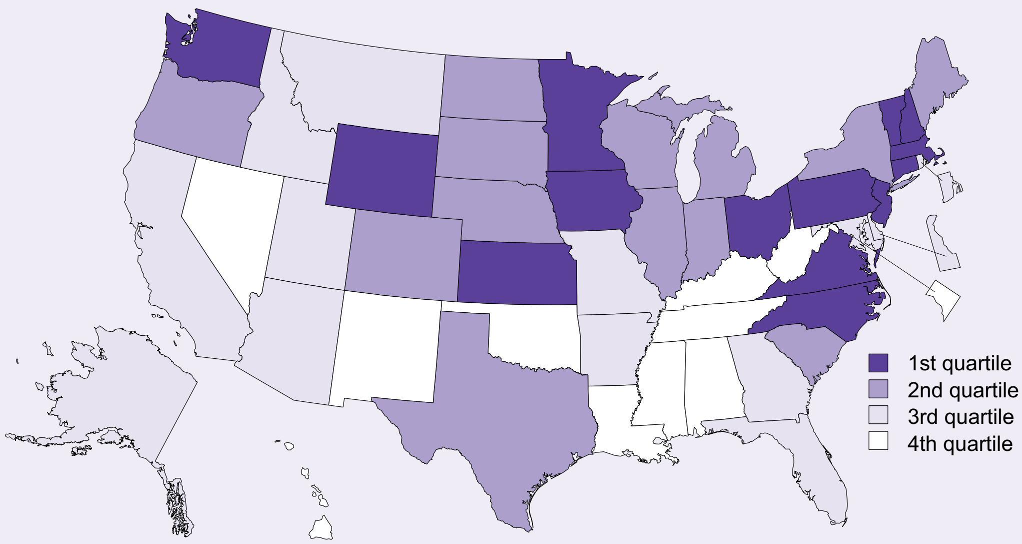
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 mathematics scores are for public schools only. Comparative performance results may be affected by changes in exclusion rates for students with disabilities and limited English proficiency students in NAEP samples. In addition to allowing for accommodations, the accommodations-permitted results for national public schools (2000 and 2003) differ slightly from previous years' results and from previously reported results for 2000 because of changes in sample weighting procedures.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, various years.

Science and Engineering Indicators 2006

Fourth Grade Mathematics Proficiency

Figure 8-2
Fourth grade mathematics proficiency: 2003



1st quartile (43%–36%)	2nd quartile (35%–32%)	3rd quartile (31%–25%)	4th quartile (24%–7%)
Connecticut	Colorado	Alaska	Alabama
Iowa	Illinois	Arizona	District of Columbia
Kansas	Indiana	Arkansas	Hawaii
Massachusetts	Maine	California	Kentucky
Minnesota	Michigan	Delaware	Louisiana
New Hampshire	Nebraska	Florida	Mississippi
New Jersey	New York	Georgia	Nevada
North Carolina	North Dakota	Idaho	New Mexico
Ohio	Oregon	Maryland	Oklahoma
Pennsylvania	South Carolina	Missouri	Tennessee
Vermont	South Dakota	Montana	West Virginia
Virginia	Texas	Rhode Island	
Washington	Wisconsin	Utah	
Wyoming			

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-2.

Findings

- In 2003, the nationwide percentage of fourth grade public school students who performed at or above the proficient level in mathematics was 31%, which represented a significant increase from 22% in 2000 and 19% in 1996 based on testing with accommodations.
- The proportion of fourth graders reaching the proficient achievement level was 43% for whites, 10% for blacks, 16% for Hispanics, 48% for Asians/Pacific Islanders, and 17% for American Indians/Alaska Natives.
- Gender differences in mathematics proficiency were observed among fourth grade students; 34% of males reached the proficient level compared with 29% of females.

This indicator provides a measure of the extent to which a state's fourth grade students in public schools have achieved proficiency in mathematics. High values show that a high percentage of a state's fourth graders have demonstrated a solid foundation for adult mathematics competency. Such competency is an important characteristic of a state's future workforce.

Proficiency in mathematics is based on achievement level in the National Assessment of Educational Progress (NAEP) 2003 Mathematics Assessment. Achievement levels represent performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP.

The basic level (scores of 214–248) denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at the fourth grade level. The proficient level (249–281) represents solid academic performance at the fourth grade level. Students who reach this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter. The advanced level (282–500) signifies superior performance. Approximately 190,100 fourth grade students participated in the NAEP assessment.

Table 8-2
Fourth grade mathematics proficiency, by state: 1996, 2000, and 2003
(Percent)

State	1996[a]	2000[a]	2000	2003
National average	20	25	22	31
Alabama	11	14	13	19
Alaska	21	NA	NA	30
Arizona	15	17	16	25
Arkansas	13	13	14	26
California	11	15	13	25
Colorado	22	NA	NA	34
Connecticut	31	32	31	41
Delaware	16	NA	NA	31
District of Columbia	5	6	5	7
Florida	15	NA	NA	31
Georgia	13	18	17	27
Hawaii	16	14	14	23
Idaho	NA	21	20	31
Illinois	NA	21	20	32
Indiana	24	31	30	35
Iowa	22	28	26	36
Kansas	NA	30	29	41
Kentucky	16	17	17	22
Louisiana	8	14	14	21
Maine	27	25	23	34
Maryland	22	22	21	31
Massachusetts	24	33	31	41
Michigan	23	29	28	34
Minnesota	29	34	33	42
Mississippi	8	9	9	17
Missouri	20	23	23	30
Montana	22	25	24	31
Nebraska	24	24	24	34
Nevada	14	16	16	23
New Hampshire	NA	NA	NA	43
New Jersey	25	NA	NA	39
New Mexico	13	12	12	17
New York	20	22	21	33
North Carolina	21	28	25	41
North Dakota	24	25	25	34
Ohio	NA	26	25	36
Oklahoma	NA	16	16	23
Oregon	21	23	23	33
Pennsylvania	20	NA	NA	36
Rhode Island	17	23	22	28
South Carolina	12	18	18	32
South Dakota	NA	NA	NA	34
Tennessee	17	18	18	24
Texas	25	27	25	33
Utah	23	24	23	31
Vermont	23	29	29	42
Virginia	19	25	24	36
Washington	21	NA	NA	36
West Virginia	19	18	17	24
Wisconsin	27	NA	NA	35
Wyoming	19	25	25	39

NA = not available

[a]Accommodations not permitted.

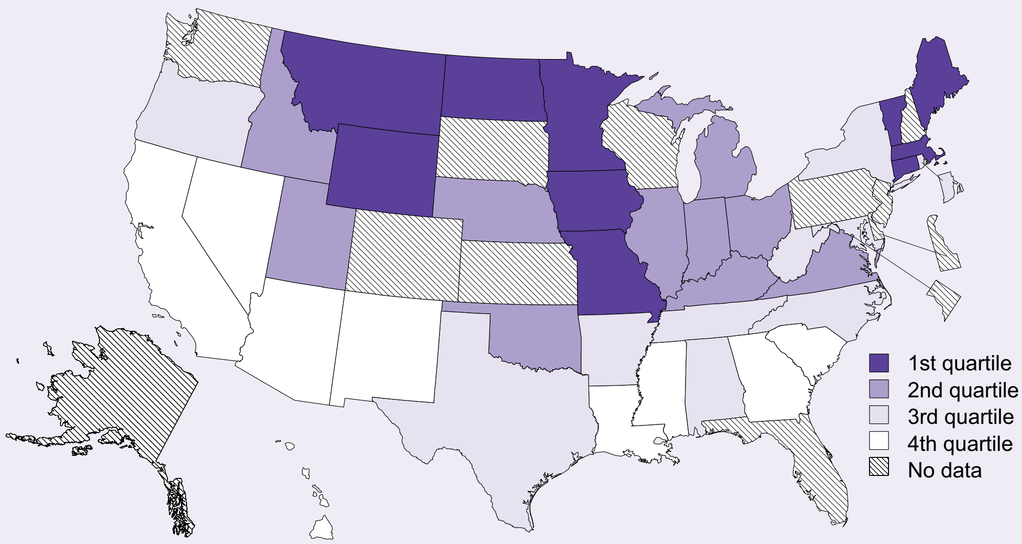
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 mathematics scores are for public schools only. Comparative performance results may be affected by changes in exclusion rates for students with disabilities and limited English proficiency students in NAEP samples. In addition to allowing for accommodations, accommodations-permitted results for national public schools (2000 and 2003) differ slightly from previous years' results and from previously reported results for 2000 because of changes in sample weighting procedures.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, various years.

Science and Engineering Indicators 2006

Fourth Grade Science Performance

Figure 8-3
Fourth grade science performance: 2000



1st quartile (161–156)	2nd quartile (155–150)	3rd quartile (149–143)	4th quartile (142–129)	No data
Connecticut	Idaho	Alabama	Arizona	Alaska
Iowa	Illinois	Arkansas	California	Colorado
Maine	Indiana	Maryland	Georgia	Delaware
Massachusetts	Kentucky	New York	Hawaii	District of Columbia
Minnesota	Michigan	North Carolina	Louisiana	Florida
Missouri	Nebraska	Oregon	Mississippi	Kansas
Montana	Ohio	Rhode Island	Nevada	New Hampshire
North Dakota	Oklahoma	Tennessee	New Mexico	New Jersey
Vermont	Utah	Texas	South Carolina	Pennsylvania
Wyoming	Virginia	West Virginia		South Dakota
				Washington
				Wisconsin

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-3.

Findings

- Nationally, fourth graders in public schools had an average score of 148 in both the 1996 and 2000 science assessments when accommodations were not permitted.
- State-level data are available only for 2000 when 11 states and the District of Columbia did not meet minimum participation guidelines.
- Within the limits of statistical significance, 18 states exceeded the 2000 national average science score, 11 had average scores, and 10 fell below the national average.
- Between the 1996 and 2000 assessments, the average scale scores for various percentiles of student performance remained unchanged.

Science achievement at the fourth grade level lays the foundation for future science education. The National Assessment of Educational Progress (NAEP) is a federally authorized ongoing assessment of student performance in various subjects on a state and national scale. State participation is optional. NAEP does not compute scores for states that do not meet the minimum guidelines for the percentage of students or schools participating. This indicator reports the average scores in science for fourth grade students in public schools across each state.

For the fourth grade, a national sample and separate state-by-state samples were used. Both national and state results are reported only for public school students. In 1996, NAEP started permitting students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, small-group testing). At grade 4, the accommodations-permitted average score was one point lower than the accommodations-not-permitted average score for national data in 2000. The differences in state-level data were not statistically significant.

The NAEP science scale ranges from 0 to 300.

Table 8-3
Fourth grade science performance, by state: 2000
(Score)

State	2000[a]	2000
National average	148	147
Alabama	143	143
Alaska	NA	NA
Arizona	141	140
Arkansas	144	145
California	131	129
Colorado	NA	NA
Connecticut	156	156
Delaware	NA	NA
District of Columbia	NA	NA
Florida	NA	NA
Georgia	143	142
Hawaii	136	136
Idaho	153	152
Illinois	151	150
Indiana	155	154
Iowa	160	159
Kansas	NA	NA
Kentucky	152	152
Louisiana	139	139
Maine	161	161
Maryland	146	145
Massachusetts	162	161
Michigan	154	152
Minnesota	157	157
Mississippi	133	133
Missouri	156	157
Montana	160	160
Nebraska	150	150
Nevada	142	142
New Hampshire	NA	NA
New Jersey	NA	NA
New Mexico	138	140
New York	149	148
North Carolina	148	147
North Dakota	160	160
Ohio	154	155
Oklahoma	152	151
Oregon	150	148
Pennsylvania	NA	NA
Rhode Island	148	148
South Carolina	141	140
South Dakota	NA	NA
Tennessee	147	145
Texas	147	145
Utah	155	154
Vermont	159	160
Virginia	156	155
Washington	NA	NA
West Virginia	150	149
Wisconsin	NA	NA
Wyoming	158	156

NA = not available (did not meet minimum participation guidelines)

[a]Accommodations not permitted.

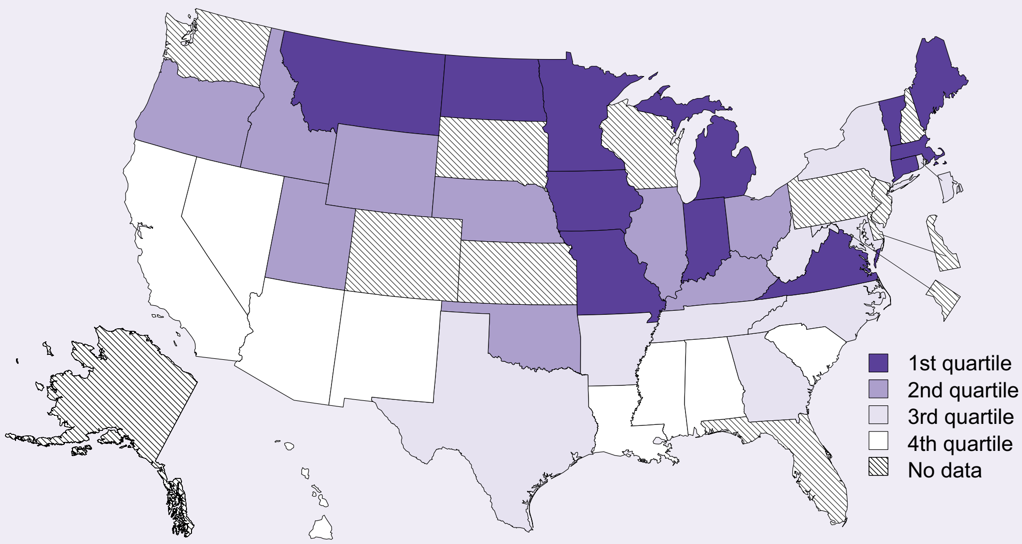
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) report. NAEP grade 4 science scores are for public schools only. California, Idaho, Illinois, Indiana, Iowa, Maine, Michigan, Minnesota, Montana, New York, Ohio, Oregon, and Vermont met minimum participation guidelines but did not meet one or more guidelines for school participation.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress.

Science and Engineering Indicators 2006

Fourth Grade Science Proficiency

Figure 8-4
Fourth grade science proficiency: 2000



1st quartile (42%–32%)	2nd quartile (31%–26%)	3rd quartile (25%–23%)	4th quartile (22%–13%)	No data
Connecticut	Idaho	Arkansas	Alabama	Alaska
Indiana	Illinois	Georgia	Arizona	Colorado
Iowa	Kentucky	Maryland	California	Delaware
Maine	Nebraska	New York	Hawaii	District of Columbia
Massachusetts	Ohio	North Carolina	Louisiana	Florida
Michigan	Oklahoma	Rhode Island	Mississippi	Kansas
Minnesota	Oregon	Tennessee	Nevada	New Hampshire
Missouri	Utah	Texas	New Mexico	New Jersey
Montana	Wyoming	West Virginia	South Carolina	Pennsylvania
North Dakota				South Dakota
Vermont				Washington
Virginia				Wisconsin

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-4.

Findings

- The nationwide percentage of fourth grade public school students who performed at or above the proficient level in science was 28% in 2000 and 27% in 1996 in testing without accommodations.
- The proportion of fourth graders reaching the proficient achievement level in science was 38% for whites, 7% for blacks, 11% for Hispanics, and 19% for American Indians/Alaska Natives in 2000. Data for Asians/Pacific Islanders were not reported.
- Gender differences in science proficiency were observed among fourth grade students; 33% of males reached the proficient level compared with 26% of females.

This indicator provides a measure of the extent to which a state's fourth grade students in public schools have achieved proficiency in science. High values show that a high percentage of a state's fourth grade students have demonstrated a solid foundation for adult science competency. Such competency is an important characteristic of a state's future workforce.

Proficiency in science is based on achievement level in the National Assessment of Educational Progress (NAEP) 2000 Science Assessment. Achievement levels represent performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP.

The basic level (138–169) denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at the fourth grade level. The proficient level (170–204) represents solid academic performance at the fourth grade level. Students who reach this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter. The advanced level (205–300) signifies superior performance in science.

A National Academy of Sciences panel evaluated the process used to establish the achievement levels for the science assessment and urged that they be considered developmental and interpreted with caution.

Table 8-4
Fourth grade science proficiency, by state: 2000
(Percent)

State	2000[a]	2000
National average	28	27
Alabama	22	22
Alaska	NA	NA
Arizona	22	22
Arkansas	24	23
California	14	13
Colorado	NA	NA
Connecticut	35	35
Delaware	NA	NA
District of Columbia	NA	NA
Florida	NA	NA
Georgia	23	23
Hawaii	16	16
Idaho	30	29
Illinois	31	31
Indiana	32	32
Iowa	37	36
Kansas	NA	NA
Kentucky	29	28
Louisiana	19	18
Maine	38	37
Maryland	26	24
Massachusetts	43	42
Michigan	33	32
Minnesota	35	34
Mississippi	14	13
Missouri	35	34
Montana	37	36
Nebraska	26	26
Nevada	19	19
New Hampshire	NA	NA
New Jersey	NA	NA
New Mexico	18	17
New York	26	24
North Carolina	24	23
North Dakota	38	36
Ohio	31	31
Oklahoma	26	26
Oregon	28	27
Pennsylvania	NA	NA
Rhode Island	27	25
South Carolina	21	20
South Dakota	NA	NA
Tennessee	26	24
Texas	24	23
Utah	32	31
Vermont	39	38
Virginia	33	32
Washington	NA	NA
West Virginia	25	24
Wisconsin	NA	NA
Wyoming	33	31

NA = not available (did not meet minimum participation guidelines)

[a]Accommodations not permitted.

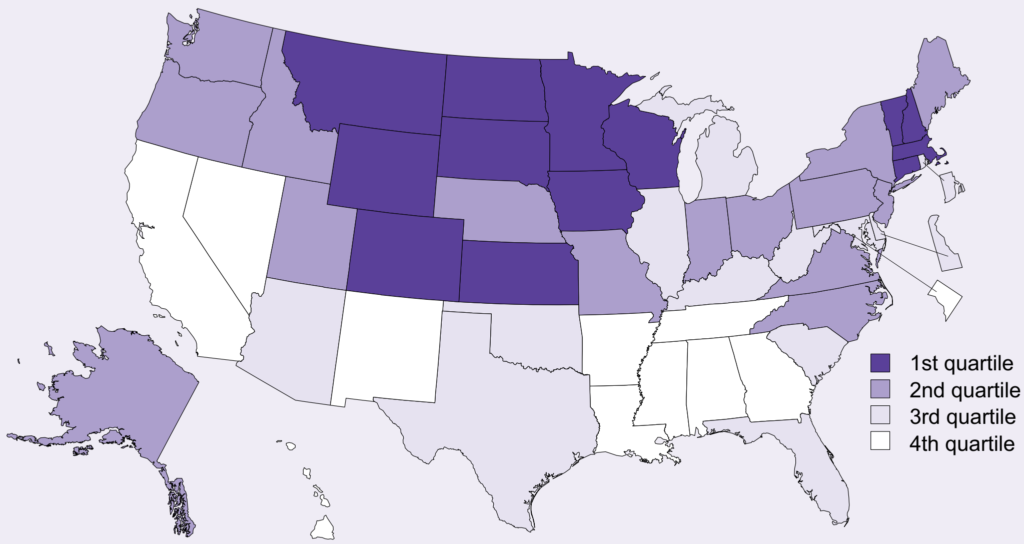
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) report. NAEP grade 4 science scores are for public schools only. California, Idaho, Illinois, Indiana, Iowa, Maine, Michigan, Minnesota, Montana, New York, Ohio, Oregon, and Vermont met minimum participation guidelines but did not meet one or more guidelines for school participation.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress.

Science and Engineering Indicators 2006

Eighth Grade Mathematics Performance

Figure 8-5
Eighth grade mathematics performance: 2003



1st quartile (291–283)	2nd quartile (282–279)	3rd quartile (278–271)	4th quartile (270–243)
Colorado	Alaska	Arizona	Alabama
Connecticut	Idaho	Delaware	Arkansas
Iowa	Indiana	Florida	California
Kansas	Maine	Illinois	District of Columbia
Massachusetts	Missouri	Kentucky	Georgia
Minnesota	Nebraska	Maryland	Hawaii
Montana	New Jersey	Michigan	Louisiana
New Hampshire	New York	Oklahoma	Mississippi
North Dakota	North Carolina	Rhode Island	Nevada
South Dakota	Ohio	South Carolina	New Mexico
Vermont	Oregon	Texas	Tennessee
Wisconsin	Pennsylvania	West Virginia	
Wyoming	Utah		
	Virginia		
	Washington		

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-5.

Findings

- Nationwide, eighth grade students in public schools showed increases in mathematics mastery as average scale scores for the accommodations-permitted sample rose from 269 in 1996 and 272 in 2000 to 276 in 2003.
- Within the limits of statistical significance, 28 states exceeded the 2003 national average mathematics score, 7 had average scores, and 15 fell below the national average.
- Gains in score between 2000 and 2003 occurred throughout the entire student sample at all levels of performance. They ranged from 3 scale points for students who performed at the 90th percentile to 7 scale points for students who performed at the 10th percentile.

Mathematics achievement at the eighth grade level indicates how prepared students are to undertake high school mathematics studies and acquire key skills needed for careers in science and technology. The National Assessment of Educational Progress (NAEP), a federally authorized ongoing assessment of student performance in various subjects on a state and national scale, assessed eighth grade achievement in mathematics in 2003. All 50 states participated.

National and state results are based on only public school students. Beginning in 2002, NAEP obtained the national sample by aggregating state samples rather than by selecting an independent national sample. Since 1996, NAEP permitted students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, small-group testing). National-level data with and without accommodations were published beginning in 1996, but state-level data with accommodations were not published until 2000. In math, only accommodations-permitted data are available at the state level for 2003. These data are not comparable with data from students who were not permitted accommodations.

Student performance is described in terms of average scores on a scale from 0 to 500.

Table 8-5
Eighth grade mathematics performance, by state: 1996, 2000, and 2003
(Score)

State	1996[a]	2000[a]	2000	2003
National average	271	274	272	276
Alabama	257	262	264	262
Alaska	278	NA	NA	279
Arizona	268	271	269	271
Arkansas	262	261	257	266
California	263	262	260	267
Colorado	276	NA	NA	283
Connecticut	280	282	281	284
Delaware	267	NA	NA	277
District of Columbia	233	234	235	243
Florida	264	NA	NA	271
Georgia	262	266	265	270
Hawaii	262	263	262	266
Idaho	NA	278	277	280
Illinois	NA	277	275	277
Indiana	276	283	281	281
Iowa	284	NA	NA	284
Kansas	NA	284	283	284
Kentucky	267	272	270	274
Louisiana	252	259	259	266
Maine	284	284	281	282
Maryland	270	276	272	278
Massachusetts	278	283	279	287
Michigan	277	278	277	276
Minnesota	284	288	287	291
Mississippi	250	254	254	261
Missouri	273	274	271	279
Montana	283	287	285	286
Nebraska	283	281	280	282
Nevada	NA	268	265	268
New Hampshire	NA	NA	NA	286
New Jersey	NA	NA	NA	281
New Mexico	262	260	259	263
New York	270	276	271	280
North Carolina	268	280	276	281
North Dakota	284	283	282	287
Ohio	NA	283	281	282
Oklahoma	NA	272	270	272
Oregon	276	281	280	281
Pennsylvania	NA	NA	NA	279
Rhode Island	269	273	269	272
South Carolina	261	266	265	277
South Dakota	NA	NA	NA	285
Tennessee	263	263	262	268
Texas	270	275	273	277
Utah	277	275	274	281
Vermont	279	283	281	286
Virginia	270	277	275	282
Washington	276	NA	NA	281
West Virginia	265	271	266	271
Wisconsin	283	NA	NA	284
Wyoming	275	277	276	284

NA = not available

[a]Accommodations not permitted.

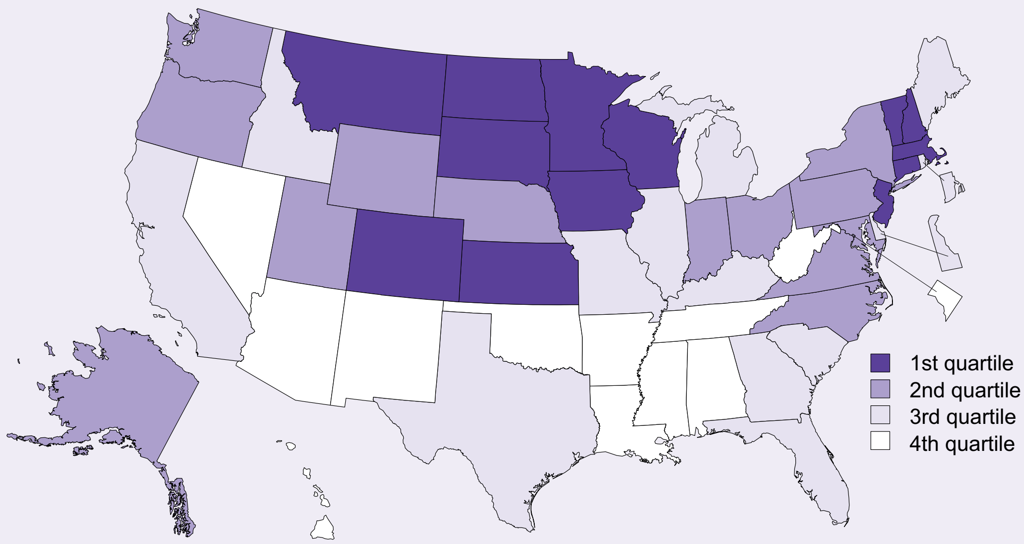
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 mathematics scores are for public schools only. Comparative performance results may be affected by changes in exclusion rates for students with disabilities and limited English proficiency students in NAEP samples. In addition to allowing for accommodations, accommodations-permitted results for national public schools (2000 and 2003) differ slightly from previous years' results and from previously reported results for 2000 because of changes in sample weighting procedures.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, various years.

Science and Engineering Indicators 2006

Eighth Grade Mathematics Proficiency

Figure 8-6
Eighth grade mathematics proficiency: 2003



1st quartile (44%–33%)	2nd quartile (32%–30%)	3rd quartile (29%–22%)	4th quartile (21%–6%)
Colorado	Alaska	California	Alabama
Connecticut	Indiana	Delaware	Arizona
Iowa	Maryland	Florida	Arkansas
Kansas	Nebraska	Georgia	District of Columbia
Massachusetts	New York	Idaho	Hawaii
Minnesota	North Carolina	Illinois	Louisiana
Montana	Ohio	Kentucky	Mississippi
New Hampshire	Oregon	Maine	Nevada
New Jersey	Pennsylvania	Michigan	New Mexico
North Dakota	Utah	Missouri	Oklahoma
South Dakota	Virginia	Rhode Island	Tennessee
Vermont	Washington	South Carolina	West Virginia
Wisconsin	Wyoming	Texas	

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-6.

Findings

- In 2003, the nationwide percentage of eighth grade public school students who performed at or above the proficient level in mathematics was 27%, an increase from 25% in 2000 and 22% in 1996 based on testing with accommodations.
- The proportion of eighth grade students who reached the proficient achievement level was 35% for whites, 7% for blacks, 10% for Hispanics, 41% for Asians/Pacific Islanders, and 9% for American Indians/ Alaska Natives.
- Gender differences in mathematics proficiency were smaller in the eighth grade (3%) than in the fourth grade (5%). Among eighth grade students, 29% of males reached the proficient level in mathematics compared with 26% of females.

This indicator provides a measure of the extent to which a state's eighth grade students in public schools have achieved proficiency in mathematics. High values show that a high percentage of a state's eighth graders have demonstrated the ability to undertake the study of high school mathematics, a prerequisite to the further study of science and engineering and a necessary life skill.

Proficiency in mathematics is based on achievement level in the National Assessment of Educational Progress (NAEP) 2003 Mathematics Assessment. Achievement levels represent performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP.

The basic level (262–298) denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at the eighth grade level. The proficient level (299–332) represents solid academic performance at the eighth grade level. Students who reach this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter. The advanced level (333–500) signifies superior performance. Approximately 153,200 eighth graders participated in the NAEP assessment.

Table 8-6
Eighth grade mathematics proficiency, by state: 1996, 2000, and 2003
(Percent)

State	1996[a]	2000[a]	2000	2003
National average	23	26	25	27
Alabama	12	16	16	16
Alaska	30	NA	NA	30
Arizona	18	21	20	21
Arkansas	13	14	13	19
California	17	18	17	22
Colorado	25	NA	NA	34
Connecticut	31	34	33	35
Delaware	19	NA	NA	26
District of Columbia	5	6	6	6
Florida	17	NA	NA	23
Georgia	16	19	19	22
Hawaii	16	16	16	17
Idaho	NA	27	26	28
Illinois	NA	27	26	29
Indiana	24	31	29	31
Iowa	31	NA	NA	33
Kansas	NA	34	34	34
Kentucky	16	21	20	24
Louisiana	7	12	11	17
Maine	31	32	30	29
Maryland	24	29	27	30
Massachusetts	28	32	30	38
Michigan	28	28	28	28
Minnesota	34	40	39	44
Mississippi	7	8	9	12
Missouri	22	22	21	28
Montana	32	37	36	35
Nebraska	31	31	30	32
Nevada	NA	20	18	20
New Hampshire	NA	NA	NA	35
New Jersey	NA	NA	NA	33
New Mexico	14	13	12	15
New York	22	26	24	32
North Carolina	20	30	27	32
North Dakota	33	31	30	36
Ohio	NA	31	30	30
Oklahoma	NA	19	18	20
Oregon	26	32	31	32
Pennsylvania	NA	NA	NA	30
Rhode Island	20	24	22	24
South Carolina	14	18	17	26
South Dakota	NA	NA	NA	35
Tennessee	15	17	16	21
Texas	21	24	24	25
Utah	24	26	25	31
Vermont	27	32	31	35
Virginia	21	26	25	31
Washington	26	NA	NA	32
West Virginia	14	18	17	20
Wisconsin	32	NA	NA	35
Wyoming	22	25	23	32

NA = not available

[a]Accommodations not permitted.

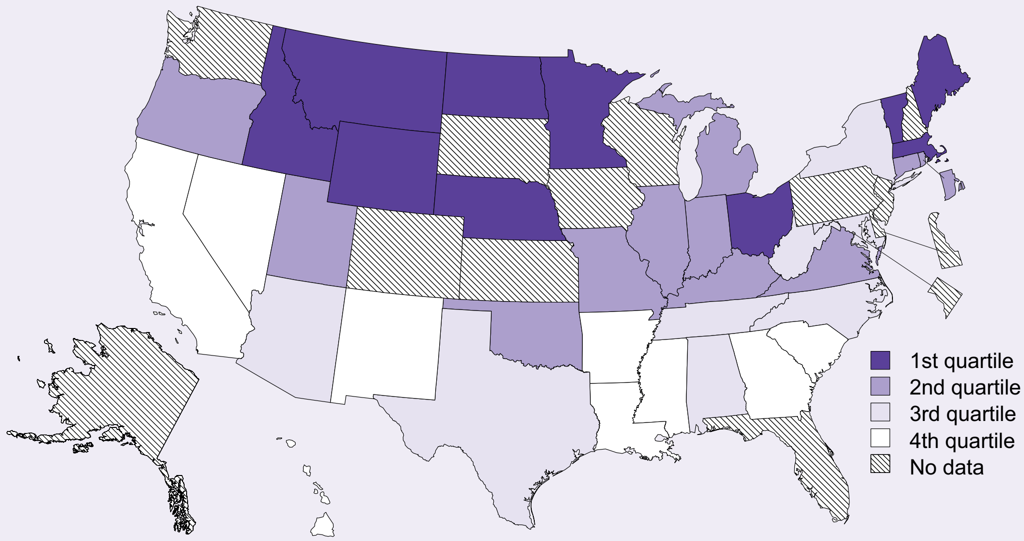
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 mathematics scores are for public schools only. Comparative performance results may be affected by changes in exclusion rates for students with disabilities and limited English proficiency students in NAEP samples. In addition to allowing for accommodations, accommodations-permitted results for national public schools (2000 and 2003) differ slightly from previous years' results and from previously reported results for 2000 because of changes in sample weighting procedures.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, various years.

Science and Engineering Indicators 2006

Eighth Grade Science Performance

Figure 8-7
Eighth grade science performance: 2000



1st quartile (164–156)	2nd quartile (155–148)	3rd quartile (146–143)	4th quartile (142–129)	No data
Idaho	Connecticut	Alabama	Arkansas	Alaska
Maine	Illinois	Arizona	California	Colorado
Massachusetts	Indiana	Maryland	Georgia	Delaware
Minnesota	Kentucky	New York	Hawaii	District of Columbia
Montana	Michigan	North Carolina	Louisiana	Florida
Nebraska	Missouri	Tennessee	Mississippi	Iowa
North Dakota	Oklahoma	Texas	Nevada	Kansas
Ohio	Oregon	West Virginia	New Mexico	New Hampshire
Vermont	Rhode Island		South Carolina	New Jersey
Wyoming	Utah			Pennsylvania
	Virginia			South Dakota
				Washington
				Wisconsin

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-7.

Findings

- Nationally, eighth grade students in public schools had an average score of 149 in the 2000 science assessment, which is not statistically different from the 1996 average science score of 148. Both scores represent samples in which accommodations were not permitted.
- Within the limits of statistical significance, 16 states exceeded the 2000 national average science score, 11 had average scores, and 11 fell below the national average.
- A statistically significant increase was observed in the scale score of the 90th percentile of the national sample, which indicates that the top performing students improved between the 1996 and 2000 assessments. Scale scores for the remaining students were not significantly different in the two assessments.

Science achievement at the eighth grade level is important because it represents how prepared students are to undertake high school courses in biology, chemistry, and physics. This indicator measures the knowledge of a state's eighth grade students in science.

The National Assessment of Educational Progress (NAEP) is a federally authorized ongoing assessment of student achievement in various subjects on a state and national scale. State participation is optional. NAEP does not compute scores for states that do not meet the minimum guidelines for the percentage of students or schools participating. For the eighth grade, a national sample and separate state-by-state samples were conducted. Both national and state results are reported only for public school students. Since 1996, NAEP permitted students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, small-group testing). At grade 8, the accommodations-permitted average score was identical to the accommodations-not-permitted average score for national data. The differences in state-level data were not statistically significant.

The NAEP science scale ranges from 0 to 300.

Table 8-7
Eighth grade science performance, by state: 1996 and 2000
(Score)

State	1996[a]	2000[a]	2000
National average	148	149	149
Alabama	139	141	143
Alaska	NA	NA	NA
Arizona	145	146	145
Arkansas	144	143	142
California	138	132	129
Colorado	NA	NA	NA
Connecticut	155	154	153
Delaware	NA	NA	NA
District of Columbia	NA	NA	NA
Florida	NA	NA	NA
Georgia	142	144	142
Hawaii	135	132	130
Idaho	NA	159	158
Illinois	NA	150	148
Indiana	153	156	154
Iowa	NA	NA	NA
Kansas	NA	NA	NA
Kentucky	147	152	150
Louisiana	132	136	134
Maine	163	160	158
Maryland	145	149	146
Massachusetts	157	161	158
Michigan	153	156	155
Minnesota	159	160	159
Mississippi	133	134	134
Missouri	151	156	154
Montana	162	165	164
Nebraska	157	157	158
Nevada	NA	143	141
New Hampshire	NA	NA	NA
New Jersey	NA	NA	NA
New Mexico	141	140	139
New York	146	149	145
North Carolina	147	147	145
North Dakota	162	161	159
Ohio	NA	161	159
Oklahoma	NA	149	149
Oregon	155	154	154
Pennsylvania	NA	NA	NA
Rhode Island	149	150	148
South Carolina	139	142	140
South Dakota	NA	NA	NA
Tennessee	143	146	145
Texas	145	144	143
Utah	156	155	154
Vermont	157	161	159
Virginia	149	152	151
Washington	NA	NA	NA
West Virginia	147	150	146
Wisconsin	NA	NA	NA
Wyoming	158	158	156

NA = not available (did not meet minimum participation guidelines)

[a]Accommodations not permitted.

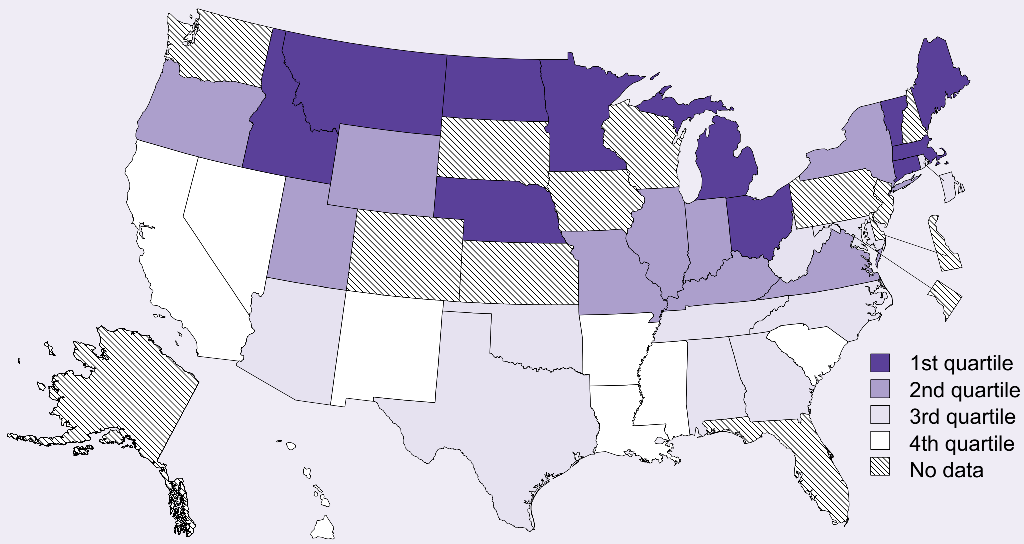
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 science scores are for public schools only. In 2000, Arizona, California, Idaho, Illinois, Indiana, Maine, Michigan, Minnesota, Montana, New York, Oregon, and Vermont met the minimum participation guidelines but did not satisfy one or more school participation rate guidelines for school sample(s).

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, various years.

Science and Engineering Indicators 2006

Eighth Grade Science Proficiency

Figure 8-8
Eighth grade science proficiency: 2000



1st quartile (44%–35%)	2nd quartile (34%–28%)	3rd quartile (27%–23%)	4th quartile (22%–14%)	No data
Connecticut	Illinois	Alabama	Arkansas	Alaska
Idaho	Indiana	Arizona	California	Colorado
Maine	Kentucky	Georgia	Hawaii	Delaware
Massachusetts	Missouri	Maryland	Louisiana	District of Columbia
Michigan	New York	North Carolina	Mississippi	Florida
Minnesota	Oregon	Oklahoma	Nevada	Iowa
Montana	Utah	Rhode Island	New Mexico	Kansas
Nebraska	Virginia	Tennessee	South Carolina	New Hampshire
North Dakota	Wyoming	Texas		New Jersey
Ohio		West Virginia		Pennsylvania
Vermont				South Dakota
				Washington
				Wisconsin

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-8.

Findings

- In 2000, the nationwide percentage of eighth grade public school students who performed at or above the proficient level in science was 30%, an increase from 27% in 1996 in testing without accommodations.
- In 2000, the percentage of public school students who performed at the proficient level in science was slightly higher in the eighth grade (30%) than in the fourth grade (28%).
- The proportion of eighth grade students who reached the proficient achievement level was 41% for whites, 7% for blacks, 12% for Hispanics, 37% for Asians/Pacific Islanders, and 14% for American Indians/Alaska Natives.
- Sex differences in science proficiency were larger in the eighth grade (9%) than in the fourth grade (7%).

This indicator provides a measure of the extent to which a state's eighth grade students in public schools have achieved proficiency in science. High values show that a high percentage of a state's eighth grade students have demonstrated the ability to undertake the study of high school science, a prerequisite to the further study of science and engineering and a necessary life skill.

Proficiency in science is based on achievement level in the National Assessment of Educational Progress (NAEP) 2000 Science Assessment. Achievement levels represent performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP.

The basic level (143–169) denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at the eighth grade level. The proficient level (170–207) represents solid academic performance at the eighth grade level. Students who reach this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter. The advanced level (208–300) signifies superior performance in science.

A National Academy of Sciences panel evaluated the process used to establish the achievement levels for the science assessment and urged that they be considered developmental and interpreted with caution.

Table 8-8
Eighth grade science proficiency, by state: 1996 and 2000
(Percent)

State	1996[a]	2000[a]	2000
National average	27	30	30
Alabama	18	22	23
Alaska	NA	NA	NA
Arizona	23	24	23
Arkansas	22	23	22
California	20	15	14
Colorado	NA	NA	NA
Connecticut	36	35	35
Delaware	NA	NA	NA
District of Columbia	NA	NA	NA
Florida	NA	NA	NA
Georgia	21	23	23
Hawaii	15	15	14
Idaho	NA	38	37
Illinois	NA	30	29
Indiana	30	35	33
Iowa	NA	NA	NA
Kansas	NA	NA	NA
Kentucky	23	29	28
Louisiana	13	18	18
Maine	41	37	35
Maryland	25	28	27
Massachusetts	37	42	39
Michigan	32	37	35
Minnesota	37	42	41
Mississippi	12	15	15
Missouri	28	36	33
Montana	41	46	44
Nebraska	35	36	38
Nevada	NA	23	22
New Hampshire	NA	NA	NA
New Jersey	NA	NA	NA
New Mexico	19	20	20
New York	27	30	28
North Carolina	24	27	25
North Dakota	41	40	38
Ohio	NA	41	39
Oklahoma	NA	26	25
Oregon	32	33	34
Pennsylvania	NA	NA	NA
Rhode Island	26	29	27
South Carolina	17	20	20
South Dakota	NA	NA	NA
Tennessee	22	25	24
Texas	23	23	23
Utah	32	34	34
Vermont	34	40	39
Virginia	27	31	29
Washington	NA	NA	NA
West Virginia	21	26	24
Wisconsin	NA	NA	NA
Wyoming	34	36	34

NA = not available (did not meet minimum participation guidelines)

[a]Accommodations not permitted.

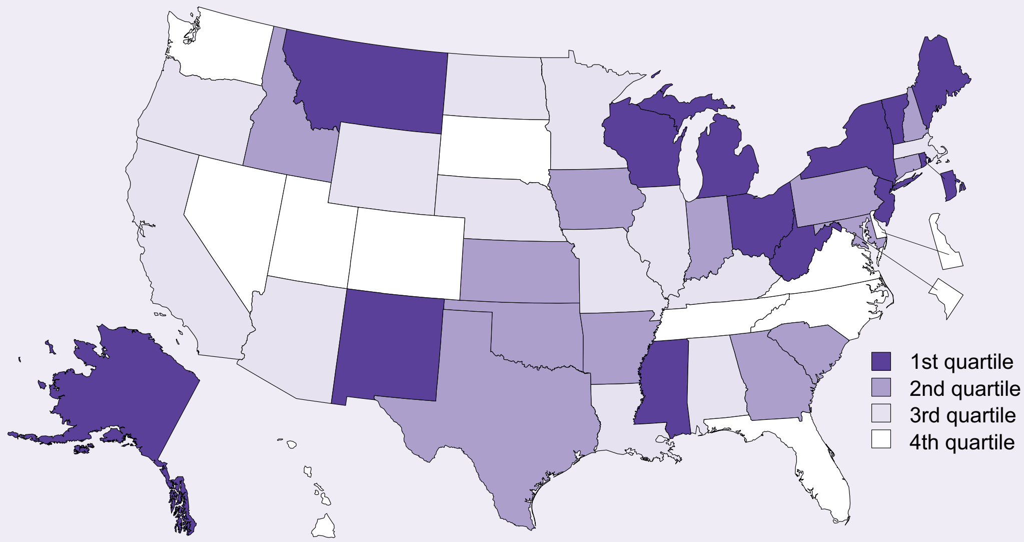
NOTES: National average is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 science scores are for public schools only. In 2000, Arizona, California, Idaho, Illinois, Indiana, Maine, Michigan, Minnesota, Montana, New York, Oregon, and Vermont met the minimum participation guidelines but did not satisfy one or more school participation rate guidelines for school sample(s).

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, various years.

Science and Engineering Indicators 2006

Elementary and Secondary Public School Current Expenditures as Share of Gross State Product

Figure 8-9
Elementary and secondary public school current expenditures as share of gross state product: 2003



1st quartile (5.09%–3.97%)	2nd quartile (3.92%–3.57%)	3rd quartile (3.56%–3.21%)	4th quartile (3.19%–1.28%)
Alaska	Arkansas	Alabama	Colorado
Maine	Connecticut	Arizona	Delaware
Michigan	Georgia	California	District of Columbia
Mississippi	Idaho	Illinois	Florida
Montana	Indiana	Kentucky	Hawaii
New Jersey	Iowa	Louisiana	Nevada
New Mexico	Kansas	Massachusetts	North Carolina
New York	Maryland	Minnesota	South Dakota
Ohio	New Hampshire	Missouri	Tennessee
Rhode Island	Oklahoma	Nebraska	Utah
Vermont	Pennsylvania	North Dakota	Virginia
West Virginia	South Carolina	Oregon	Washington
Wisconsin	Texas	Wyoming	

SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), NCES Common Core of Data, National Public Education Financial Survey; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data. See table 8-9.

Findings

- The 2003 national average for spending on elementary and secondary education was 3.55% of gross domestic product, an increase from 3.37% in 1994.
- Among individual states, it ranged from 2.23% to 5.09% of GSP.
- States spending the highest percentage of their GSP on elementary and secondary education tended to have relatively small student populations (100,000–300,000 students), indicating that some level of state spending may be required regardless of the size of the student population or the GSP.
- Actual spending for elementary and secondary current expenditures as a share of GSP decreased in 17 states during the 1994–2003 period.

The priority that state residents place on their elementary and secondary schools is reflected in the percentage of a state's wealth spent for these purposes. Nationally, state support represented the largest source of revenue for elementary and secondary education: 49% in 2002–03; local sources made up 43%; and the remaining 8% came from the federal government. In this indicator, current expenditures for public education in prekindergarten through grade 12 are reported as a share of gross state product (GSP).

In school year 2002–03, current expenditures (excluding capital projects and interest on debt) totaled approximately $388 billion, or 88% of the $440 billion in total spending for public education in prekindergarten through grade 12.

Financial data on public elementary and secondary education are reported by the National Center for Educational Statistics (NCES), U.S. Department of Education. The data are part of the National Public Education Financial Survey and are included in the Common Core of Data, a comprehensive annual national statistical database covering all 94,000 public elementary and secondary schools. Current expenditures are expressed in actual dollars. The year is the latter date of the academic year.

Table 8-9
Elementary and secondary public school current expenditures as share of gross state product, by state: 1994, 1999, and 2003

State	Public school expenditures ($ thousands)			GSP ($ millions)			School expenditures/ GSP (%)		
	1994	1999	2003	1994	1999	2003	1994	1999	2003
United States	231,542,764	302,876,294	387,592,494	6,865,515	9,201,138	10,923,851	3.37	3.29	3.55
Alabama	2,809,713	3,880,188	4,657,643	88,581	111,777	130,792	3.17	3.47	3.56
Alaska	1,002,515	1,137,610	1,326,226	23,110	24,621	31,704	4.34	4.62	4.18
Arizona	2,911,304	3,963,455	5,891,105	95,292	147,871	183,272	3.06	2.68	3.21
Arkansas	1,782,645	2,241,244	2,923,401	50,179	65,174	74,540	3.55	3.44	3.92
California	25,140,639	34,379,878	47,983,402	862,481	1,183,578	1,438,134	2.91	2.90	3.34
Colorado	2,954,793	4,140,699	5,551,506	100,434	156,603	188,397	2.94	2.64	2.95
Connecticut	3,943,891	5,075,580	6,302,988	111,171	150,713	174,085	3.55	3.37	3.62
Delaware	643,915	872,786	1,127,745	25,128	39,752	50,486	2.56	2.20	2.23
District of Columbia	713,427	693,712	902,318	46,842	56,082	70,668	1.52	1.24	1.28
Florida	10,331,896	13,534,374	16,355,123	322,073	442,476	553,709	3.21	3.06	2.95
Georgia	5,643,843	8,537,177	11,630,576	184,256	277,324	321,199	3.06	3.08	3.62
Hawaii	998,143	1,143,713	1,489,092	36,256	38,702	46,671	2.75	2.96	3.19
Idaho	859,088	1,239,755	1,511,862	24,817	32,846	40,358	3.46	3.77	3.75
Illinois	10,076,889	13,602,965	17,271,301	343,363	443,718	499,731	2.93	3.07	3.46
Indiana	5,064,685	6,697,468	8,088,684	141,157	185,925	213,342	3.59	3.60	3.79
Iowa	2,527,434	3,110,585	3,652,022	69,150	86,531	102,400	3.66	3.59	3.57
Kansas	2,325,247	2,841,147	3,510,675	61,805	79,159	93,263	3.76	3.59	3.76
Kentucky	2,952,119	3,696,331	4,401,627	86,283	114,423	128,315	3.42	3.23	3.43
Louisiana	3,309,018	4,264,981	5,056,583	101,943	125,413	144,321	3.25	3.40	3.50
Maine	1,208,411	1,510,024	1,909,268	26,204	33,519	40,829	4.61	4.50	4.68
Maryland	4,783,023	6,165,934	7,933,055	132,052	171,046	213,073	3.62	3.60	3.72
Massachusetts	5,637,337	7,948,502	10,281,820	185,335	254,042	297,113	3.04	3.13	3.46
Michigan	9,816,830	12,785,480	15,674,698	246,064	326,731	359,440	3.99	3.91	4.36
Minnesota	4,328,093	5,836,186	6,867,403	124,733	173,303	210,184	3.47	3.37	3.27
Mississippi	1,725,386	2,293,188	2,853,531	50,642	62,934	71,872	3.41	3.64	3.97
Missouri	3,981,614	5,348,366	6,793,957	128,473	168,999	193,828	3.10	3.16	3.51
Montana	822,015	955,695	1,124,291	16,961	20,420	25,584	4.85	4.68	4.39
Nebraska	1,513,971	1,821,310	2,304,223	42,838	53,612	65,399	3.53	3.40	3.52
Nevada	1,099,685	1,738,009	2,251,044	44,855	69,470	89,711	2.45	2.50	2.51
New Hampshire	1,007,129	1,316,946	1,781,594	29,456	40,230	48,202	3.42	3.27	3.70
New Jersey	10,448,096	12,874,579	17,185,966	254,546	326,106	394,040	4.10	3.95	4.36
New Mexico	1,323,459	1,788,382	2,281,608	41,143	49,258	57,078	3.22	3.63	4.00
New York	22,059,949	26,885,444	34,546,965	569,398	725,709	838,035	3.87	3.70	4.12
North Carolina	5,145,416	7,097,882	8,766,968	179,574	257,604	315,456	2.87	2.76	2.78
North Dakota	522,377	625,428	716,007	14,036	17,168	21,597	3.72	3.64	3.32
Ohio	9,612,678	12,138,937	15,868,494	278,508	360,109	398,918	3.45	3.37	3.98
Oklahoma	2,680,113	3,332,697	3,804,570	67,137	83,896	101,168	3.99	3.97	3.76
Oregon	2,852,723	3,706,044	4,150,747	74,435	104,620	119,973	3.83	3.54	3.46
Pennsylvania	11,236,417	13,532,211	16,344,439	298,329	377,019	443,709	3.77	3.59	3.68
Rhode Island	990,094	1,283,859	1,647,587	24,375	31,019	39,363	4.06	4.14	4.19
South Carolina	2,790,878	3,759,042	4,888,250	81,033	109,231	127,963	3.44	3.44	3.82
South Dakota	584,894	696,785	851,429	17,014	21,681	27,337	3.44	3.21	3.11
Tennessee	3,305,579	4,638,924	5,674,773	128,905	169,373	203,071	2.56	2.74	2.79
Texas	16,193,722	22,430,153	30,399,603	478,143	667,644	821,943	3.39	3.36	3.70
Utah	1,511,205	2,025,714	2,366,897	42,218	64,143	76,674	3.58	3.16	3.09
Vermont	643,828	792,664	1,045,213	13,717	16,726	20,544	4.69	4.74	5.09
Virginia	5,441,384	7,137,419	9,208,329	177,008	241,909	304,116	3.07	2.95	3.03
Washington	4,892,690	6,098,008	7,359,566	146,726	214,223	245,143	3.33	2.85	3.00
West Virginia	1,663,868	1,986,562	2,349,833	34,855	41,306	46,726	4.77	4.81	5.03
Wisconsin	5,170,343	6,620,653	7,934,755	128,394	169,338	198,096	4.03	3.91	4.01
Wyoming	558,353	651,622	791,732	14,087	16,062	22,279	3.96	4.06	3.55
Puerto Rico	1,360,762	2,024,499	2,541,385	39,691	57,841	74,362	3.43	3.50	3.42

GSP = gross state product

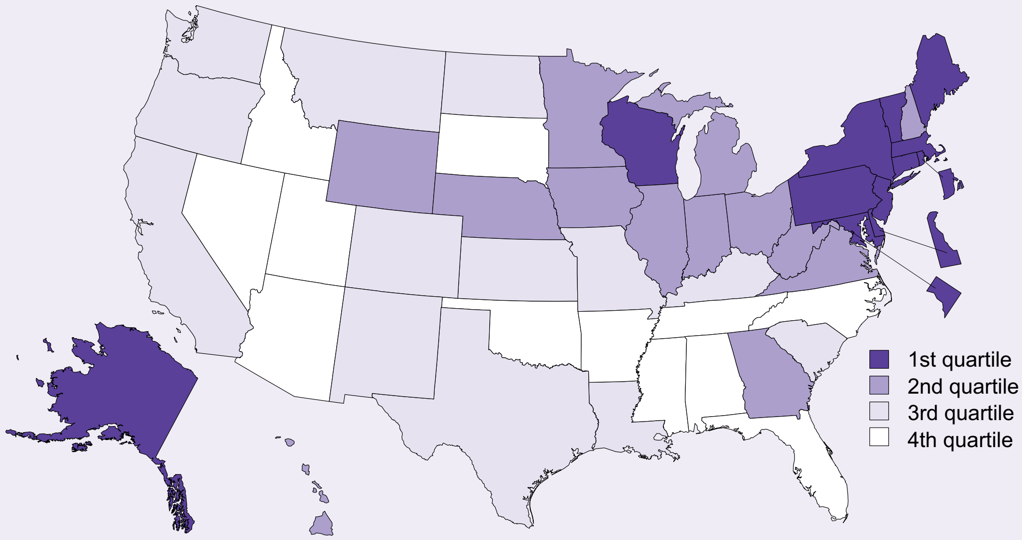
NOTES: Public school expenditures for Missouri, Tennessee, and Washington for 2003 are affected by redistribution of reported values to correct for missing data items. GSP is reported in current dollars.

SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), NCES Common Core of Data, National Public Education Financial Survey; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2006

Current Expenditures per Pupil for Elementary and Secondary Public Schools

Figure 8-10
Current expenditures per pupil for elementary and secondary public schools: 2003



1st quartile ($12,568–$8,997)	2nd quartile ($8,985–$7,574)	3rd quartile ($7,552–$6,661)	4th quartile ($6,562–$4,838)
Alaska	Georgia	California	Alabama
Connecticut	Hawaii	Colorado	Arizona
Delaware	Illinois	Kansas	Arkansas
District of Columbia	Indiana	Kentucky	Florida
Maine	Iowa	Louisiana	Idaho
Maryland	Michigan	Missouri	Mississippi
Massachusetts	Minnesota	Montana	Nevada
New Jersey	Nebraska	New Mexico	North Carolina
New York	New Hampshire	North Dakota	Oklahoma
Pennsylvania	Ohio	Oregon	South Dakota
Rhode Island	Virginia	South Carolina	Tennessee
Vermont	West Virginia	Texas	Utah
Wisconsin	Wyoming	Washington	

SOURCES: U.S. Department of Education, National Center for Education Statistics, NCES Common Core of Data, State Nonfiscal Survey of Public Elementary/Secondary Education and National Public Education Financial Survey. See table 8-10.

Findings

- Expenditures per student in public schools rose during the late 1980s, remained stable during the first part of the 1990s, then rose again in the late 1990s.
- In academic year 2002–03, expenditures for public education totaled approximately $388 billion, a 5.2% increase over the previous year.
- Instructional costs accounted for 61%, support services were 35%, and noninstructional costs accounted for 4% of 2002–03 expenditures for elementary and secondary schools.
- A direct correlation between spending and academic performance cannot be made because several states that ranked in the lower two quartiles of this indicator ranked in the upper quartiles of the NAEP indicators.

Investment in education at the elementary and secondary levels is important in creating a well-educated populace and preparing individual students for their careers. One measure used to compare states' investment in elementary and secondary education is current expenditures per student at the elementary and secondary levels. Current expenditures per pupil include three major components: instructional costs, support services, and noninstructional costs. Current expenditures do not include longer-term financing, building construction, and the costs of programs outside the scope of preschool to grade 12, such as adult education, community colleges, and community services.

Current expenditures per pupil are calculated by dividing the total current expenditures for prekindergarten through grade 12 for the entire academic year by the number of pupils enrolled in those grades during the fall of the academic year. All figures represent actual spending and have not been adjusted for inflation. The year is the latter date of the academic year.

Table 8-10
Current expenditures per pupil for elementary and secondary public schools, by state: 1994, 1999, and 2003

State	Public school expenditures ($ thousands)			Student enrollment			Per-pupil expenditures ($)		
	1994	1999	2003	1994	1999	2003	1994	1999	2003
United States	231,542,764	302,876,294	387,592,494	43,464,916	46,538,585	48,201,032	5,327	6,508	8,041
Alabama	2,809,713	3,880,188	4,657,643	734,288	747,980	739,366	3,826	5,188	6,300
Alaska	1,002,515	1,137,610	1,326,226	125,948	135,373	134,364	7,960	8,404	9,870
Arizona	2,911,304	3,963,455	5,891,105	709,453	848,262	937,755	4,104	4,672	6,282
Arkansas	1,782,645	2,241,244	2,923,401	444,271	452,256	450,985	4,013	4,956	6,482
California	25,140,639	34,379,878	47,983,402	5,327,231	5,926,037	6,353,667	4,719	5,801	7,552
Colorado	2,954,793	4,140,699	5,551,506	625,062	699,135	751,862	4,727	5,923	7,384
Connecticut	3,943,891	5,075,580	6,302,988	496,298	544,698	570,023	7,947	9,318	11,057
Delaware	643,915	872,786	1,127,745	105,547	113,262	116,342	6,101	7,706	9,693
District of Columbia	713,427	693,712	902,318	80,678	71,889	76,166	8,843	9,650	11,847
Florida	10,331,896	13,534,374	16,355,123	2,040,763	2,337,633	2,539,929	5,063	5,790	6,439
Georgia	5,643,843	8,537,177	11,630,576	1,235,304	1,401,291	1,496,012	4,569	6,092	7,774
Hawaii	998,143	1,143,713	1,489,092	180,410	188,069	183,829	5,533	6,081	8,100
Idaho	859,088	1,239,755	1,511,862	236,774	244,722	248,604	3,628	5,066	6,081
Illinois	10,076,889	13,602,965	17,271,301	1,893,078	2,011,530	2,084,187	5,323	6,762	8,287
Indiana	5,064,685	6,697,468	8,088,684	965,633	989,001	1,003,875	5,245	6,772	8,057
Iowa	2,527,434	3,110,585	3,652,022	498,519	498,214	482,210	5,070	6,243	7,574
Kansas	2,325,247	2,841,147	3,510,675	457,614	472,353	470,957	5,081	6,015	7,454
Kentucky	2,952,119	3,696,331	4,401,627	655,265	655,687	660,782	4,505	5,637	6,661
Louisiana	3,309,018	4,264,981	5,056,583	800,560	768,734	730,464	4,133	5,548	6,922
Maine	1,208,411	1,510,024	1,909,268	216,995	211,051	204,337	5,569	7,155	9,344
Maryland	4,783,023	6,165,934	7,933,055	772,638	841,671	866,743	6,191	7,326	9,153
Massachusetts	5,637,337	7,948,502	10,281,820	877,726	962,317	982,989	6,423	8,260	10,460
Michigan	9,816,830	12,785,480	15,674,698	1,599,377	1,720,287	1,785,160	6,138	7,432	8,781
Minnesota	4,328,093	5,836,186	6,867,403	810,233	856,455	846,891	5,342	6,814	8,109
Mississippi	1,725,386	2,293,188	2,853,531	505,907	502,379	492,645	3,410	4,565	5,792
Missouri	3,981,614	5,348,366	6,793,957	866,378	913,494	924,445	4,596	5,855	7,349
Montana	822,015	955,695	1,124,291	163,009	159,988	149,995	5,043	5,974	7,496
Nebraska	1,513,971	1,821,310	2,304,223	285,097	291,140	285,402	5,310	6,256	8,074
Nevada	1,099,685	1,738,009	2,251,044	235,800	311,061	369,498	4,664	5,587	6,092
New Hampshire	1,007,129	1,316,946	1,781,594	185,360	204,713	207,671	5,433	6,433	8,579
New Jersey	10,448,096	12,874,579	17,185,966	1,151,307	1,268,996	1,367,438	9,075	10,145	12,568
New Mexico	1,323,459	1,788,382	2,281,608	322,292	328,753	320,234	4,106	5,440	7,125
New York	22,059,949	26,885,444	34,546,965	2,733,813	2,877,143	2,888,233	8,069	9,344	11,961
North Carolina	5,145,416	7,097,882	8,766,968	1,133,231	1,254,821	1,335,954	4,540	5,656	6,562
North Dakota	522,377	625,428	716,007	119,127	114,927	104,225	4,385	5,442	6,870
Ohio	9,612,678	12,138,937	15,868,494	1,807,319	1,842,163	1,838,285	5,319	6,590	8,632
Oklahoma	2,680,113	3,332,697	3,804,570	604,076	628,492	624,548	4,437	5,303	6,092
Oregon	2,852,723	3,706,044	4,150,747	516,611	542,809	554,071	5,522	6,828	7,491
Pennsylvania	11,236,417	13,532,211	16,344,439	1,744,082	1,816,414	1,816,747	6,443	7,450	8,997
Rhode Island	990,094	1,283,859	1,647,587	145,676	154,785	159,205	6,797	8,294	10,349
South Carolina	2,790,878	3,759,042	4,888,250	643,696	664,600	694,389	4,336	5,656	7,040
South Dakota	584,894	696,785	851,429	142,825	132,495	130,048	4,095	5,259	6,547
Tennessee	3,305,579	4,638,924	5,674,773	866,557	905,454	927,608	3,815	5,123	6,118
Texas	16,193,722	22,430,153	30,399,603	3,608,262	3,945,367	4,259,823	4,488	5,685	7,136
Utah	1,511,205	2,025,714	2,366,897	471,365	481,176	489,262	3,206	4,210	4,838
Vermont	643,828	792,664	1,045,213	102,755	105,120	99,978	6,266	7,541	10,454
Virginia	5,441,384	7,137,419	9,208,329	1,045,471	1,124,022	1,177,229	5,205	6,350	7,822
Washington	4,892,690	6,098,008	7,359,566	915,952	998,053	1,014,798	5,342	6,110	7,252
West Virginia	1,663,868	1,986,562	2,349,833	314,383	297,530	282,455	5,292	6,677	8,319
Wisconsin	5,170,343	6,620,653	7,934,755	844,001	879,542	881,231	6,126	7,527	9,004
Wyoming	558,353	651,622	791,732	100,899	95,241	88,116	5,534	6,842	8,985
Puerto Rico	1,360,762	2,024,499	2,541,385	631,460	613,862	596,502	2,155	3,298	4,260

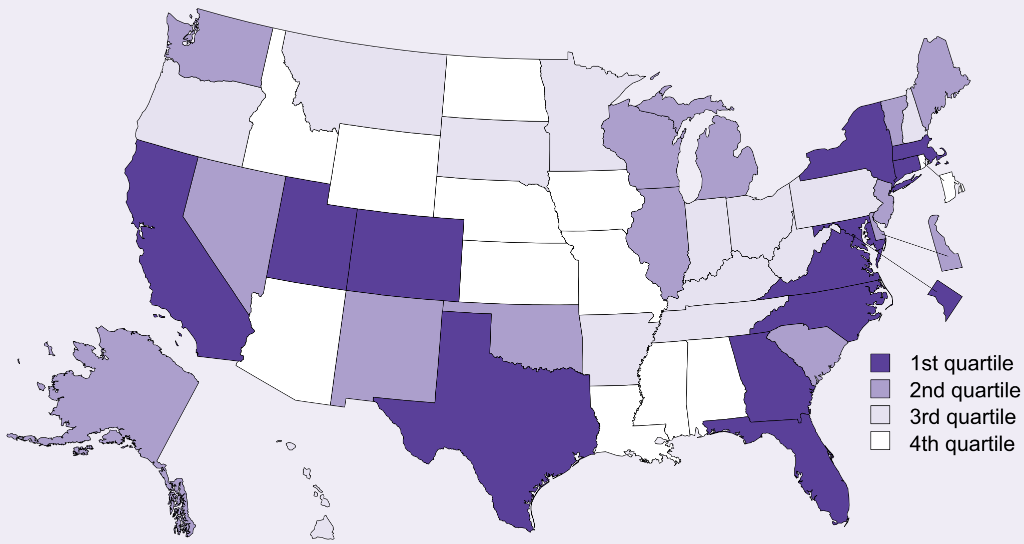
NOTES: Public school expenditures for Missouri, Tennessee, and Washington for 2003 are affected by redistribution of reported values to correct for missing data items. Both the District of Columbia and Hawaii have only one school district each; therefore, their data for 2003 are not comparable to other states.

SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), NCES Common Core of Data, State Nonfiscal Survey of Public Elementary/Secondary Education; and National Public Education Financial Survey.

Science and Engineering Indicators 2006

Share of Public High School Students Taking Advanced Placement Exams

Figure 8-11
Share of public high school students taking Advanced Placement Exams: 2004



1st quartile (33.5%–21.5%)	2nd quartile (21.3%–16.7%)	3rd quartile (16.4%–13.0%)	4th quartile (12.9%–5.0%)
California	Alaska	Arkansas	Alabama
Colorado	Delaware	Hawaii	Arizona
Connecticut	Illinois	Indiana	Idaho
District of Columbia	Maine	Kentucky	Iowa
Florida	Michigan	Minnesota	Kansas
Georgia	Nevada	Montana	Louisiana
Maryland	New Jersey	New Hampshire	Mississippi
Massachusetts	New Mexico	Ohio	Missouri
New York	Oklahoma	Oregon	Nebraska
North Carolina	South Carolina	Pennsylvania	North Dakota
Texas	Vermont	South Dakota	Rhode Island
Utah	Washington	Tennessee	Wyoming
Virginia	Wisconsin	West Virginia	

SOURCE: College Board, *Advanced Placement Report to the Nation: 2005*. See table 8-11.

Findings

- Nationwide, the percentage of public school students who took an AP Exam rose from 15.9% of the class of 2000 to 20.9% of the class of 2004.
- The percentage of public school students taking an AP Exam varied greatly among states and ranged from 5.0% to 33.5% of the class of 2004, with 15 states exceeding the national average.
- Values were higher for all states in 2004 than in 2000. Florida and Maryland showed the largest increases; class of 2004 members in the two states exceeded the performance of class of 2000 participants by 9 or more percentage points.
- The ratio of the percentage of public school students who took an AP Exam to the percentage who achieved a grade of 3 or higher was consistent across many of the states, which may indicate a consistent degree of rigor in the AP curriculum.

More than 1.1 million students took nearly 1.9 million Advanced Placement (AP) Exams in 2004. Generally, students who take AP Exams have completed a rigorous course of study in a specific subject area in high school with the expectation of obtaining college credit or advanced placement. AP Exams were taken most frequently in U.S. history, English literature and composition, English language and composition, calculus AB, and U.S. government and politics.

In the 50 states and the District of Columbia, 14,144 schools—about 40% of the schools that provide secondary education—participated in the AP program. Approximately 79% were public schools. The schools offered students an average of seven different AP courses. High school students' participation in AP Exams is likely to reflect the access they had to AP courses and their willingness to undertake the more rigorous curriculum.

Table 8-11
Share of public high school students taking Advanced Placement Exams, by state: 2000 and 2004
(Percent)

State	2000	2004
National average	15.9	20.9
Alabama	7.2	8.8
Alaska	15.4	16.7
Arizona	11.3	12.9
Arkansas	8.1	13.0
California	22.2	28.5
Colorado	18.6	25.3
Connecticut	19.1	24.6
Delaware	13.3	19.6
District of Columbia	17.3	23.1
Florida	22.7	33.5
Georgia	17.2	21.5
Hawaii	10.6	14.8
Idaho	9.6	12.5
Illinois	13.4	18.6
Indiana	11.9	15.5
Iowa	6.9	10.0
Kansas	7.0	9.2
Kentucky	10.6	15.5
Louisiana	3.2	5.0
Maine	14.8	19.9
Maryland	20.2	29.2
Massachusetts	19.6	25.3
Michigan	13.9	16.8
Minnesota	13.4	16.4
Mississippi	5.6	7.0
Missouri	5.5	8.1
Montana	10.1	13.0
Nebraska	5.0	6.3
Nevada	15.1	19.8
New Hampshire	13.3	16.0
New Jersey	17.9	21.3
New Mexico	11.1	17.0
New York	27.3	32.4
North Carolina	19.7	26.9
North Dakota	5.9	8.4
Ohio	11.3	15.2
Oklahoma	9.5	17.0
Oregon	10.5	13.6
Pennsylvania	12.4	14.9
Rhode Island	10.7	12.1
South Carolina	17.7	19.2
South Dakota	9.6	13.5
Tennessee	10.4	13.6
Texas	16.6	23.2
Utah	24.5	27.6
Vermont	16.6	21.2
Virginia	25.0	28.1
Washington	11.5	18.5
West Virginia	8.4	13.0
Wisconsin	15.2	20.0
Wyoming	6.1	11.2

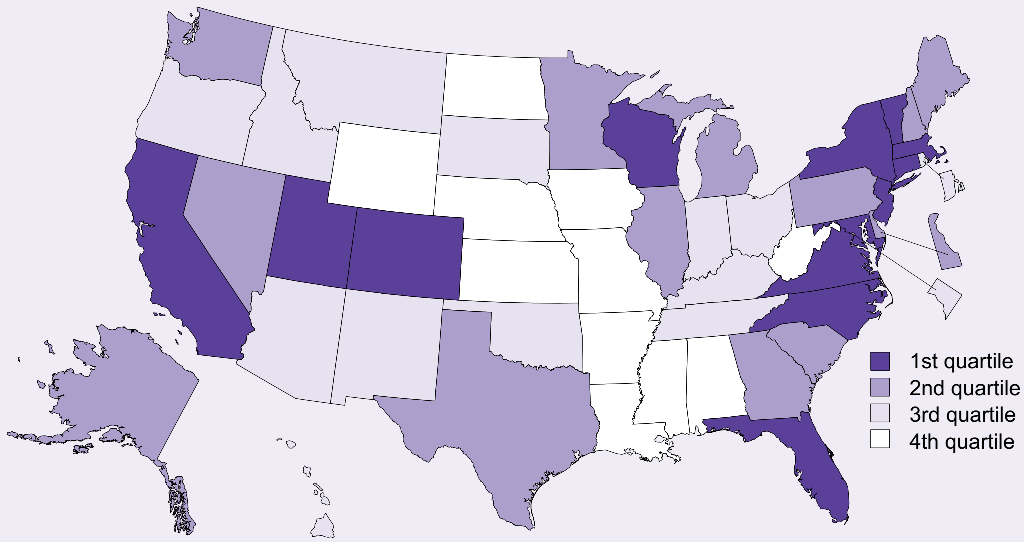
NOTE: National average is reported value in *Advanced Placement Report to the Nation: 2005*.

SOURCE: College Board, *Advanced Placement Report to the Nation: 2005*.

Science and Engineering Indicators 2006

Share of Public High School Students Scoring 3 or Higher on at Least One Advanced Placement Exam

Figure 8-12
Share of public high school students scoring 3 or higher on at least one Advanced Placement Exam: 2004



1st quartile (21.2%–13.7%)	2nd quartile (13.3%–10.1%)	3rd quartile (9.4%–7.7%)	4th quartile (6.7%–2.5%)
California	Alaska	Arizona	Alabama
Colorado	Delaware	District of Columbia	Arkansas
Connecticut	Georgia	Hawaii	Iowa
Florida	Illinois	Idaho	Kansas
Maryland	Maine	Indiana	Louisiana
Massachusetts	Michigan	Kentucky	Mississippi
New Jersey	Minnesota	Montana	Missouri
New York	Nevada	New Mexico	Nebraska
North Carolina	New Hampshire	Ohio	North Dakota
Utah	Pennsylvania	Oklahoma	West Virginia
Vermont	South Carolina	Oregon	Wyoming
Virginia	Texas	Rhode Island	
Wisconsin	Washington	South Dakota	
		Tennessee	

SOURCE: College Board, *Advanced Placement Report to the Nation: 2005*. See table 8-12.

Findings

- Nationally, 13.2% of public school students in the class of 2004 demonstrated the ability to do college level work by obtaining a score of 3 or higher on at least one AP Exam, compared with 10.2% of the class of 2000.
- Values for public school students in individual states for the class of 2004 ranged from a low of 2.5% to a high of 21.2%. Fourteen states exceeded the national average.
- Values were higher for all states in 2004 than in 2000. Florida and Maryland showed the largest increases; class of 2004 members in the two states exceeded the performance of class of 2000 participants by more than 5 percentage points.

High school students can demonstrate their ability to master college-level material through their performance on Advanced Placement (AP) Exams that cover specific subject areas. A total of 34 different AP Exams are offered each spring by the College Board. The exams are scored on a scale of 1 to 5, with 3 representing a range of work equivalent to midlevel B to midlevel C performance in college. Many colleges and universities grant college credit or advanced placement for AP Exam grades of 3 or higher.

To prepare for the AP Exam in a subject area, most students enroll in an AP class that employs a curriculum of high academic intensity. Scoring a 3 or higher indicates that the student has mastered the content of at least one such course of rigorous academic intensity at a level that would be acceptable in college. Performance on AP Exams is considered by many colleges and universities to be one of the best predictors of success in college. A high value on this indicator shows the extent to which the class of 2004 has been offered access to a rigorous curriculum and has successfully mastered the requirements.

Table 8-12
Share of public high school students scoring 3 or higher on at least one Advanced Placement Exam, by state: 2000 and 2004
(Percent)

State	2000	2004
National average	10.2	13.2
Alabama	3.9	5.0
Alaska	10.1	10.8
Arizona	7.2	8.0
Arkansas	4.3	6.1
California	15.0	18.7
Colorado	12.2	16.2
Connecticut	13.6	17.6
Delaware	7.6	11.1
District of Columbia	6.6	8.2
Florida	13.5	19.2
Georgia	9.7	12.0
Hawaii	5.8	7.7
Idaho	6.5	8.1
Illinois	9.9	13.3
Indiana	6.0	7.7
Iowa	4.9	6.6
Kansas	4.4	6.3
Kentucky	5.5	7.7
Louisiana	1.9	2.5
Maine	10.1	12.8
Maryland	14.1	19.4
Massachusetts	14.5	18.1
Michigan	8.8	10.9
Minnesota	8.1	10.6
Mississippi	2.3	2.9
Missouri	3.7	5.3
Montana	6.8	8.8
Nebraska	3.2	4.0
Nevada	9.1	12.4
New Hampshire	9.2	10.9
New Jersey	12.9	15.5
New Mexico	6.1	8.1
New York	17.9	21.2
North Carolina	11.3	15.8
North Dakota	4.4	5.7
Ohio	7.1	9.4
Oklahoma	5.4	8.3
Oregon	7.1	8.8
Pennsylvania	8.3	10.1
Rhode Island	6.9	7.8
South Carolina	10.0	11.2
South Dakota	5.9	8.3
Tennessee	6.2	7.9
Texas	9.9	13.1
Utah	17.4	19.3
Vermont	11.5	14.0
Virginia	15.9	17.7
Washington	7.6	11.6
West Virginia	4.6	6.4
Wisconsin	10.5	13.7
Wyoming	3.8	6.7

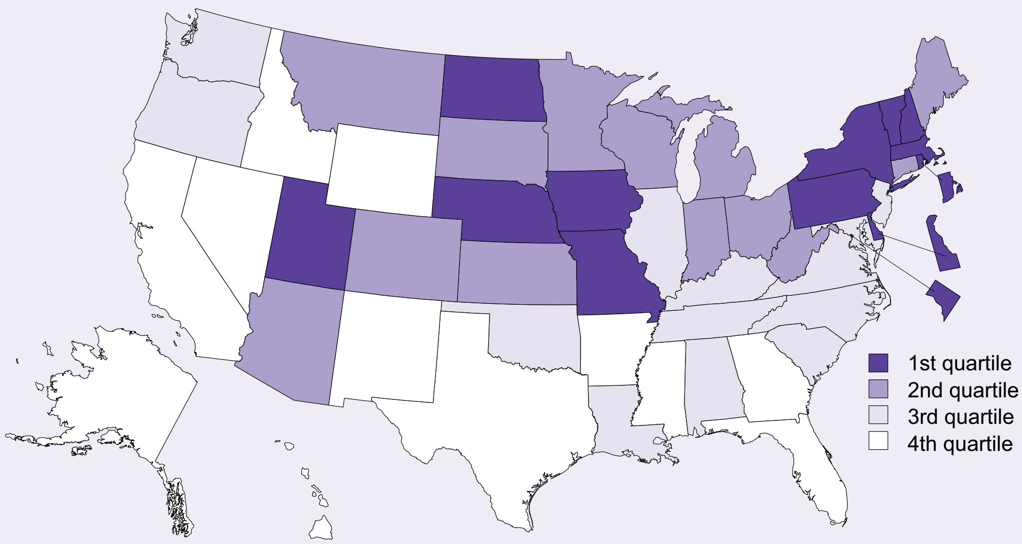
NOTE: National average is reported value in *Advanced Placement Report to the Nation: 2005.*

SOURCE: College Board, *Advanced Placement Report to the Nation: 2005.*

Science and Engineering Indicators 2006

Bachelor's Degrees Conferred per 1,000 Individuals 18–24 Years Old

Figure 8-13
Bachelor's degrees conferred per 1,000 individuals 18–24 years old: 2003



1st quartile (137.4–57.3)	2nd quartile (55.6–49.1)	3rd quartile (47.8–39.7)	4th quartile (39.3–19.6)
Delaware	Arizona	Alabama	Alaska
District of Columbia	Colorado	Illinois	Arkansas
Iowa	Connecticut	Kentucky	California
Massachusetts	Indiana	Louisiana	Florida
Missouri	Kansas	Maryland	Georgia
Nebraska	Maine	New Jersey	Hawaii
New Hampshire	Michigan	North Carolina	Idaho
New York	Minnesota	Oklahoma	Mississippi
North Dakota	Montana	Oregon	Nevada
Pennsylvania	Ohio	South Carolina	New Mexico
Rhode Island	South Dakota	Tennessee	Texas
Utah	West Virginia	Virginia	Wyoming
Vermont	Wisconsin	Washington	

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years; and U.S. Census Bureau, Population Division. See table 8-13.

Findings

- In 2003, 1.34 million bachelor's degrees were conferred nationally in all fields, up from 1.17 million in 1993.
- Over the past decade, the number of bachelor's degrees awarded in the United States has remained essentially constant relative to the size of the 18–24-year-old population.
- Across the United States, approximately 46 bachelor's degrees were conferred per 1,000 18–24-year-olds, ranging from about 20 to 82 across the states; the District of Columbia exceeded 137 (an outlier reflecting a large concentration of academic institutions relative to the size of the resident population).

Earning a bachelor's degree gives people greater opportunities to work in higher-paying jobs than are generally available to those with less education; it also prepares them for advanced education. In addition, the capacity to produce degrees generates resources for the state. The ratio of bachelor's degrees awarded to a state's 18–24-year-old population is a broad measure of a state's relative success in producing degrees at this level. The 18–24-year-old cohort was chosen to approximate the age range of most students who are pursuing an undergraduate degree.

A high value for this indicator may suggest the successful provision of educational opportunity at this level. Student and graduate mobility after graduation, however, may make this indicator less meaningful in predicting the qualifications of a state's future workforce. The indicator's value may also be high when a higher education system draws a large percentage of out-of-state students, a situation that sometimes occurs in states with small resident populations and the District of Columbia.

Table 8-13
Bachelor's degrees conferred per 1,000 individuals 18–24 years old, by state: 1993, 1998, and 2003

State	Bachelor's degrees			Population 18–24 years old			Degrees/1,000 individuals 18–24 years old		
	1993	1998	2003	1993	1998	2003	1993	1998	2003
United States	1,165,168	1,185,030	1,342,686	25,739,925	25,476,201	28,900,513	45.3	46.5	46.5
Alabama	20,525	20,318	20,336	454,770	438,019	453,710	45.1	46.4	44.8
Alaska	1,260	1,476	1,363	60,022	68,962	69,574	21.0	21.4	19.6
Arizona	15,809	21,746	27,862	395,208	444,734	552,538	40.0	48.9	50.4
Arkansas	8,449	9,222	10,591	246,273	250,431	276,347	34.3	36.8	38.3
California	110,876	109,097	130,593	3,170,388	3,171,047	3,569,122	35.0	34.4	36.6
Colorado	19,808	20,624	23,559	342,578	376,366	454,558	57.8	54.8	51.8
Connecticut	15,116	13,750	16,038	295,584	256,388	303,176	51.1	53.6	52.9
Delaware	4,067	4,383	5,123	70,787	67,054	81,585	57.5	65.4	62.8
District of Columbia	8,095	7,973	8,834	64,384	43,865	64,273	125.7	181.8	137.4
Florida	43,202	48,304	55,544	1,180,537	1,209,003	1,493,632	36.6	40.0	37.2
Georgia	25,390	29,263	31,703	730,881	754,676	889,162	34.7	38.8	35.7
Hawaii	4,186	4,588	4,922	116,670	119,378	125,284	35.9	38.4	39.3
Idaho	3,923	4,602	5,974	114,637	139,586	153,101	34.2	33.0	39.0
Illinois	51,482	51,932	59,732	1,155,733	1,125,624	1,254,527	44.5	46.1	47.6
Indiana	31,453	30,985	35,251	602,192	572,453	634,269	52.2	54.1	55.6
Iowa	17,598	17,510	19,839	279,421	276,610	316,933	63.0	63.3	62.6
Kansas	14,453	14,182	16,135	251,584	263,410	295,852	57.4	53.8	54.5
Kentucky	14,396	14,972	16,325	403,547	400,137	411,637	35.7	37.4	39.7
Louisiana	17,825	18,532	21,064	461,025	473,066	500,616	38.7	39.2	42.1
Maine	5,976	5,442	6,143	118,437	110,125	120,783	50.5	49.4	50.9
Maryland	21,494	21,715	24,277	452,016	433,031	507,475	47.6	50.1	47.8
Massachusetts	42,747	40,676	44,612	599,360	505,584	596,934	71.3	80.5	74.7
Michigan	45,711	44,152	49,758	967,872	922,891	992,111	47.2	47.8	50.2
Minnesota	24,737	22,999	25,634	421,533	439,358	520,699	58.7	52.3	49.2
Mississippi	10,673	10,290	11,797	304,375	300,061	322,505	35.1	34.3	36.6
Missouri	26,929	28,806	33,115	504,892	509,453	577,581	53.3	56.5	57.3
Montana	4,194	4,932	5,238	77,645	88,262	96,129	54.0	55.9	54.5
Nebraska	9,522	10,071	11,028	157,809	166,811	188,391	60.3	60.4	58.5
Nevada	3,029	3,852	4,616	119,846	148,028	199,143	25.3	26.0	23.2
New Hampshire	7,524	7,297	7,572	103,606	95,661	119,503	72.6	76.3	63.4
New Jersey	25,185	25,056	29,604	707,317	669,415	726,145	35.6	37.4	40.8
New Mexico	5,654	6,219	6,379	159,007	174,353	198,398	35.6	35.7	32.2
New York	98,357	96,187	108,441	1,766,276	1,601,269	1,826,944	55.7	60.1	59.4
North Carolina	31,852	34,086	37,345	751,837	702,132	824,233	42.4	48.5	45.3
North Dakota	4,555	4,588	4,882	66,568	67,835	76,213	68.4	67.6	64.1
Ohio	51,651	49,244	55,020	1,105,197	1,056,810	1,119,732	46.7	46.6	49.1
Oklahoma	15,002	15,881	16,102	329,713	336,797	382,078	45.5	47.2	42.1
Oregon	13,139	13,513	15,053	276,672	303,895	347,267	47.5	44.5	43.3
Pennsylvania	65,125	63,501	72,787	1,149,074	1,022,583	1,180,592	56.7	62.1	61.7
Rhode Island	9,396	8,323	9,389	104,444	83,023	114,254	90.0	100.2	82.2
South Carolina	15,199	15,034	18,299	404,863	385,887	426,854	37.5	39.0	42.9
South Dakota	4,387	4,476	4,460	70,155	76,172	85,043	62.5	58.8	52.4
Tennessee	20,371	21,538	24,199	522,815	515,066	571,200	39.0	41.8	42.4
Texas	67,598	71,755	82,507	1,907,830	2,038,563	2,351,723	35.4	35.2	35.1
Utah	12,728	16,405	18,338	225,001	290,363	313,689	56.6	56.5	58.5
Vermont	4,707	4,441	4,510	58,910	52,029	63,895	79.9	85.4	70.6
Virginia	30,858	30,350	34,623	685,233	656,887	735,711	45.0	46.2	47.1
Washington	20,784	23,403	25,558	493,660	539,707	618,757	42.1	43.4	41.3
West Virginia	8,606	8,290	9,335	191,056	182,025	174,583	45.0	45.5	53.5
Wisconsin	27,709	27,343	29,538	493,627	498,268	566,174	56.1	54.9	52.2
Wyoming	1,856	1,706	1,739	47,058	53,048	55,878	39.4	32.2	31.1
Puerto Rico	13,756	13,932	NA	NA	NA	418,390	NA	NA	NA

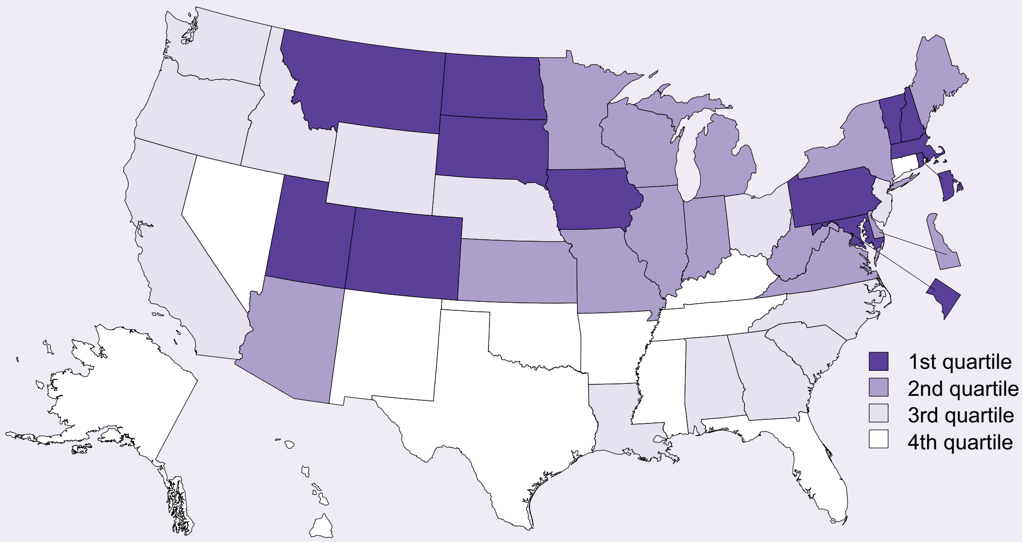
NA = not available

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years; and U.S. Census Bureau, Population Division.

Science and Engineering Indicators 2006

Bachelor's Degrees in Natural Sciences and Engineering Conferred per 1,000 Individuals 18–24 Years Old

Figure 8-14
Bachelor's degrees in natural sciences and engineering conferred per 1,000 individuals 18–24 years old: 2003



1st quartile (27.26–9.85)	2nd quartile (9.69–7.95)	3rd quartile (7.88–6.80)	4th quartile (6.54–3.23)
Colorado	Arizona	Alabama	Alaska
District of Columbia	Delaware	California	Arkansas
Iowa	Illinois	Georgia	Connecticut
Maryland	Indiana	Idaho	Florida
Massachusetts	Kansas	Louisiana	Hawaii
Montana	Maine	Nebraska	Kentucky
New Hampshire	Michigan	New Jersey	Mississippi
North Dakota	Minnesota	North Carolina	Nevada
Pennsylvania	Missouri	Ohio	New Mexico
Rhode Island	New York	Oregon	Oklahoma
South Dakota	Virginia	South Carolina	Tennessee
Utah	West Virginia	Washington	Texas
Vermont	Wisconsin	Wyoming	

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years; and U.S. Census Bureau, Population Division. See Table 8-14.

Findings

- During the past decade, the value of this indicator increased across the nation as the number of NS&E bachelor's degrees awarded increased by roughly 28%, from nearly 177,000 in 1993 to nearly 226,000 in 2003, while the number of 18–24-year-olds increased by 12%.
- In 2003, NS&E bachelor's degrees accounted for nearly 17% of all bachelor's degrees, an increase from 15% in 1993.
- The value of this indicator for the United States was 7.8 in 2003, ranging from 3.2 to 14.1 for individual states. However, the value for the District of Columbia exceeded 27 (an outlier reflecting a large concentration of academic institutions relative to the size of the resident population).
- State ratings were generally in the same quartile for this indicator as for the number of bachelor's degrees conferred per 1,000 18–24-year-olds.

Natural sciences and engineering (NS&E) fields include physical, earth, ocean, atmospheric, biological, agricultural, and computer sciences; mathematics; and engineering. NS&E fields differ from science and engineering fields because NS&E fields do not include degrees in social sciences or psychology. The ratio of new NS&E bachelor's degrees to the 18–24-year-old population indicates the degree to which a state prepares young people to enter the types of technology-intensive occupations that are fundamental to a knowledge-based, technology-driven economy. The capacity to produce NS&E degrees also generates resources for the state. The 18–24-year-old cohort was chosen to approximate the age range of most students who are pursuing an undergraduate degree.

A high value for this indicator may suggest relative success in providing a technical undergraduate education. Student and graduate mobility after graduation, however, may make this indicator less meaningful in predicting the qualifications of a state's future workforce. The indicator's value may also be high when a higher education system draws a large percentage of out-of-state students to study in NS&E fields, a situation that sometimes occurs in states with small resident populations and the District of Columbia.

Table 8-14
Bachelor's degrees in natural sciences and engineering conferred per 1,000 individuals 18–24 years old, by state: 1993, 1998, and 2003

	NS&E bachelor's degrees			Population 18–24 years old			Degrees/1,000 individuals 18–24 years old		
State	1993	1998	2003	1993	1998	2003	1993	1998	2003
United States	177,288	202,470	225,874	25,739,925	25,476,201	28,900,513	6.89	7.95	7.82
Alabama	3,447	3,601	3,244	454,770	438,019	453,710	7.58	8.22	7.15
Alaska	186	314	247	60,022	68,962	69,574	3.10	4.55	3.55
Arizona	2,192	3,084	4,403	395,208	444,734	552,538	5.55	6.93	7.97
Arkansas	1,152	1,364	1,632	246,273	250,431	276,347	4.68	5.45	5.91
California	19,329	21,808	24,610	3,170,388	3,171,047	3,569,122	6.10	6.88	6.90
Colorado	3,870	4,632	4,959	342,578	376,366	454,558	11.30	12.31	10.91
Connecticut	2,116	1,970	1,984	295,584	256,388	303,176	7.16	7.68	6.54
Delaware	590	679	704	70,787	67,054	81,585	8.33	10.13	8.63
District of Columbia	1,081	1,311	1,752	64,384	43,865	64,273	16.79	29.89	27.26
Florida	5,350	6,776	7,552	1,180,537	1,209,003	1,493,632	4.53	5.60	5.06
Georgia	3,761	4,963	6,049	730,881	754,676	889,162	5.15	6.58	6.80
Hawaii	540	576	651	116,670	119,378	125,284	4.63	4.83	5.20
Idaho	681	896	1,104	114,637	139,586	153,101	5.94	6.42	7.21
Illinois	7,611	8,434	10,043	1,155,733	1,125,624	1,254,527	6.59	7.49	8.01
Indiana	4,990	5,118	5,364	602,192	572,453	634,269	8.29	8.94	8.46
Iowa	2,693	2,940	3,408	279,421	276,610	316,933	9.64	10.63	10.75
Kansas	2,203	2,241	2,538	251,584	263,410	295,852	8.76	8.51	8.58
Kentucky	1,832	2,221	1,961	403,547	400,137	411,637	4.54	5.55	4.76
Louisiana	2,485	3,319	3,550	461,025	473,066	500,616	5.39	7.02	7.09
Maine	911	995	1,137	118,437	110,125	120,783	7.69	9.04	9.41
Maryland	3,793	4,364	5,278	452,016	433,031	507,475	8.39	10.08	10.40
Massachusetts	6,639	7,193	7,500	599,360	505,584	596,934	11.08	14.23	12.56
Michigan	7,749	8,323	9,300	967,872	922,891	992,111	8.01	9.02	9.37
Minnesota	3,314	3,921	4,283	421,533	439,358	520,699	7.86	8.92	8.23
Mississippi	1,624	1,726	1,553	304,375	300,061	322,505	5.34	5.75	4.82
Missouri	3,737	4,565	5,358	504,892	509,453	577,581	7.40	8.96	9.28
Montana	848	1,108	1,275	77,645	88,262	96,129	10.92	12.55	13.26
Nebraska	1,205	1,479	1,485	157,809	166,811	188,391	7.64	8.87	7.88
Nevada	361	578	644	119,846	148,028	199,143	3.01	3.90	3.23
New Hampshire	1,137	1,314	1,196	103,606	95,661	119,503	10.97	13.74	10.01
New Jersey	3,927	4,806	5,605	707,317	669,415	726,145	5.55	7.18	7.72
New Mexico	1,041	1,147	1,197	159,007	174,353	198,398	6.55	6.58	6.03
New York	13,430	13,856	17,094	1,766,276	1,601,269	1,826,944	7.60	8.65	9.36
North Carolina	5,307	6,378	6,411	751,837	702,132	824,233	7.06	9.08	7.78
North Dakota	767	855	956	66,568	67,835	76,213	11.52	12.60	12.54
Ohio	7,167	8,115	8,330	1,105,197	1,056,810	1,119,732	6.48	7.68	7.44
Oklahoma	2,026	2,348	2,230	329,713	336,797	382,078	6.14	6.97	5.84
Oregon	1,726	2,240	2,490	276,672	303,895	347,267	6.24	7.37	7.17
Pennsylvania	10,582	11,323	13,521	1,149,074	1,022,583	1,180,592	9.21	11.07	11.45
Rhode Island	1,088	1,202	1,615	104,444	83,023	114,254	10.42	14.48	14.14
South Carolina	2,285	2,710	2,946	404,863	385,887	426,854	5.64	7.02	6.90
South Dakota	839	976	961	70,155	76,172	85,043	11.96	12.81	11.30
Tennessee	3,086	3,598	3,400	522,815	515,066	571,200	5.90	6.99	5.95
Texas	9,973	11,641	12,988	1,907,830	2,038,563	2,351,723	5.23	5.71	5.52
Utah	2,010	2,838	3,091	225,001	290,363	313,689	8.93	9.77	9.85
Vermont	660	766	861	58,910	52,029	63,895	11.20	14.72	13.48
Virginia	5,046	5,474	5,846	685,233	656,887	735,711	7.36	8.33	7.95
Washington	3,108	3,918	4,231	493,660	539,707	618,757	6.30	7.26	6.84
West Virginia	1,045	1,197	1,451	191,056	182,025	174,583	5.47	6.58	8.31
Wisconsin	4,375	4,838	5,488	493,627	498,268	566,174	8.86	9.71	9.69
Wyoming	373	431	398	47,058	53,048	55,878	7.93	8.12	7.12
Puerto Rico	2,137	2,841	NA	NA	NA	418,390	NA	NA	NA

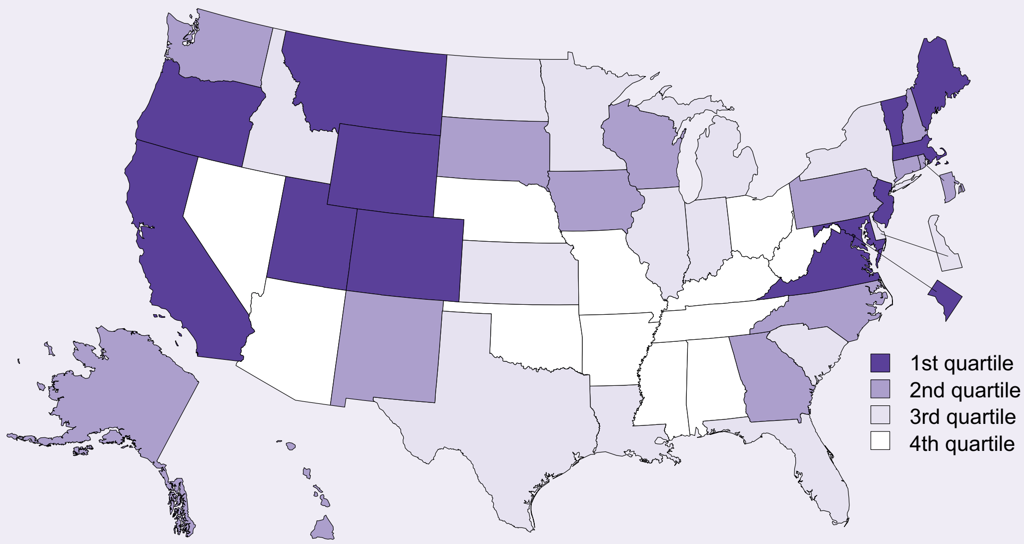
NA = not available
NS&E = natural sciences and engineering

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years; and U.S. Census Bureau, Population Division.

Science and Engineering Indicators 2006

S&E Degrees as Share of Higher Education Degrees Conferred

Figure 8-15
S&E degrees as share of higher education degrees conferred: 2003



1st quartile (42.7%–32.5%)	2nd quartile (32.0%–29.1%)	3rd quartile (28.9%–26.1%)	4th quartile (25.9%–19.5%)
California	Alaska	Delaware	Alabama
Colorado	Connecticut	Florida	Arizona
District of Columbia	Georgia	Idaho	Arkansas
Maine	Hawaii	Illinois	Kentucky
Maryland	Iowa	Indiana	Mississippi
Massachusetts	New Hampshire	Kansas	Missouri
Montana	New Mexico	Louisiana	Nebraska
New Jersey	North Carolina	Michigan	Nevada
Oregon	Pennsylvania	Minnesota	Ohio
Utah	Rhode Island	New York	Oklahoma
Vermont	South Dakota	North Dakota	Tennessee
Virginia	Washington	South Carolina	West Virginia
Wyoming	Wisconsin	Texas	

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System. See Table 8-15.

Findings

- In 2003, more than 564,000 S&E bachelor's, master's, and doctoral degrees were conferred nationwide; since 1993, S&E degrees have represented about 30% of all higher education degrees.
- There is a significant difference in the emphasis that states place on technical higher education. In some states, nearly 40% of their degrees are awarded in S&E fields; in others, fewer than 20% of their degrees are awarded in these fields.
- The District of Columbia has a high value of 43% because of the large S&E graduate programs in political science and public administration at several of its academic institutions.

This indicator is a measure of the extent to which a state's higher education programs are concentrated in science and engineering fields. The indicator is expressed as the percentage of higher education degrees that were conferred in S&E fields. High values for this indicator are from states that emphasize S&E fields in their higher education systems.

S&E fields include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. For both S&E degrees and higher education degrees conferred, bachelor's, master's, and doctoral degrees are included; associate's degrees are excluded. Geographic location refers to the location of the degree-granting institution and does not reflect the state where students permanently reside. The year is the latter date of the academic year. For example, data for 2003 represent degrees conferred during the 2002–03 academic year.

Table 8-15
S&E degrees as share of higher education degrees conferred, by state: 1993, 1998, and 2003

State	S&E degrees			All higher education degrees			S&E/higher education degrees (%)		
	1993	1998	2003	1993	1998	2003	1993	1998	2003
United States	473,414	506,827	564,444	1,576,838	1,661,105	1,897,322	30.0	30.5	29.7
Alabama	6,676	6,872	6,919	26,567	27,205	29,363	25.1	25.3	23.6
Alaska	476	714	605	1,633	2,028	1,905	29.1	35.2	31.8
Arizona	5,984	7,298	8,669	22,212	33,186	44,485	26.9	22.0	19.5
Arkansas	2,341	2,827	3,137	10,422	11,572	13,167	22.5	24.4	23.8
California	56,919	58,687	68,369	153,400	153,238	182,805	37.1	38.3	37.4
Colorado	10,348	11,460	12,692	26,967	29,100	33,280	38.4	39.4	38.1
Connecticut	7,000	7,012	7,776	22,336	21,603	24,948	31.3	32.5	31.2
Delaware	1,817	1,806	2,027	5,154	5,981	7,054	35.3	30.2	28.7
District of Columbia	5,953	6,545	7,201	14,716	15,891	16,870	40.5	41.2	42.7
Florida	14,658	17,462	20,638	57,848	66,845	76,775	25.3	26.1	26.9
Georgia	9,126	11,470	13,427	34,247	40,778	44,271	26.6	28.1	30.3
Hawaii	1,710	2,034	2,000	5,715	6,178	6,598	29.9	32.9	30.3
Idaho	1,383	1,660	2,146	4,993	5,719	7,592	27.7	29.0	28.3
Illinois	20,620	21,888	25,263	76,596	80,329	93,032	26.9	27.2	27.2
Indiana	11,799	11,498	12,186	39,441	40,026	45,871	29.9	28.7	26.6
Iowa	6,155	6,394	7,060	21,798	21,747	24,284	28.2	29.4	29.1
Kansas	4,914	5,135	5,816	18,894	19,293	22,294	26.0	26.6	26.1
Kentucky	4,420	5,034	5,062	18,919	20,155	22,308	23.4	25.0	22.7
Louisiana	5,754	6,940	7,212	22,976	24,730	27,336	25.0	28.1	26.4
Maine	2,237	2,211	2,546	6,933	6,600	7,548	32.3	33.5	33.7
Maryland	10,683	11,778	13,985	30,463	32,918	37,229	35.1	35.8	37.6
Massachusetts	20,745	22,001	24,047	64,238	66,924	73,802	32.3	32.9	32.6
Michigan	18,024	18,615	21,001	62,168	63,482	74,158	29.0	29.3	28.3
Minnesota	8,755	9,358	9,873	30,741	31,068	35,094	28.5	30.1	28.1
Mississippi	3,400	3,376	3,311	13,648	14,046	15,554	24.9	24.0	21.3
Missouri	8,949	10,947	12,521	36,961	41,264	49,805	24.2	26.5	25.1
Montana	1,541	2,073	2,279	5,007	5,852	6,292	30.8	35.4	36.2
Nebraska	2,777	3,213	3,277	11,767	13,400	14,995	23.6	24.0	21.9
Nevada	910	1,372	1,520	3,913	5,037	5,994	23.3	27.2	25.4
New Hampshire	2,890	3,037	3,050	9,589	9,514	9,848	30.1	31.9	31.0
New Jersey	11,988	13,023	15,234	34,260	34,904	41,796	35.0	37.3	36.4
New Mexico	2,544	2,669	2,628	8,039	8,910	8,985	31.6	30.0	29.2
New York	43,020	42,658	49,108	144,939	146,141	170,122	29.7	29.2	28.9
North Carolina	12,952	14,576	15,558	39,696	43,291	48,705	32.6	33.7	31.9
North Dakota	1,354	1,543	1,583	5,278	5,425	5,900	25.7	28.4	26.8
Ohio	19,026	19,596	19,706	69,415	69,467	76,541	27.4	28.2	25.7
Oklahoma	4,938	5,747	5,654	19,875	21,590	21,828	24.8	26.6	25.9
Oregon	5,779	6,297	6,869	17,324	18,128	21,022	33.4	34.7	32.7
Pennsylvania	25,350	26,174	29,675	85,052	86,601	99,234	29.8	30.2	29.9
Rhode Island	3,065	2,933	3,446	11,735	10,500	11,691	26.1	27.9	29.5
South Carolina	5,499	5,836	6,493	19,852	20,053	23,393	27.7	29.1	27.8
South Dakota	1,677	1,962	1,796	5,352	5,484	5,605	31.3	35.8	32.0
Tennessee	7,173	8,080	8,359	26,091	29,254	32,993	27.5	27.6	25.3
Texas	25,466	27,773	31,303	91,031	98,209	113,409	28.0	28.3	27.6
Utah	5,323	6,572	7,187	15,905	19,875	22,124	33.5	33.1	32.5
Vermont	2,146	2,215	2,042	5,863	6,013	5,957	36.6	36.8	34.3
Virginia	14,834	14,786	16,379	41,181	42,110	46,845	36.0	35.1	35.0
Washington	8,639	9,847	10,852	27,973	31,360	33,890	30.9	31.4	32.0
West Virginia	2,266	2,590	2,839	10,621	11,010	11,974	21.3	23.5	23.7
Wisconsin	10,589	10,328	11,299	34,846	34,914	38,539	30.4	29.6	29.3
Wyoming	822	905	819	2,248	2,157	2,212	36.6	42.0	37.0
Puerto Rico	3,675	4,425	NA	15,207	15,798	NA	24.2	28.0	NA

NA = not available

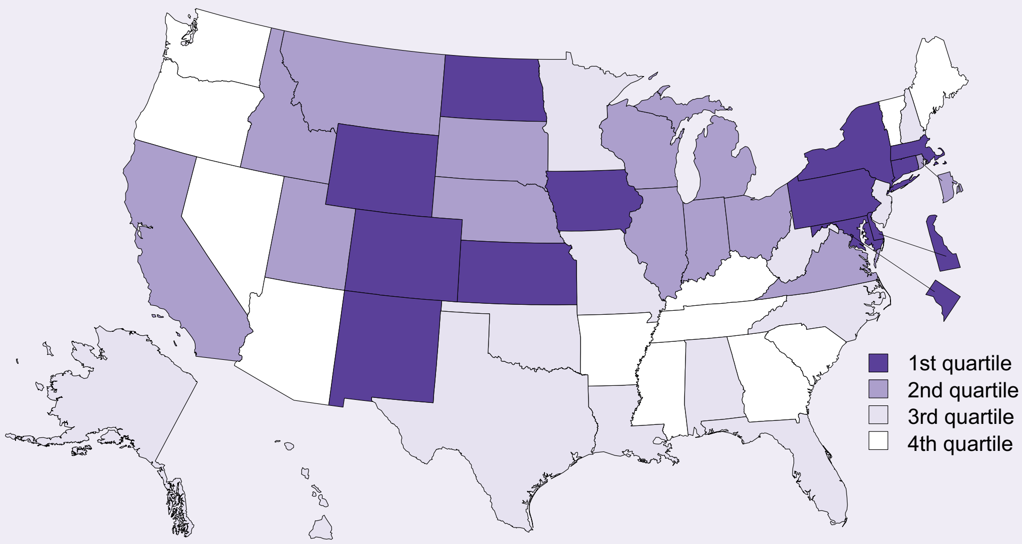
NOTES: S&E degrees conferred include bachelor's, master's, and doctoral degrees. S&E degrees include physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering. All degrees conferred include bachelor's, master's, and doctoral degrees.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years.

Science and Engineering Indicators 2006

S&E Graduate Students per 1,000 Individuals 25–34 Years Old

Figure 8-16
S&E graduate students per 1,000 individuals 25–34 years old: 2003



1st quartile (70.33–13.93)	2nd quartile (13.91–10.98)	3rd quartile (10.79–8.85)	4th quartile (8.84–4.65)
Colorado	California	Alabama	Arizona
Connecticut	Idaho	Alaska	Arkansas
Delaware	Illinois	Florida	Georgia
District of Columbia	Indiana	Hawaii	Kentucky
Iowa	Michigan	Louisiana	Maine
Kansas	Montana	Minnesota	Mississippi
Maryland	Nebraska	Missouri	Nevada
Massachusetts	Ohio	New Hampshire	Oregon
New Mexico	Rhode Island	New Jersey	South Carolina
New York	South Dakota	North Carolina	Tennessee
North Dakota	Utah	Oklahoma	Vermont
Pennsylvania	Virginia	Texas	Washington
Wyoming	Wisconsin	West Virginia	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and U.S. Census Bureau, Population Division. See table 8-16.

Findings

- The number of S&E graduate students in the United States grew 8% over the last decade, rising from approximately 434,000 in 1993 to nearly 469,000 in 2003.
- Individual states showed varying levels of graduate level S&E training, with 0.46% to 2.48% of their 25–34-year-old population pursuing S&E graduate studies.
- The District of Columbia is an outlier, with more than 7% of its 25–34-year-old population enrolled as S&E graduate students, reflecting a large concentration of S&E graduate programs in political science and public administration and a small resident population.
- Maine and Vermont show different involvement in undergraduate- and graduate-level S&E education as their rankings on these two indicators shift from the first to the fourth quartiles. These states emphasize undergraduate S&E education at the state level, and their students pursue graduate-level S&E education regionally and nationally.

Graduate students in science and engineering fields are a source of the technical leaders of the future. The ratio of S&E graduate students to a state's 25–34-year-old population is a broad measure of a state's investment in producing high-level scientists and engineers. The 25–34-year-old cohort was chosen to approximate the age of most graduate students. This cohort includes U.S. citizens and noncitizens as well as graduate students who come from other states and countries.

Data on S&E graduate students were collected by surveying all academic institutions in the United States that offer doctorate or master's degree programs in any science or engineering field, including physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. Graduate students who are enrolled in schools of nursing, public health, dentistry, veterinary medicine, and other health-related disciplines are not included.

Table 8-16
S&E graduate students per 1,000 individuals 25–34 years old, by state: 1993, 1998, and 2003

State	S&E graduate students			Population 25–34 years old			S&E graduate students/ 1,000 individuals 25–34 years old		
	1993	1998	2003	1993	1998	2003	1993	1998	2003
United States	433,630	402,268	468,837	41,797,082	38,743,134	39,872,598	10.37	10.38	11.76
Alabama	5,820	5,118	5,859	637,081	621,468	595,804	9.14	8.24	9.83
Alaska	829	695	761	102,465	75,618	82,478	8.09	9.19	9.23
Arizona	6,974	6,417	7,104	638,087	641,023	803,477	10.93	10.01	8.84
Arkansas	2,018	2,038	2,173	344,514	331,366	353,978	5.86	6.15	6.14
California	54,281	51,615	63,595	5,650,931	5,203,609	5,296,858	9.61	9.92	12.01
Colorado	8,793	8,385	10,386	580,405	531,951	716,024	15.15	15.76	14.51
Connecticut	6,505	5,889	7,013	542,514	467,651	416,710	11.99	12.59	16.83
Delaware	1,533	1,459	1,664	120,081	116,487	107,029	12.77	12.53	15.55
District of Columbia	8,979	7,214	7,686	117,025	100,486	109,290	76.73	71.79	70.33
Florida	14,273	13,897	18,690	2,079,987	1,928,332	2,111,800	6.86	7.21	8.85
Georgia	8,677	8,466	9,907	1,196,457	1,211,587	1,349,465	7.25	6.99	7.34
Hawaii	1,747	1,575	1,761	189,366	154,881	164,500	9.23	10.17	10.71
Idaho	1,479	1,474	1,979	149,057	151,433	179,230	9.92	9.73	11.04
Illinois	22,573	21,822	23,866	1,926,485	1,743,624	1,805,301	11.72	12.52	13.22
Indiana	9,278	7,952	8,964	883,464	838,946	816,357	10.50	9.48	10.98
Iowa	4,996	4,331	5,145	399,918	364,603	362,158	12.49	11.88	14.21
Kansas	4,960	5,645	6,326	388,218	348,681	352,433	12.78	16.19	17.95
Kentucky	3,640	3,442	4,478	583,619	549,127	562,218	6.24	6.27	7.96
Louisiana	5,379	5,161	6,382	655,495	586,604	591,648	8.21	8.80	10.79
Maine	786	586	679	188,363	169,350	146,110	4.17	3.46	4.65
Maryland	9,124	9,160	10,667	882,453	789,089	720,652	10.34	11.61	14.80
Massachusetts	19,991	19,597	22,016	1,061,596	979,008	888,560	18.83	20.02	24.78
Michigan	15,982	14,405	16,937	1,498,084	1,393,047	1,312,899	10.67	10.34	12.90
Minnesota	7,035	6,662	7,205	738,253	647,066	673,520	9.53	10.30	10.70
Mississippi	2,635	2,943	2,511	381,258	380,593	382,352	6.91	7.73	6.57
Missouri	6,289	5,658	7,175	806,964	736,889	737,924	7.79	7.68	9.72
Montana	1,319	1,225	1,446	108,799	95,376	103,918	12.12	12.84	13.91
Nebraska	2,843	2,252	2,784	237,918	211,365	225,838	11.95	10.65	12.33
Nevada	1,406	1,461	1,868	241,481	251,140	343,535	5.82	5.82	5.44
New Hampshire	1,144	1,141	1,458	191,727	181,466	149,659	5.97	6.29	9.74
New Jersey	11,312	10,316	11,959	1,292,830	1,137,612	1,116,460	8.75	9.07	10.71
New Mexico	3,577	2,950	3,774	241,534	216,029	231,163	14.81	13.66	16.33
New York	42,348	38,646	41,532	3,027,979	2,701,240	2,670,831	13.99	14.31	15.55
North Carolina	9,290	9,820	11,543	1,132,784	1,129,041	1,227,593	8.20	8.70	9.40
North Dakota	920	958	1,534	93,082	80,870	77,532	9.88	11.85	19.79
Ohio	19,254	16,364	17,966	1,704,983	1,566,982	1,465,077	11.29	10.44	12.26
Oklahoma	4,301	3,840	4,553	469,762	424,994	461,427	9.16	9.04	9.87
Oregon	4,215	3,585	4,369	440,878	427,402	500,562	9.56	8.39	8.73
Pennsylvania	19,901	18,325	20,555	1,788,478	1,617,666	1,475,595	11.13	11.33	13.93
Rhode Island	2,022	1,550	1,878	163,192	150,218	136,881	12.39	10.32	13.72
South Carolina	3,877	3,342	3,440	581,100	566,157	560,094	6.67	5.90	6.14
South Dakota	947	829	1,000	100,108	87,577	90,400	9.46	9.47	11.06
Tennessee	6,474	5,891	6,646	797,271	787,562	820,123	8.12	7.48	8.10
Texas	29,886	26,525	32,820	2,992,253	2,811,983	3,284,470	9.99	9.43	9.99
Utah	4,127	3,729	4,710	284,718	291,726	380,431	14.50	12.78	12.38
Vermont	669	610	613	87,896	84,759	70,529	7.61	7.20	8.69
Virginia	11,332	11,202	12,892	1,136,797	1,069,562	1,017,047	9.97	10.47	12.68
Washington	6,057	5,813	6,689	850,276	802,313	854,311	7.12	7.25	7.83
West Virginia	2,129	2,145	2,390	238,946	227,943	224,273	8.91	9.41	10.66
Wisconsin	8,827	7,354	8,620	787,430	706,440	686,324	11.21	10.41	12.56
Wyoming	877	789	869	62,720	53,192	59,750	13.98	14.83	14.54
Puerto Rico	2,004	2,464	3,366	NA	NA	543,455	NA	NA	6.19

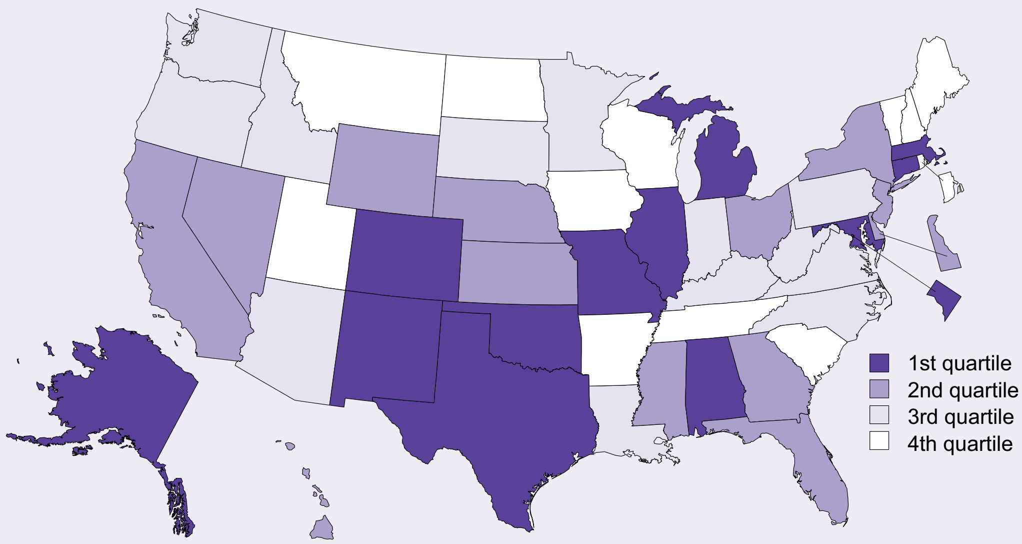
NA = not available

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and U.S. Census Bureau, Population Division.

Science and Engineering Indicators 2006

Advanced S&E Degrees as Share of S&E Degrees Conferred

Figure 8-17
Advanced S&E degrees as share of S&E degrees conferred: 2003



1st quartile (42.3%–25.4%)	2nd quartile (25.2%–21.5%)	3rd quartile (21.1%–17.3%)	4th quartile (17.2%–7.9%)
Alabama	California	Arizona	Arkansas
Alaska	Delaware	Idaho	Iowa
Colorado	Florida	Indiana	Maine
Connecticut	Georgia	Kentucky	Montana
District of Columbia	Hawaii	Louisiana	New Hampshire
Illinois	Kansas	Minnesota	North Dakota
Maryland	Mississippi	North Carolina	Rhode Island
Massachusetts	Nebraska	Oregon	South Carolina
Michigan	Nevada	Pennsylvania	Tennessee
Missouri	New Jersey	South Dakota	Utah
New Mexico	New York	Virginia	Vermont
Oklahoma	Ohio	Washington	Wisconsin
Texas	Wyoming	West Virginia	

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System. See Table 8-17.

Findings

- In 2003, nearly 132,000 advanced S&E degrees were awarded nationwide; this total represented approximately 19% more than in 1993, but the share of advanced degrees remained stable at 23% of all S&E degrees conferred.
- Some states specialize in providing graduate-level technical training, with just over 30% of their S&E graduates completing training at the master's or doctoral level; other states have much smaller graduate S&E programs, with values as low as 8%.
- The District of Columbia is an outlier, with 42% reflecting large S&E graduate programs in political science and public administration at several of its academic institutions.
- States that emphasize advanced S&E education are not necessarily the same states as those that emphasize undergraduate-level S&E education; only about half of the states in the top two quartiles for intensity of advanced S&E degree production would appear in the top two quartiles for a similar indicator showing intensity of S&E bachelor's degree production.

This indicator shows the extent to which a state's higher education programs in science and engineering are concentrated at the graduate level. S&E fields include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. Advanced S&E degrees include master's and doctoral degrees. All degrees include bachelor's, master's, and doctoral degrees. Associate's degrees are excluded from this indicator.

The indicator value is obtained by dividing the number of advanced S&E degrees by the total number of S&E degrees awarded by the higher education institutions within the state. A high value shows that a state is significantly investing its S&E training budget at the graduate level.

Table 8-17
Advanced S&E degrees as share of S&E degrees conferred, by state: 1993, 1998, and 2003

	Advanced S&E degrees			All S&E degrees			Advanced/ all S&E degrees (%)		
State	1993	1998	2003	1993	1998	2003	1993	1998	2003
United States	110,701	120,203	131,656	473,414	506,827	564,444	23.4	23.7	23.3
Alabama	1,420	1,504	1,897	6,676	6,872	6,919	21.3	21.9	27.4
Alaska	135	235	194	476	714	605	28.4	32.9	32.1
Arizona	1,618	2,023	1,785	5,984	7,298	8,669	27.0	27.7	20.6
Arkansas	367	449	487	2,341	2,827	3,137	15.7	15.9	15.5
California	14,445	14,166	15,796	56,919	58,687	68,369	25.4	24.1	23.1
Colorado	2,583	2,949	3,230	10,348	11,460	12,692	25.0	25.7	25.4
Connecticut	1,668	1,793	2,078	7,000	7,012	7,776	23.8	25.6	26.7
Delaware	369	376	448	1,817	1,806	2,027	20.3	20.8	22.1
District of Columbia	2,448	2,989	3,045	5,953	6,545	7,201	41.1	45.7	42.3
Florida	3,372	3,908	4,593	14,658	17,462	20,638	23.0	22.4	22.3
Georgia	2,078	2,532	3,081	9,126	11,470	13,427	22.8	22.1	22.9
Hawaii	428	532	473	1,710	2,034	2,000	25.0	26.2	23.7
Idaho	350	343	405	1,383	1,660	2,146	25.3	20.7	18.9
Illinois	5,782	6,390	7,691	20,620	21,888	25,263	28.0	29.2	30.4
Indiana	2,372	2,534	2,458	11,799	11,498	12,186	20.1	22.0	20.2
Iowa	1,097	1,211	1,127	6,155	6,394	7,060	17.8	18.9	16.0
Kansas	987	1,176	1,302	4,914	5,135	5,816	20.1	22.9	22.4
Kentucky	827	954	1,067	4,420	5,034	5,062	18.7	19.0	21.1
Louisiana	1,206	1,509	1,403	5,754	6,940	7,212	21.0	21.7	19.5
Maine	188	217	201	2,237	2,211	2,546	8.4	9.8	7.9
Maryland	2,969	3,431	4,096	10,683	11,778	13,985	27.8	29.1	29.3
Massachusetts	5,827	6,514	7,218	20,745	22,001	24,047	28.1	29.6	30.0
Michigan	4,189	4,823	5,696	18,024	18,615	21,001	23.2	25.9	27.1
Minnesota	1,390	1,679	1,809	8,755	9,358	9,873	15.9	17.9	18.3
Mississippi	714	664	712	3,400	3,376	3,311	21.0	19.7	21.5
Missouri	2,135	2,869	3,257	8,949	10,947	12,521	23.9	26.2	26.0
Montana	276	380	384	1,541	2,073	2,279	17.9	18.3	16.8
Nebraska	551	626	706	2,777	3,213	3,277	19.8	19.5	21.5
Nevada	210	341	370	910	1,372	1,520	23.1	24.9	24.3
New Hampshire	417	406	472	2,890	3,037	3,050	14.4	13.4	15.5
New Jersey	3,092	2,928	3,569	11,988	13,023	15,234	25.8	22.5	23.4
New Mexico	799	801	721	2,544	2,669	2,628	31.4	30.0	27.4
New York	11,202	10,753	12,372	43,020	42,658	49,108	26.0	25.2	25.2
North Carolina	2,117	2,454	2,898	12,952	14,576	15,558	16.3	16.8	18.6
North Dakota	191	228	231	1,354	1,543	1,583	14.1	14.8	14.6
Ohio	5,030	5,281	4,625	19,026	19,596	19,706	26.4	26.9	23.5
Oklahoma	1,334	1,756	1,793	4,938	5,747	5,654	27.0	30.6	31.7
Oregon	1,207	1,298	1,307	5,779	6,297	6,869	20.9	20.6	19.0
Pennsylvania	5,326	5,489	6,134	25,350	26,174	29,675	21.0	21.0	20.7
Rhode Island	614	579	532	3,065	2,933	3,446	20.0	19.7	15.4
South Carolina	920	1,007	1,032	5,499	5,836	6,493	16.7	17.3	15.9
South Dakota	281	379	373	1,677	1,962	1,796	16.8	19.3	20.8
Tennessee	1,270	1,475	1,440	7,173	8,080	8,359	17.7	18.3	17.2
Texas	6,434	7,445	8,080	25,466	27,773	31,303	25.3	26.8	25.8
Utah	1,013	1,006	1,060	5,323	6,572	7,187	19.0	15.3	14.7
Vermont	330	457	181	2,146	2,215	2,042	15.4	20.6	8.9
Virginia	2,853	3,092	3,374	14,834	14,786	16,379	19.2	20.9	20.6
Washington	1,899	1,777	1,953	8,639	9,847	10,852	22.0	18.0	18.0
West Virginia	355	501	492	2,266	2,590	2,839	15.7	19.3	17.3
Wisconsin	1,803	1,712	1,809	10,589	10,328	11,299	17.0	16.6	16.0
Wyoming	213	262	199	822	905	819	25.9	29.0	24.3
Puerto Rico	415	536	NA	3,675	4,425	NA	11.3	12.1	NA

NA = not avaiablle

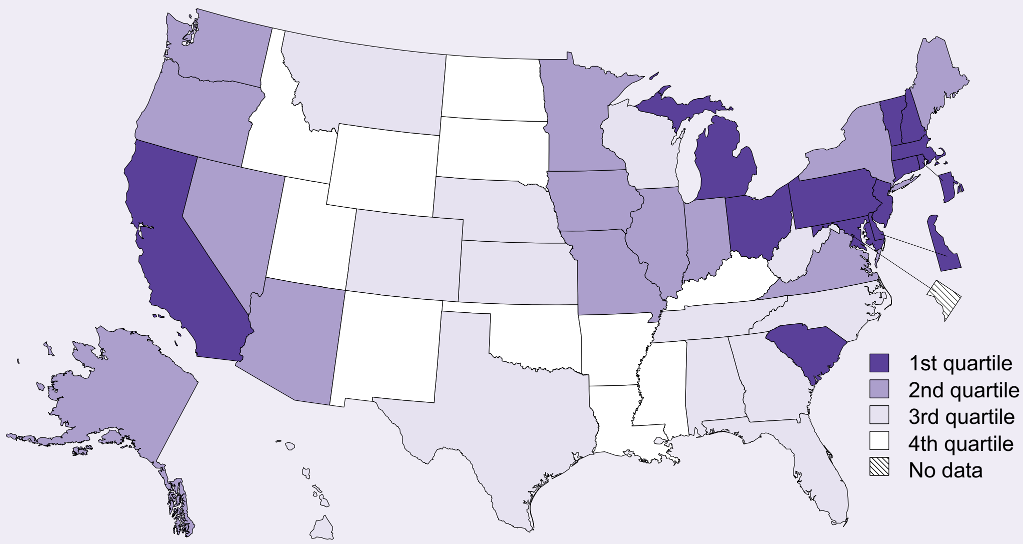
NOTES: All degrees include bachelor's, master's, and doctoral degrees; advanced degrees include only master's and doctoral degrees. S&E degrees include physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years.

Science and Engineering Indicators 2006

Average Undergraduate Charge at Public 4-Year Institutions

Figure 8-18
Average undergraduate charge at public 4-year institutions: 2004



1st quartile ($15,109–$12,208)	2nd quartile ($12,002–$10,118)	3rd quartile ($9,751–$8,604)	4th quartile ($8,547–$7,494)	No data
California	Alaska	Alabama	Arkansas	District of Columbia
Connecticut	Arizona	Colorado	Idaho	
Delaware	Illinois	Florida	Kentucky	
Maryland	Indiana	Georgia	Louisiana	
Massachusetts	Iowa	Hawaii	Mississippi	
Michigan	Maine	Kansas	New Mexico	
New Hampshire	Minnesota	Montana	North Dakota	
New Jersey	Missouri	Nebraska	Oklahoma	
Ohio	Nevada	North Carolina	South Dakota	
Pennsylvania	New York	Tennessee	Utah	
Rhode Island	Oregon	Texas	Wyoming	
South Carolina	Virginia	West Virginia		
Vermont	Washington	Wisconsin		

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-18.

Findings

- During 2004, the total annual nominal charge for a full-time undergraduate student to attend a public 4-year institution averaged $10,720 nationally, an increase of 9% from the previous year.
- Total annual nominal charges at a private 4-year institution averaged $25,204, an increase of 5% from the previous year.
- State averages for public 4-year institutions ranged from a low of $7,494 to a high of $15,109.
- Tuition and required fees averaged approximately 40% of the total charges at public 4-year institutions, but individual states had different cost structures.

The average annual charge for an undergraduate student to attend a public 4-year academic institution is one indicator of how accessible higher education in science and engineering is to a state's less-affluent students. The annual charge includes standard in-state charges for tuition, required fees, room, and board for a full-time undergraduate student who is a resident of that state. These charges were weighted by the number of full-time undergraduates at public institutions. The total charge for all public 4-year institutions in the state was divided by the total number of full-time undergraduates attending public 4-year institutions in the state. The year is the latter date of the academic year. For example, data for 2004 represent costs for the 2003–04 academic year.

To improve the educational attainment of their residents, many states have chosen to reduce the charge to students by providing state subsidies or direct financial aid. Additional financial aid is provided by the federal government and by the academic institutions. The data in this indicator do not include any adjustment for financial aid that a student might receive.

Table 8-18
Average undergraduate charge at public 4-year institutions, by state: 1994, 1999, and 2004
(Dollars)

State	1994	1999	2004
National average	6,365	8,024	10,720
Alabama	5,295	6,558	8,983
Alaska	5,978	8,403	10,118
Arizona	5,463	6,985	10,140
Arkansas	5,296	6,172	8,349
California	7,524	9,035	12,275
Colorado	6,190	7,840	9,751
Connecticut	7,915	9,902	12,772
Delaware	7,790	9,515	12,496
District of Columbia	NA	NA	NA
Florida	5,861	7,283	9,207
Georgia	5,063	7,457	9,090
Hawaii	1,452	8,182	8,760
Idaho	4,977	6,321	8,091
Illinois	6,999	8,812	11,804
Indiana	6,640	8,584	11,637
Iowa	5,439	6,762	10,878
Kansas	5,137	6,236	8,604
Kentucky	5,027	6,222	8,521
Louisiana	5,214	5,919	7,494
Maine	7,503	8,926	11,010
Maryland	8,147	10,512	13,419
Massachusetts	8,503	9,099	12,250
Michigan	7,668	9,205	12,208
Minnesota	5,929	7,561	10,845
Mississippi	5,088	6,015	8,547
Missouri	5,833	7,728	10,320
Montana	5,668	7,054	9,348
Nebraska	4,925	6,482	9,620
Nevada	6,379	7,596	10,333
New Hampshire	7,801	10,532	13,852
New Jersey	8,251	10,977	15,109
New Mexico	5,062	6,433	8,238
New York	7,721	9,698	12,002
North Carolina	4,706	6,525	8,805
North Dakota	5,253	6,615	8,028
Ohio	6,992	9,428	13,319
Oklahoma	4,027	5,740	7,901
Oregon	6,630	8,755	11,626
Pennsylvania	8,277	10,085	13,754
Rhode Island	8,604	10,284	12,763
South Carolina	6,206	7,989	12,710
South Dakota	4,917	6,264	8,379
Tennessee	5,019	6,386	8,936
Texas	4,934	6,756	9,202
Utah	5,125	6,196	7,865
Vermont	10,054	12,238	14,766
Virginia	7,725	8,980	10,900
Washington	6,476	7,985	11,353
West Virginia	5,687	6,755	8,751
Wisconsin	5,249	6,730	9,066
Wyoming	4,900	6,830	8,485

NA = not available

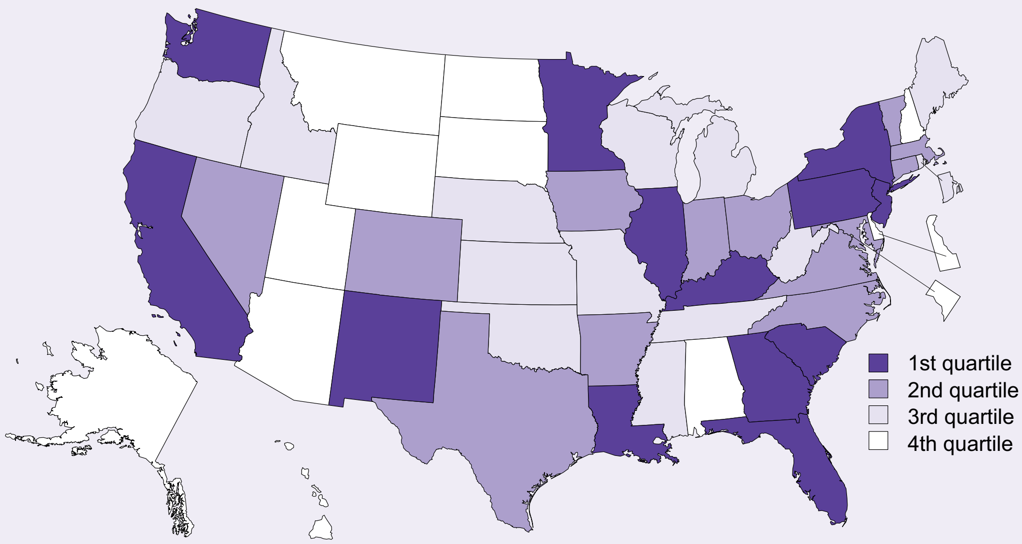
NOTES: National average is reported value in *Digest of Education Statistics* data tables. Data are for entire academic year and are average charges. Tuition and fees were weighted by number of full-time-equivalent undergraduates but are not adjusted to reflect student residency. Room and board are based on full-time students.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years.

Science and Engineering Indicators 2006

State Expenditures on Student Aid per Full-Time Undergraduate Student

Figure 8-19
State expenditures on student aid per full-time undergraduate student: 2002



1st quartile ($1,827–$712)	2nd quartile ($682–$424)	3rd quartile ($399–$94)	4th quartile ($84–$0)
California	Arkansas	Idaho	Alabama
Florida	Colorado	Kansas	Alaska
Georgia	Connecticut	Maine	Arizona
Illinois	Indiana	Michigan	Delaware
Kentucky	Iowa	Mississippi	District of Columbia
Louisiana	Maryland	Missouri	Hawaii
Minnesota	Massachusetts	Nebraska	Montana
New Jersey	Nevada	Oklahoma	New Hampshire
New Mexico	North Carolina	Oregon	North Dakota
New York	Ohio	Rhode Island	South Dakota
Pennsylvania	Texas	Tennessee	Utah
South Carolina	Vermont	West Virginia	Wyoming
Washington	Virginia	Wisconsin	

SOURCES: National Association of State Scholarship and Grant Programs, Annual Survey Report; and U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-19.

Findings

- In the United States, the total amount of state financial aid from grants that were provided to undergraduates rose from nearly $2.8 billion in 1995 to nearly $5.0 billion in 2002, an average annual increase of 8.7%. On a per-student basis, this represented an average annual increase of 7.1%, rising from $414 in 1995 to $671 in 2002.
- The amount of financial assistance provided by the states and the District of Columbia varied greatly; 13 averaged less than $100 per undergraduate student, and 6 provided more than $1,000 per student.
- Most states showed rather small increases in the amount of state aid they provided to undergraduates between 1995 and 2002.

The cost of an undergraduate education can be reduced with financial assistance from the state, federal government, or academic institution. This indicator measures the amount of financial support from state grants that go to undergraduate students at both public and private institutions in the state. It is calculated by dividing the total state grant aid to undergraduates by the number of full-time undergraduates who are attending school in the state. A high value is one indicator of state efforts to provide access to higher education at a time of escalating undergraduate costs.

This indicator should be viewed relative to the level of tuition charged to undergraduates in a state because some states have chosen to subsidize tuition for all students at public institutions rather than provide grants.

Total state grant expenditures for financial aid include both need-based and non-need-based grants. State assistance through subsidized or unsubsidized loans and awards to students at the graduate and first professional degree levels are not included. The number of undergraduate students represents the total full-time undergraduate enrollment in both public and private 4-year institutions in the state. The year is the latter date of the academic year. For example, data for 2002 represent costs for the 2001–02 academic year.

Table 8-19
State expenditures on student aid per full-time undergraduate student, by state: 1995, 1999, and 2002

State	State expenditures on student aid ($ thousands)			Undergraduate enrollment at 4-year institutions			State expenditures on student aid/ undergraduate ($)		
	1995	1999	2002	1995	1999	2002	1995	1999	2002
United States	2,782,809	3,595,204	4,999,047	6,718,904	6,946,479	7,450,520	414	518	671
Alabama	9,087	7,665	7,335	120,585	121,407	127,475	75	63	58
Alaska	444	0	0	26,256	24,882	24,939	17	0	0
Arizona	3,482	2,731	2,812	89,595	97,317	124,389	39	28	23
Arkansas	9,647	20,235	37,897	65,790	69,246	73,369	147	292	517
California	232,067	331,636	514,348	511,753	566,462	636,105	453	585	809
Colorado	30,873	54,151	60,013	120,787	130,146	138,846	256	416	432
Connecticut	20,905	33,117	45,175	79,583	79,499	87,335	263	417	517
Delaware	1,235	1,692	1,626	26,940	27,107	28,125	46	62	58
District of Columbia	1,022	728	1,321	43,623	40,163	52,262	23	18	25
Florida	98,710	169,947	321,447	231,199	258,869	310,145	427	656	1,036
Georgia	116,557	221,350	362,201	170,969	182,796	198,254	682	1,211	1,827
Hawaii	732	493	531	27,945	27,345	27,637	26	18	19
Idaho	1,043	1,053	4,810	36,007	37,751	50,969	29	28	94
Illinois	270,322	338,128	407,622	259,977	269,283	281,619	1,040	1,256	1,447
Indiana	68,162	100,824	126,390	207,468	210,951	222,510	329	478	568
Iowa	36,111	48,719	51,668	91,540	96,438	99,468	394	505	519
Kansas	11,920	11,774	13,099	80,616	81,270	86,126	148	145	152
Kentucky	25,517	38,441	86,325	108,355	109,480	112,935	235	351	764
Louisiana	13,079	55,237	104,117	143,355	145,791	146,230	91	379	712
Maine	5,787	7,701	12,021	41,113	40,585	43,082	141	190	279
Maryland	31,635	45,339	51,910	107,952	110,860	122,430	293	409	424
Massachusetts	61,945	92,173	114,600	231,396	233,905	235,697	268	394	486
Michigan	81,340	92,299	106,244	263,243	275,495	295,912	309	335	359
Minnesota	97,960	113,429	130,408	139,479	143,570	152,381	702	790	856
Mississippi	1,306	926	21,481	56,057	59,660	62,595	23	16	343
Missouri	23,186	35,178	43,488	167,120	175,718	182,463	139	200	238
Montana	419	1,396	2,810	31,318	32,508	33,462	13	43	84
Nebraska	2,726	4,692	7,380	62,187	59,602	59,388	44	79	124
Nevada	342	5,900	19,899	25,138	26,944	34,274	14	219	581
New Hampshire	1,493	1,753	3,075	40,633	42,964	42,534	37	41	72
New Jersey	169,824	176,843	212,195	146,273	149,904	161,329	1,161	1,180	1,315
New Mexico	14,031	28,637	39,395	41,719	41,833	43,285	336	685	910
New York	643,863	628,246	699,481	568,788	558,962	581,671	1,132	1,124	1,203
North Carolina	42,714	94,886	134,196	178,074	187,603	196,748	240	506	682
North Dakota	2,312	2,322	1,776	28,432	27,340	29,951	81	85	59
Ohio	124,132	144,646	194,039	307,053	306,685	309,285	404	472	627
Oklahoma	16,311	26,462	31,464	92,153	91,467	102,808	177	289	306
Oregon	13,761	16,027	19,866	66,039	70,883	80,385	208	226	247
Pennsylvania	218,668	270,724	337,014	353,751	364,879	386,220	618	742	873
Rhode Island	6,340	5,717	6,077	46,611	48,231	50,452	136	119	120
South Carolina	17,297	22,853	102,039	85,494	89,909	95,652	202	254	1,067
South Dakota	661	0	0	32,873	30,884	33,125	20	0	0
Tennessee	19,146	21,499	37,915	131,281	137,237	142,697	146	157	266
Texas	29,102	61,728	199,523	406,673	411,305	449,177	72	150	444
Utah	2,660	1,957	4,069	101,974	106,939	128,285	26	18	32
Vermont	11,838	12,837	15,636	25,640	26,983	26,395	462	476	592
Virginia	71,224	95,322	110,467	165,321	174,801	180,228	431	545	613
Washington	54,210	75,692	102,458	96,388	101,282	110,310	562	747	929
West Virginia	13,081	13,103	21,054	66,783	67,762	69,795	196	193	302
Wisconsin	52,355	56,841	68,167	160,494	164,978	170,859	326	345	399
Wyoming	225	155	163	9,111	8,598	8,907	25	18	18
Puerto Rico	22,074	18,510	35,602	122,844	157,988	156,795	180	117	227

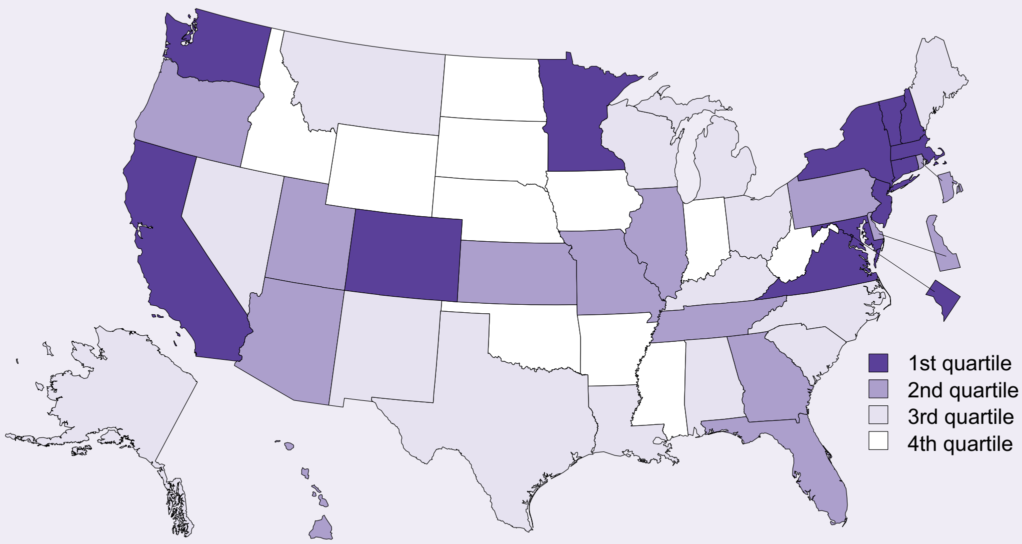
NOTE: Enrollment data are for 4-year degree-granting institutions that participated in Title IV federal financial aid programs.

SOURCE: National Association of State Scholarship and Grant Programs, Annual Survey Report, various years; and U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years.

Science and Engineering Indicators 2006

Bachelor's Degree Holders as Share of Workforce

Figure 8-20
Bachelor's degree holders as share of workforce: 2004



1st quartile (65.9%–38.6%)	2nd quartile (37.4%–34.9%)	3rd quartile (34.4%–30.9%)	4th quartile (30.5%–25.3%)
California	Arizona	Alabama	Arkansas
Colorado	Delaware	Alaska	Idaho
Connecticut	Florida	Kentucky	Indiana
District of Columbia	Georgia	Louisiana	Iowa
Maryland	Hawaii	Maine	Mississippi
Massachusetts	Illinois	Michigan	Nebraska
Minnesota	Kansas	Montana	North Dakota
New Hampshire	Missouri	Nevada	Oklahoma
New Jersey	Oregon	New Mexico	South Dakota
New York	Pennsylvania	North Carolina	West Virginia
Vermont	Rhode Island	Ohio	Wyoming
Virginia	Tennessee	South Carolina	
Washington	Utah	Texas	
		Wisconsin	

SOURCES: U.S. Census Bureau, Population Division, Education and Social Stratification Branch, *Educational Attainment in the United States*; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-20.

Findings

- In 2004, 51.8 million individuals held bachelor's degrees in the United States, up from 36.5 million in 1994.
- Nationwide, the percentage of the workforce with at least a bachelor's degree rose from 29.5% in 1994 to 37.2% in 2004. The proportion of the workforce with a bachelor's degree increased considerably in many states. This may reflect a replacement of older cohorts of workers with younger, more-educated ones. It may also indicate the restructuring of state economies to emphasize work that requires more education or credentialism.
- The geographic distribution of bachelor's degree holders in the workforce bears little resemblance to any of the degree-production indicators, which attests to the considerable mobility of the college-educated population in the United States.

The proportion of a state's workers with bachelor's, graduate, and professional degrees is an indicator of the educational and skill levels of its workforce. These workers have a clear advantage over less-educated workers in terms of expected lifetime earnings. A high value for this indicator denotes that a state has a large percentage of workers who completed an undergraduate education.

Degree data, based on the U.S. Census Bureau's Current Population Survey (CPS), are limited to individuals who are age 25 years and older. Civilian workforce data are Bureau of Labor Statistics estimates based on CPS. Estimates for sparsely populated states and the District of Columbia may be imprecise because of their small representation in the survey samples.

Table 8-20
Bachelor's degree holders as share of workforce, by state: 1994, 1999, and 2004

State	Bachelor's degree holders (thousands)			Employed workforce			Bachelor's degree holders in workforce (%)		
	1994	1999	2004	1994	1999	2004	1994	1999	2004
United States	36,538	43,812	51,751	123,901,653	135,145,914	139,253,285	29.5	32.4	37.2
Alabama	402	610	645	1,909,881	2,070,210	2,029,314	21.0	29.5	31.8
Alaska	86	95	99	278,198	297,019	307,704	30.9	32.0	32.2
Arizona	508	715	983	1,976,722	2,355,357	2,636,773	25.7	30.4	37.3
Arkansas	190	276	331	1,148,393	1,198,016	1,232,126	16.5	23.0	26.9
California	4,803	5,593	7,004	13,953,855	15,566,900	16,459,862	34.4	35.9	42.6
Colorado	657	1,008	1,014	1,953,111	2,269,668	2,382,873	33.6	44.4	42.6
Connecticut	579	738	778	1,670,083	1,695,174	1,709,836	34.7	43.5	45.5
Delaware	99	119	144	360,866	387,808	405,669	27.4	30.7	35.5
District of Columbia	141	150	181	285,207	288,016	274,465	49.4	52.1	65.9
Florida	1,943	2,162	2,987	6,502,124	7,401,659	7,997,077	29.9	29.2	37.4
Georgia	1,085	1,048	1,525	3,412,606	3,951,684	4,188,271	31.8	26.5	36.4
Hawaii	188	199	219	555,749	576,314	595,772	33.8	34.5	36.8
Idaho	147	155	203	552,354	620,962	669,728	26.6	25.0	30.3
Illinois	1,749	1,939	2,217	5,766,671	6,143,130	6,000,140	30.3	31.6	36.9
Indiana	526	691	846	2,911,781	3,046,922	3,005,247	18.1	22.7	28.2
Iowa	339	394	467	1,510,253	1,560,848	1,545,412	22.4	25.2	30.2
Kansas	353	443	515	1,279,098	1,359,908	1,383,654	27.6	32.6	37.2
Kentucky	400	501	578	1,729,483	1,854,270	1,870,249	23.1	27.0	30.9
Louisiana	439	556	618	1,785,654	1,926,732	1,940,315	24.6	28.9	31.9
Maine	166	199	213	589,073	641,351	667,223	28.2	31.0	31.9
Maryland	872	1,209	1,270	2,545,413	2,687,843	2,761,015	34.3	45.0	46.0
Massachusetts	1,205	1,253	1,594	2,989,123	3,245,761	3,219,487	40.3	38.6	49.5
Michigan	1,144	1,313	1,572	4,508,900	4,897,144	4,719,343	25.4	26.8	33.3
Minnesota	737	954	1,085	2,471,516	2,686,942	2,813,831	29.8	35.5	38.6
Mississippi	310	329	359	1,159,959	1,223,725	1,248,056	26.7	26.9	28.8
Missouri	711	821	1,039	2,622,286	2,819,853	2,858,897	27.1	29.1	36.3
Montana	131	134	159	410,957	440,646	461,746	31.9	30.4	34.4
Nebraska	209	214	274	862,659	916,270	947,882	24.2	23.4	28.9
Nevada	161	238	359	764,451	978,969	1,126,346	21.1	24.3	31.9
New Hampshire	192	212	293	594,935	666,066	695,739	32.3	31.8	42.1
New Jersey	1,472	1,604	1,957	3,789,960	4,092,714	4,176,230	38.8	39.2	46.9
New Mexico	242	268	296	725,387	793,052	859,962	33.4	33.8	34.4
New York	2,996	3,205	3,827	8,080,243	8,657,431	8,811,784	37.1	37.0	43.4
North Carolina	852	1,173	1,243	3,511,339	3,921,244	4,020,788	24.3	29.9	30.9
North Dakota	76	89	104	327,377	336,481	342,221	23.2	26.5	30.4
Ohio	1,396	1,850	1,811	5,254,199	5,534,376	5,523,037	26.6	33.4	32.8
Oklahoma	415	514	496	1,469,487	1,590,838	1,627,828	28.2	32.3	30.5
Oregon	492	585	629	1,546,552	1,697,288	1,718,504	31.8	34.5	36.6
Pennsylvania	1,545	1,887	2,093	5,529,551	5,809,824	5,926,978	27.9	32.5	35.3
Rhode Island	156	176	193	480,669	518,848	533,313	32.5	33.9	36.2
South Carolina	412	537	656	1,729,363	1,876,895	1,906,572	23.8	28.6	34.4
South Dakota	75	111	117	364,452	394,898	413,121	20.6	28.1	28.3
Tennessee	535	626	965	2,511,085	2,722,124	2,751,755	21.3	23.0	35.1
Texas	2,294	2,965	3,272	8,778,660	9,766,299	10,362,982	26.1	30.4	31.6
Utah	228	316	398	945,389	1,080,441	1,140,498	24.1	29.2	34.9
Vermont	107	112	142	301,836	325,581	340,374	35.4	34.4	41.7
Virginia	1,074	1,383	1,610	3,265,139	3,441,589	3,674,434	32.9	40.2	43.8
Washington	848	1,068	1,205	2,566,663	2,917,577	3,032,299	33.0	36.6	39.7
West Virginia	138	215	189	712,664	762,395	746,542	19.4	28.2	25.3
Wisconsin	665	791	906	2,713,392	2,879,024	2,919,201	24.5	27.5	31.0
Wyoming	48	69	71	236,885	251,828	270,810	20.3	27.4	26.2
Puerto Rico	NA	NA	NA	1,032,283	1,142,466	1,226,251	NA	NA	NA

NA = not available

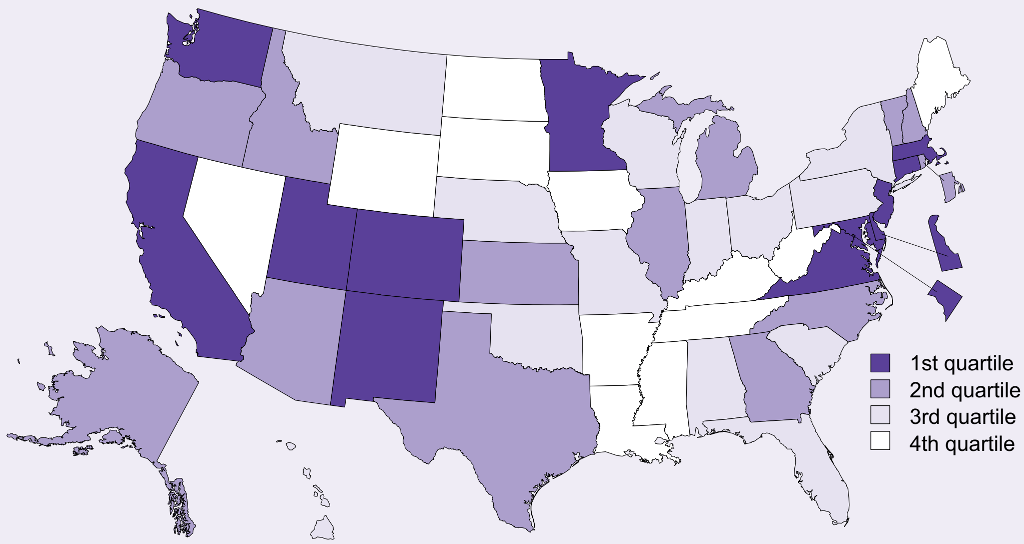
NOTES: Bachelor's degree holders include those who have completed a bachelor's or higher degree. Workforce represents employed component of civilian labor force and is reported as annual data, not seasonally adjusted.

SOURCES: U.S. Census Bureau, Population Division, Education and Social Stratification Branch, *Educational Attainment in the United States*, various years; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science and Engineering Indicators 2006

Individuals in S&E Occupations as Share of Workforce

Figure 8-21
Individuals in S&E occupations as share of workforce: 2003



1st quartile (19.84%–3.92%)	2nd quartile (3.90%–3.35%)	3rd quartile (3.28%–2.53%)	4th quartile (2.49%–1.77%)
California	Alaska	Alabama	Arkansas
Colorado	Arizona	Florida	Iowa
Connecticut	Georgia	Hawaii	Kentucky
Delaware	Idaho	Indiana	Louisiana
District of Columbia	Illinois	Missouri	Maine
Maryland	Kansas	Montana	Mississippi
Massachusetts	Michigan	Nebraska	Nevada
Minnesota	New Hampshire	New York	North Dakota
New Jersey	North Carolina	Ohio	South Dakota
New Mexico	Oregon	Oklahoma	Tennessee
Utah	Rhode Island	Pennsylvania	West Virginia
Virginia	Texas	South Carolina	Wyoming
Washington	Vermont	Wisconsin	

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-21.

Findings

- In 2003, 3.6% of the U.S. workforce, or about 5 million people, worked in occupations classified as S&E.
- In individual states in 2003, the percentage of the workforce engaged in S&E occupations ranged from 1.77% to 5.79%.
- The District of Columbia was an outlier at 19.84%, reflecting the many S&E jobs it provides for individuals who work there but live in neighboring states.
- States located in the Northeast, Southwest, and West Coast tended to be in the top two quartiles on this indicator, signifying a high concentration of S&E jobs.

This indicator shows the extent to which a state's workforce is college educated and employed in science and engineering occupations. A high value for this indicator shows that a state's economy has a high percentage of technical jobs relative to other states.

S&E occupations are defined by 77 standard occupational codes that encompass mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any of these S&E fields. People with job titles such as manager are excluded.

The location of S&E occupations primarily reflects where the individuals work and is based on estimates from the Occupational Employment Statistics survey, a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. Civilian workforce data are BLS estimates based on the Current Population Survey, which assigns workers to a location based on residence. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Table 8-21
Individuals in S&E occupations as share of workforce, by state: 2003

State	S&E occupations	Employed workforce	Workforce in S&E occupations (%)
United States	4,961,550	137,406,413	3.61
Alabama	56,380	2,009,039	2.81
Alaska	10,600	305,063	3.47
Arizona	92,120	2,553,169	3.61
Arkansas	21,340	1,204,539	1.77
California	676,180	16,223,451	4.17
Colorado	124,140	2,325,210	5.34
Connecticut	81,380	1,706,170	4.77
Delaware	17,370	403,759	4.30
District of Columbia	54,890	276,595	19.84
Florida	221,070	7,763,860	2.85
Georgia	144,170	4,134,525	3.49
Hawaii	16,090	588,637	2.73
Idaho	22,150	654,222	3.39
Illinois	211,230	5,934,131	3.56
Indiana	78,410	3,000,784	2.61
Iowa	37,320	1,548,215	2.41
Kansas	51,970	1,366,061	3.80
Kentucky	45,230	1,856,204	2.44
Louisiana	41,900	1,914,550	2.19
Maine	15,020	659,579	2.28
Maryland	149,250	2,751,455	5.42
Massachusetts	184,690	3,215,624	5.74
Michigan	182,940	4,695,148	3.90
Minnesota	117,120	2,786,091	4.20
Mississippi	22,190	1,237,198	1.79
Missouri	84,150	2,845,802	2.96
Montana	11,450	452,493	2.53
Nebraska	30,710	936,736	3.28
Nevada	22,330	1,089,709	2.05
New Hampshire	23,430	685,366	3.42
New Jersey	161,420	4,115,123	3.92
New Mexico	33,600	840,858	4.00
New York	272,440	8,705,319	3.13
North Carolina	132,440	3,957,077	3.35
North Dakota	8,430	338,809	2.49
Ohio	177,100	5,506,038	3.22
Oklahoma	44,360	1,614,418	2.75
Oregon	61,230	1,701,577	3.60
Pennsylvania	185,560	5,835,076	3.18
Rhode Island	18,740	537,873	3.48
South Carolina	48,740	1,878,397	2.59
South Dakota	9,150	408,805	2.24
Tennessee	63,680	2,742,225	2.32
Texas	365,270	10,195,950	3.58
Utah	45,570	1,121,088	4.06
Vermont	11,420	335,823	3.40
Virginia	209,280	3,612,229	5.79
Washington	150,230	2,926,836	5.13
West Virginia	16,220	747,637	2.17
Wisconsin	93,320	2,896,670	3.22
Wyoming	6,130	265,200	2.31
Puerto Rico	19,940	1,200,322	1.66

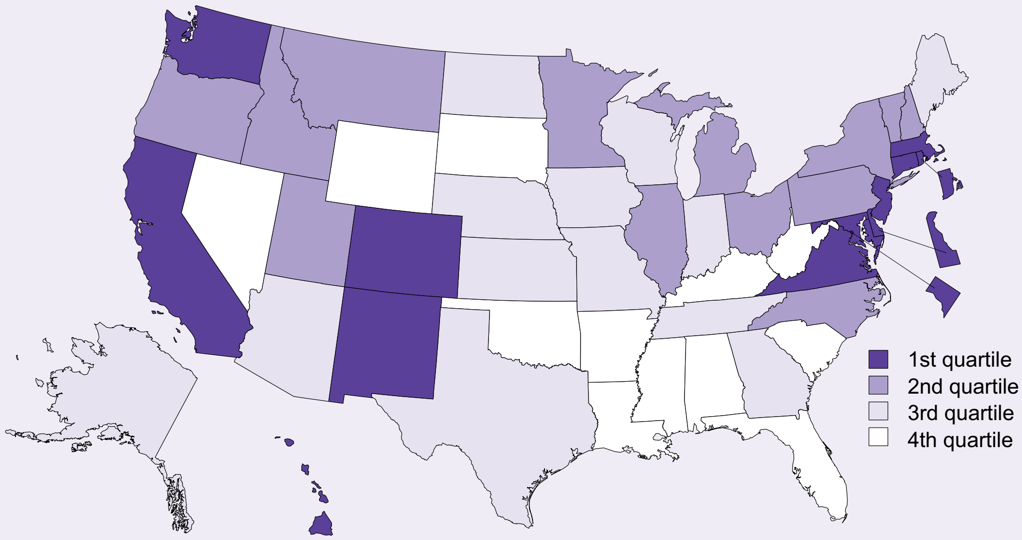
NOTE: Workforce represents employed component of civilian labor force and is reported as annual data, not seasonally adjusted.

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2006

S&E Doctorate Holders as Share of Workforce

Figure 8-22
S&E doctorate holders as share of workforce: 2003



1st quartile (2.35%–0.50%)	2nd quartile (0.49%–0.35%)	3rd quartile (0.34%–0.28%)	4th quartile (0.27%–0.17%)
California	Idaho	Alaska	Alabama
Colorado	Illinois	Arizona	Arkansas
Connecticut	Michigan	Georgia	Florida
Delaware	Minnesota	Indiana	Kentucky
District of Columbia	Montana	Iowa	Louisiana
Hawaii	New Hampshire	Kansas	Mississippi
Maryland	New York	Maine	Nevada
Massachusetts	North Carolina	Missouri	Oklahoma
New Jersey	Ohio	Nebraska	South Carolina
New Mexico	Oregon	North Dakota	South Dakota
Rhode Island	Pennsylvania	Tennessee	West Virginia
Virginia	Utah	Texas	Wyoming
Washington	Vermont	Wisconsin	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See Table 8-22.

Findings

- The number of S&E doctorate holders in the United States rose from 503,000 in 1997 to 568,000 in 2003, an increase of nearly 13%.
- For the United States, the value of this indicator climbed from 0.38% to 0.41% of the workforce because the number of S&E doctorate holders increased more rapidly than the size of the workforce during this period.
- In 2003, the values for this indicator in individual states ranged from 0.17% to 0.98% of the state's workforce; the District of Columbia was an outlier at 2.35%, reflecting a high concentration of S&E doctorate holders who work there but live in neighboring states.
- States in the top quartile tend to be home to major research laboratories, research universities, or research-intensive industries.

This indicator shows a state's tendency to attract and retain highly trained scientists and engineers. These individuals often conduct research and development, manage R&D activities, or are otherwise engaged in knowledge-intensive activities. A high value for this indicator in a state suggests employment opportunities for individuals with highly advanced training in science and engineering.

S&E fields include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. S&E doctorate holders exclude those with doctorates from foreign institutions. The location of the doctorate holders primarily reflects the state in which the individuals work. Civilian workforce data are Bureau of Labor Statistics estimates from the Current Population Survey, which bases location on residence. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Table 8-22
S&E doctorate holders as share of workforce, by state: 1997, 2001, and 2003

State	S&E doctorate holders			Employed workforce			S&E doctorate holders in workforce (%)		
	1997	2001	2003	1997	2001	2003	1997	2001	2003
United States	503,290	555,360	567,690	130,988,267	137,107,740	137,406,413	0.38	0.41	0.41
Alabama	6,440	5,170	5,500	2,035,156	2,033,230	2,009,039	0.32	0.25	0.27
Alaska	1,110	1,160	1,050	289,963	300,917	305,063	0.38	0.39	0.34
Arizona	6,130	6,800	7,110	2,196,901	2,453,066	2,553,169	0.28	0.28	0.28
Arkansas	2,250	2,460	2,670	1,177,143	1,193,249	1,204,539	0.19	0.21	0.22
California	68,390	78,020	83,150	14,780,791	16,217,495	16,223,451	0.46	0.48	0.51
Colorado	10,350	11,450	12,180	2,154,294	2,301,155	2,325,210	0.48	0.50	0.52
Connecticut	8,470	9,340	10,140	1,674,937	1,698,274	1,706,170	0.51	0.55	0.59
Delaware	3,520	3,470	2,600	378,117	405,111	403,759	0.93	0.86	0.64
District of Columbia	11,580	13,840	6,490	262,789	287,552	276,595	4.41	4.81	2.35
Florida	12,820	15,040	15,590	7,040,660	7,633,728	7,763,860	0.18	0.20	0.20
Georgia	9,640	11,710	12,060	3,751,699	4,107,109	4,134,525	0.26	0.29	0.29
Hawaii	2,420	2,570	2,960	566,766	586,754	588,637	0.43	0.44	0.50
Idaho	1,990	2,160	2,480	598,004	642,908	654,222	0.33	0.34	0.38
Illinois	21,020	21,670	21,410	5,988,296	6,121,940	5,934,131	0.35	0.35	0.36
Indiana	7,460	9,490	8,980	3,014,499	3,020,287	3,000,784	0.25	0.31	0.30
Iowa	4,030	4,280	4,450	1,555,837	1,569,541	1,548,215	0.26	0.27	0.29
Kansas	3,720	3,890	4,050	1,329,797	1,348,506	1,366,061	0.28	0.29	0.30
Kentucky	3,980	4,380	4,740	1,809,785	1,854,296	1,856,204	0.22	0.24	0.26
Louisiana	5,210	5,000	5,180	1,890,102	1,921,056	1,914,550	0.28	0.26	0.27
Maine	2,140	1,940	2,000	624,410	649,955	659,579	0.34	0.30	0.30
Maryland	20,660	22,090	27,050	2,646,200	2,719,498	2,751,455	0.78	0.81	0.98
Massachusetts	22,960	28,390	28,950	3,158,851	3,274,561	3,215,624	0.73	0.87	0.90
Michigan	14,750	16,940	16,280	4,748,691	4,864,600	4,695,148	0.31	0.35	0.35
Minnesota	9,660	11,070	10,770	2,605,673	2,764,353	2,786,091	0.37	0.40	0.39
Mississippi	2,970	3,120	3,080	1,200,845	1,229,964	1,237,198	0.25	0.25	0.25
Missouri	9,300	8,860	8,730	2,780,185	2,856,402	2,845,802	0.33	0.31	0.31
Montana	1,580	1,330	1,660	427,504	447,213	452,493	0.37	0.30	0.37
Nebraska	2,930	2,840	2,730	904,492	926,926	936,736	0.32	0.31	0.29
Nevada	1,620	2,010	1,820	895,258	1,043,911	1,089,709	0.18	0.19	0.17
New Hampshire	2,190	2,320	2,710	635,469	680,587	685,366	0.34	0.34	0.40
New Jersey	19,970	22,130	21,900	4,031,022	4,111,546	4,115,123	0.50	0.54	0.53
New Mexico	7,120	7,370	7,640	768,596	819,413	840,858	0.93	0.90	0.91
New York	38,830	42,570	40,510	8,416,544	8,729,849	8,705,319	0.46	0.49	0.47
North Carolina	13,470	16,250	17,130	3,809,601	3,948,692	3,957,077	0.35	0.41	0.43
North Dakota	1,330	1,080	1,110	335,854	336,939	338,809	0.40	0.32	0.33
Ohio	18,200	19,270	20,130	5,448,161	5,570,389	5,506,038	0.33	0.35	0.37
Oklahoma	4,430	4,110	4,160	1,543,105	1,615,033	1,614,418	0.29	0.25	0.26
Oregon	5,980	6,900	7,280	1,652,997	1,708,957	1,701,577	0.36	0.40	0.43
Pennsylvania	23,110	25,520	26,900	5,775,178	5,870,495	5,835,076	0.40	0.43	0.46
Rhode Island	2,400	2,600	3,060	504,147	520,008	537,873	0.48	0.50	0.57
South Carolina	4,620	5,030	4,810	1,819,508	1,850,436	1,878,397	0.25	0.27	0.26
South Dakota	1,000	970	940	383,216	400,574	408,805	0.26	0.24	0.23
Tennessee	8,350	8,570	8,680	2,640,005	2,728,496	2,742,225	0.32	0.31	0.32
Texas	27,990	31,710	32,430	9,395,279	10,003,723	10,195,950	0.30	0.32	0.32
Utah	4,670	4,720	4,160	1,034,429	1,103,028	1,121,088	0.45	0.43	0.37
Vermont	1,750	1,630	1,660	315,806	329,460	335,823	0.55	0.49	0.49
Virginia	14,860	16,880	20,890	3,323,266	3,524,335	3,612,229	0.45	0.48	0.58
Washington	12,860	14,270	14,960	2,822,223	2,861,417	2,926,836	0.46	0.50	0.51
West Virginia	1,930	1,840	2,040	746,442	762,107	747,637	0.26	0.24	0.27
Wisconsin	8,320	8,290	8,060	2,855,830	2,898,949	2,896,670	0.29	0.29	0.28
Wyoming	810	840	670	243,944	259,750	265,200	0.33	0.32	0.25
Puerto Rico	650	1,400	1,610	1,132,658	1,133,988	1,200,322	0.06	0.12	0.13

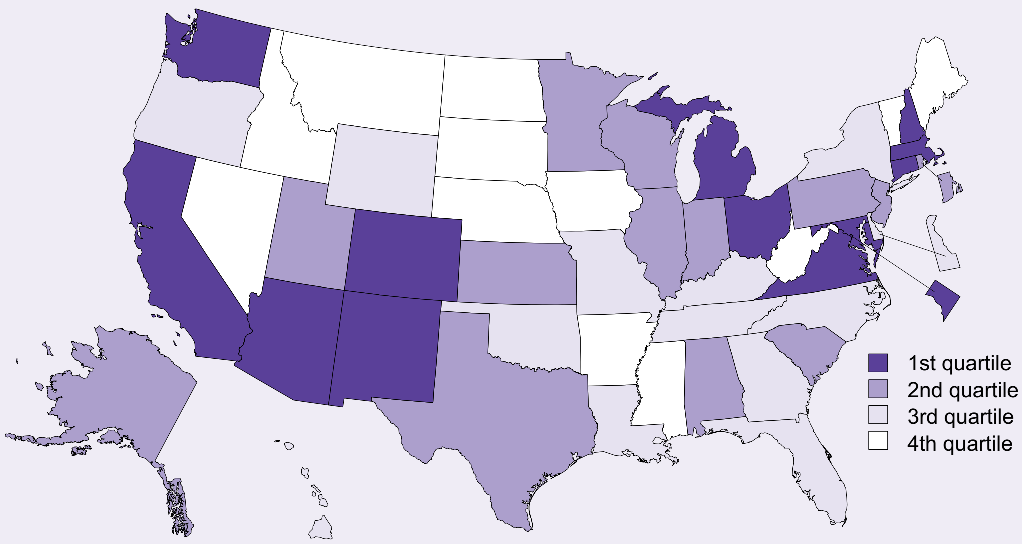
NOTES: Survey of Doctorate Recipients sample design does not include geography. Data on S&E doctorate holders are classified by employment location, and workforce data are based on respondents' residence. Thus, the reliability of data for areas with smaller populations is lower than for more populous states. Workforce represents employed component of civilian labor force and is reported as annual data, not seasonally adjusted.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science and Engineering Indicators 2006

Engineers as Share of Workforce

Figure 8-23
Engineers as share of workforce: 2003



1st quartile (3.09%–1.08%)	2nd quartile (1.06%–0.87%)	3rd quartile (0.86%–0.64%)	4th quartile (0.63%–0.45%)
Arizona	Alabama	Delaware	Arkansas
California	Alaska	Florida	Idaho
Colorado	Illinois	Georgia	Iowa
Connecticut	Indiana	Hawaii	Maine
District of Columbia	Kansas	Kentucky	Mississippi
Maryland	Minnesota	Louisiana	Montana
Massachusetts	New Jersey	Missouri	Nebraska
Michigan	Pennsylvania	New York	Nevada
New Hampshire	Rhode Island	North Carolina	North Dakota
New Mexico	South Carolina	Oklahoma	South Dakota
Ohio	Texas	Oregon	Vermont
Virginia	Utah	Tennessee	West Virginia
Washington	Wisconsin	Wyoming	

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-23.

Findings

- In the United States, 1.4 million individuals, or 1.0% of the workforce, were employed in engineering occupations in 2003.
- The concentration of engineers in individual states ranged from 0.45% to 1.54% in 2003.
- The District of Columbia was an outlier at 3.09%, reflecting the number of engineers who work there but live in neighboring states.
- States in the top quartile for this indicator tended to have a relatively high concentration of high-technology businesses.

This indicator shows the extent to which a state's workforce includes trained engineers. The indicator encompasses 20 standard occupational codes for engineering fields such as aerospace, agricultural, biomedical, chemical, civil, computer hardware, electrical and electronics, environmental, industrial, marine and naval architectural, materials, mechanical, mining and geological, nuclear, and petroleum. Engineers design and operate production processes and create new products and services.

The location of engineering occupations primarily reflects where the individuals work and is based on estimates from the Occupational Employment Statistics survey, a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. The size of a state's civilian workforce is estimated from the BLS Current Population Survey, which assigns workers to a location based on residence. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Table 8-23
Engineers as share of workforce, by state: 2003

State	Engineers	Employed workforce	Engineers in workforce (%)
United States	1,359,120	137,406,413	0.99
Alabama	20,950	2,009,039	1.04
Alaska	3,080	305,063	1.01
Arizona	30,410	2,553,169	1.19
Arkansas	5,380	1,204,539	0.45
California	212,610	16,223,451	1.31
Colorado	34,020	2,325,210	1.46
Connecticut	24,770	1,706,170	1.45
Delaware	3,050	403,759	0.76
District of Columbia	8,540	276,595	3.09
Florida	58,270	7,763,860	0.75
Georgia	30,040	4,134,525	0.73
Hawaii	3,970	588,637	0.67
Idaho	3,680	654,222	0.56
Illinois	57,780	5,934,131	0.97
Indiana	29,650	3,000,784	0.99
Iowa	9,520	1,548,215	0.61
Kansas	12,540	1,366,061	0.92
Kentucky	11,940	1,856,204	0.64
Louisiana	15,350	1,914,550	0.80
Maine	4,160	659,579	0.63
Maryland	33,550	2,751,455	1.22
Massachusetts	49,440	3,215,624	1.54
Michigan	55,090	4,695,148	1.17
Minnesota	29,490	2,786,091	1.06
Mississippi	6,410	1,237,198	0.52
Missouri	19,960	2,845,802	0.70
Montana	2,600	452,493	0.57
Nebraska	5,840	936,736	0.62
Nevada	6,070	1,089,709	0.56
New Hampshire	7,430	685,366	1.08
New Jersey	35,690	4,115,123	0.87
New Mexico	11,030	840,858	1.31
New York	62,720	8,705,319	0.72
North Carolina	28,880	3,957,077	0.73
North Dakota	1,800	338,809	0.53
Ohio	60,890	5,506,038	1.11
Oklahoma	12,810	1,614,418	0.79
Oregon	14,550	1,701,577	0.86
Pennsylvania	51,840	5,835,076	0.89
Rhode Island	5,000	537,873	0.93
South Carolina	19,880	1,878,397	1.06
South Dakota	1,850	408,805	0.45
Tennessee	20,770	2,742,225	0.76
Texas	107,810	10,195,950	1.06
Utah	10,350	1,121,088	0.92
Vermont	1,620	335,823	0.48
Virginia	46,100	3,612,229	1.28
Washington	34,850	2,926,836	1.19
West Virginia	4,610	747,637	0.62
Wisconsin	28,600	2,896,670	0.99
Wyoming	1,880	265,200	0.71
Puerto Rico	7,150	1,200,322	0.60

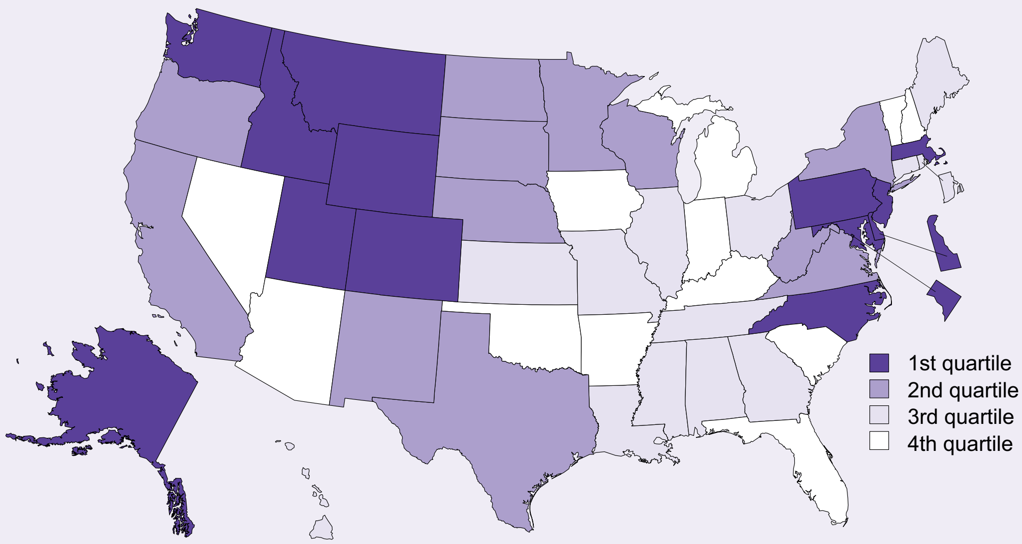
NOTE: Workforce represents employed component of civilian labor force and is reported as annual data, not seasonally adjusted.

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2006

Life and Physical Scientists as Share of Workforce

Figure 8-24
Life and physical scientists as share of workforce: 2003



1st quartile (1.88%–0.43%)	2nd quartile (0.42%–0.34%)	3rd quartile (0.33%–0.26%)	4th quartile (0.25%–0.14%)
Alaska	California	Alabama	Arizona
Colorado	Minnesota	Connecticut	Arkansas
Delaware	Nebraska	Georgia	Florida
District of Columbia	New Mexico	Hawaii	Indiana
Idaho	New York	Illinois	Iowa
Maryland	North Dakota	Kansas	Kentucky
Massachusetts	Oregon	Louisiana	Michigan
Montana	South Dakota	Maine	Nevada
New Jersey	Texas	Mississippi	New Hampshire
North Carolina	Virginia	Missouri	Oklahoma
Pennsylvania	West Virginia	Ohio	South Carolina
Utah	Wisconsin	Rhode Island	Vermont
Washington		Tennessee	
Wyoming			

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-24.

Findings

- Nearly 500,000 individuals, or 0.36% of the workforce, were employed as life and physical scientists in the United States in 2003.
- In 2003, individual states had indicator values ranging from 0.14% to 0.92%, which showed major differences in the concentration of jobs in the life and physical sciences.
- The District of Columbia was an outlier at 1.88%, reflecting the number of individuals who work there but live in neighboring states.

This indicator shows a state's ability to attract and retain life and physical scientists. Life scientists are identified from nine standard occupational codes that include agricultural and food scientists, biological scientists, conservation scientists and foresters, and medical scientists. Physical scientists are identified from 16 standard occupational codes that include astronomers, physicists, atmospheric and space scientists, chemists, materials scientists, environmental scientists, geoscientists, and postsecondary teachers in these subject areas. A high share of life and physical scientists could indicate several scenarios ranging from a robust cluster of life science companies to a high percentage of acreage in forests or national parks. The latter requires foresters, wildlife specialists, and conservationists to manage the natural assets in an area with low population density.

The location of life and physical scientists reflects where the individuals work and is based on estimates from the Occupational Employment Statistics survey, a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. The size of a state's civilian workforce is estimated from the BLS Current Population Survey, which assigns workers to a location based on residence. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Table 8-24
Life and physical scientists as share of workforce, by state: 2003

State	Life and physical scientists	Employed workforce	Life and physical scientists in workforce (%)
United States	490,850	137,406,413	0.36
Alabama	5,170	2,009,039	0.26
Alaska	2,800	305,063	0.92
Arizona	5,580	2,553,169	0.22
Arkansas	2,700	1,204,539	0.22
California	64,390	16,223,451	0.40
Colorado	11,710	2,325,210	0.50
Connecticut	5,670	1,706,170	0.33
Delaware	2,020	403,759	0.50
District of Columbia	5,210	276,595	1.88
Florida	19,440	7,763,860	0.25
Georgia	11,410	4,134,525	0.28
Hawaii	1,790	588,637	0.30
Idaho	3,100	654,222	0.47
Illinois	18,300	5,934,131	0.31
Indiana	4,070	3,000,784	0.14
Iowa	3,130	1,548,215	0.20
Kansas	3,910	1,366,061	0.29
Kentucky	2,660	1,856,204	0.14
Louisiana	5,540	1,914,550	0.29
Maine	1,830	659,579	0.28
Maryland	17,910	2,751,455	0.65
Massachusetts	20,380	3,215,624	0.63
Michigan	9,390	4,695,148	0.20
Minnesota	11,200	2,786,091	0.40
Mississippi	3,650	1,237,198	0.30
Missouri	9,240	2,845,802	0.32
Montana	2,790	452,493	0.62
Nebraska	3,920	936,736	0.42
Nevada	2,510	1,089,709	0.23
New Hampshire	1,480	685,366	0.22
New Jersey	17,530	4,115,123	0.43
New Mexico	3,200	840,858	0.38
New York	30,330	8,705,319	0.35
North Carolina	17,770	3,957,077	0.45
North Dakota	1,420	338,809	0.42
Ohio	15,100	5,506,038	0.27
Oklahoma	3,350	1,614,418	0.21
Oregon	5,870	1,701,577	0.34
Pennsylvania	25,080	5,835,076	0.43
Rhode Island	1,580	537,873	0.29
South Carolina	4,610	1,878,397	0.25
South Dakota	1,420	408,805	0.35
Tennessee	7,130	2,742,225	0.26
Texas	42,440	10,195,950	0.42
Utah	5,060	1,121,088	0.45
Vermont	850	335,823	0.25
Virginia	13,030	3,612,229	0.36
Washington	16,940	2,926,836	0.58
West Virginia	2,510	747,637	0.34
Wisconsin	11,220	2,896,670	0.39
Wyoming	1,510	265,200	0.57
Puerto Rico	4,440	1,200,322	0.37

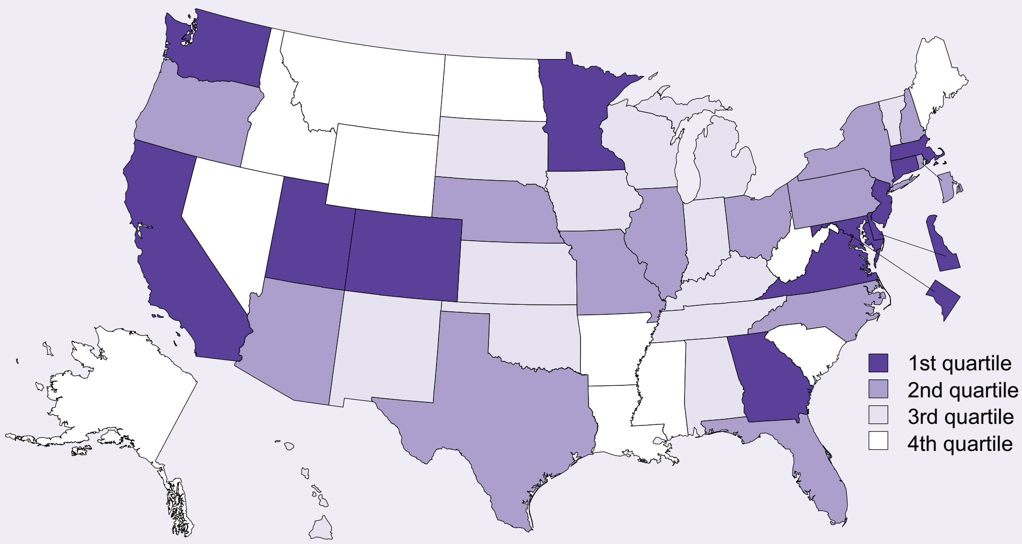
NOTE: Workforce represents employed component of civilian labor force and is reported as annual data, not seasonally adjusted.

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2006

Computer Specialists as Share of Workforce

Figure 8-25
Computer specialists as share of workforce: 2003



1st quartile (9.61%–2.10%)	2nd quartile (2.04%–1.67%)	3rd quartile (1.53%–1.20%)	4th quartile (1.18%–0.63%)
California	Arizona	Alabama	Alaska
Colorado	Florida	Hawaii	Arkansas
Connecticut	Illinois	Indiana	Idaho
Delaware	Missouri	Iowa	Louisiana
District of Columbia	Nebraska	Kansas	Maine
Georgia	New Hampshire	Kentucky	Mississippi
Maryland	New York	Michigan	Montana
Massachusetts	North Carolina	New Mexico	Nevada
Minnesota	Ohio	Oklahoma	North Dakota
New Jersey	Oregon	South Dakota	South Carolina
Utah	Pennsylvania	Tennessee	West Virginia
Virginia	Rhode Island	Vermont	Wyoming
Washington	Texas	Wisconsin	

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-25.

Findings

- In the United States, 2.7 million individuals, or 2.0% of the workforce, were employed as computer specialists in 2003.
- Individual states showed significant differences in the intensity of computer-related operations in their economies, with 0.63% to 3.94% of their workforce employed in computer-related occupations in 2003.
- There was a significant concentration of computer-intensive occupations in the District of Columbia, where the indicator value of 9.61% was affected by the large number of individuals who specialize in computer work there but live in neighboring states.

This indicator shows the extent to which a state's workforce makes use of specialists with advanced computer training. Computer specialists are identified from 10 standard occupational codes that include computer and information scientists, programmers, software engineers, support specialists, systems analysts, database administrators, and network and computer system administrators. States with higher values may indicate a state workforce that is better able to thrive in an information economy or to embrace and utilize computer technology.

The location of computer specialists reflects where the individuals work and is based on estimates from the Occupational Employment Statistics survey, a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. The size of a state's civilian workforce is estimated from the BLS Current Population Survey, which assigns workers to a location based on residence. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Table 8-25
Computer specialists as share of workforce, by state: 2003

State	Computer specialists	Employed workforce	Computer specialists in workforce (%)
United States	2,688,080	137,406,413	1.96
Alabama	28,010	2,009,039	1.39
Alaska	3,170	305,063	1.04
Arizona	45,020	2,553,169	1.76
Arkansas	11,770	1,204,539	0.98
California	361,640	16,223,451	2.23
Colorado	73,490	2,325,210	3.16
Connecticut	42,600	1,706,170	2.50
Delaware	8,930	403,759	2.21
District of Columbia	26,590	276,595	9.61
Florida	132,520	7,763,860	1.71
Georgia	86,970	4,134,525	2.10
Hawaii	7,170	588,637	1.22
Idaho	7,720	654,222	1.18
Illinois	120,840	5,934,131	2.04
Indiana	36,440	3,000,784	1.21
Iowa	20,640	1,548,215	1.33
Kansas	19,980	1,366,061	1.46
Kentucky	24,370	1,856,204	1.31
Louisiana	18,190	1,914,550	0.95
Maine	6,730	659,579	1.02
Maryland	87,350	2,751,455	3.17
Massachusetts	102,180	3,215,624	3.18
Michigan	71,830	4,695,148	1.53
Minnesota	67,110	2,786,091	2.41
Mississippi	8,200	1,237,198	0.66
Missouri	55,730	2,845,802	1.96
Montana	4,790	452,493	1.06
Nebraska	15,960	936,736	1.70
Nevada	10,490	1,089,709	0.96
New Hampshire	12,780	685,366	1.86
New Jersey	109,960	4,115,123	2.67
New Mexico	11,380	840,858	1.35
New York	167,790	8,705,319	1.93
North Carolina	68,320	3,957,077	1.73
North Dakota	3,050	338,809	0.90
Ohio	92,040	5,506,038	1.67
Oklahoma	21,600	1,614,418	1.34
Oregon	31,430	1,701,577	1.85
Pennsylvania	98,860	5,835,076	1.69
Rhode Island	9,190	537,873	1.71
South Carolina	19,560	1,878,397	1.04
South Dakota	4,910	408,805	1.20
Tennessee	35,700	2,742,225	1.30
Texas	197,310	10,195,950	1.94
Utah	25,930	1,121,088	2.31
Vermont	5,080	335,823	1.51
Virginia	142,270	3,612,229	3.94
Washington	79,320	2,926,836	2.71
West Virginia	6,960	747,637	0.93
Wisconsin	36,530	2,896,670	1.26
Wyoming	1,680	265,200	0.63
Puerto Rico	7,070	1,200,322	0.59

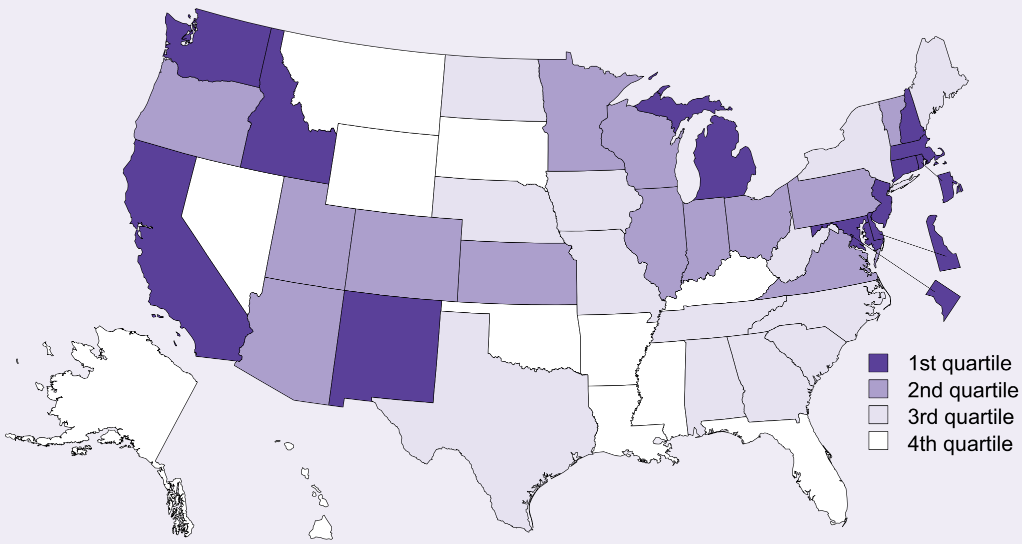
NOTE: Workforce represents employed component of civilian labor force and is reported as annual data, not seasonally adjusted.

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2006

R&D as Share of Gross State Product

Figure 8-26
R&D as share of gross state product: 2002



1st quartile (8.76%–2.80%)	2nd quartile (2.62%–1.88%)	3rd quartile (1.85%–1.09%)	4th quartile (1.06%–0.39%)
California	Arizona	Alabama	Alaska
Connecticut	Colorado	Georgia	Arkansas
Delaware	Illinois	Iowa	Florida
District of Columbia	Indiana	Maine	Hawaii
Idaho	Kansas	Missouri	Kentucky
Maryland	Minnesota	Nebraska	Louisiana
Massachusetts	Ohio	New York	Mississippi
Michigan	Oregon	North Carolina	Montana
New Hampshire	Pennsylvania	North Dakota	Nevada
New Jersey	Utah	South Carolina	Oklahoma
New Mexico	Vermont	Tennessee	South Dakota
Rhode Island	Virginia	Texas	Wyoming
Washington	Wisconsin	West Virginia	

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources*; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data. See table 8-26.

Findings

- The national value of this indicator has not changed significantly over the past decade, varying from 2.48% in 1993 to 2.46% in 2002.
- In 2002, state values for this indicator ranged from 0.39% to 8.76%, indicating large differences in the geographic concentration of R&D.
- New Mexico is an outlier on this indicator because of the presence of large federal R&D activities and a relatively small GSP.
- States with high rankings on this indicator also tended to rank high on S&E doctorate holders as a share of the workforce.

This indicator shows the extent to which research and development play a role in a state's economy. A high value indicates that the state has a high intensity of R&D activity, which may support future growth in knowledge-based industries. Industries that have a high percentage of R&D activity include pharmaceuticals, chemicals, computer equipment and services, electronic components, aerospace, and motor vehicles. R&D refers to R&D activities performed by federal agencies, industry, universities, and other nonprofit organizations. At the national level in 2002, industry performed roughly 71% of total R&D, followed by colleges and universities at 14% and government facilities, including federally funded R&D centers, at 13%. Data for the value of gross state product (GSP) and for R&D expenditures are shown in current dollars.

The methodology for assigning R&D activity at the state level was modified in 2001, and data back to 1998 were recalculated using the new methodology. State-level R&D data from years before 1998 are not comparable.

Table 8-26
R&D as share of gross state product, by state: 1998, 2000, and 2002

State	R&D performed ($ thousands)			GSP ($ millions)			R&D performed/GSP (%)		
	1998	2000	2002	1998	2000	2002	1998	2000	2002
United States	161,560,028	214,751,949	255,707,431	6,513,028	8,679,660	10,407,146	2.48	2.47	2.46
Alabama	1,967,533	1,926,127	2,323,165	84,497	107,825	125,567	2.33	1.79	1.85
Alaska	129,211	NA	307,812	23,014	22,942	29,708	0.56	NA	1.04
Arizona	1,607,378	2,317,552	4,096,021	85,483	137,457	171,781	1.88	1.69	2.38
Arkansas	301,143	283,161	427,127	47,188	61,759	71,929	0.64	0.46	0.59
California	33,721,294	43,919,295	51,388,310	847,879	1,090,979	1,367,785	3.98	4.03	3.76
Colorado	2,864,058	4,565,357	4,217,633	93,588	142,701	179,410	3.06	3.20	2.35
Connecticut	2,808,827	3,558,775	6,774,167	107,924	143,232	165,744	2.60	2.48	4.09
Delaware	1,248,672	2,555,543	1,318,622	23,827	36,993	47,150	5.24	6.91	2.80
District of Columbia	2,543,172	2,606,128	2,705,839	46,596	51,364	66,440	5.46	5.07	4.07
Florida	3,525,284	4,773,060	5,497,618	305,036	416,598	520,500	1.16	1.15	1.06
Georgia	1,577,360	2,491,906	3,934,608	172,220	254,453	305,829	0.92	0.98	1.29
Hawaii	380,150	241,560	455,679	36,308	37,568	43,998	1.05	0.64	1.04
Idaho	477,563	1,126,774	1,370,496	22,758	29,895	38,558	2.10	3.77	3.55
Illinois	6,777,207	8,830,457	10,190,059	317,248	425,049	486,139	2.14	2.08	2.10
Indiana	2,560,252	3,088,634	4,326,337	131,485	179,458	204,946	1.95	1.72	2.11
Iowa	902,050	1,053,690	1,346,336	62,764	84,499	98,232	1.44	1.25	1.37
Kansas	463,570	1,518,063	1,865,261	58,380	76,220	89,508	0.79	1.99	2.08
Kentucky	428,684	645,079	1,128,308	80,882	110,731	122,282	0.53	0.58	0.92
Louisiana	469,705	542,408	857,637	95,587	116,412	131,584	0.49	0.47	0.65
Maine	113,937	159,268	428,771	25,358	31,722	39,039	0.45	0.50	1.10
Maryland	7,530,401	8,018,944	9,030,106	126,442	161,485	201,879	5.96	4.97	4.47
Massachusetts	9,497,975	13,382,495	14,316,139	175,729	236,347	288,088	5.40	5.66	4.97
Michigan	10,777,535	13,655,250	15,082,389	222,886	310,004	351,287	4.84	4.40	4.29
Minnesota	2,922,121	3,817,731	5,247,399	115,420	166,146	200,061	2.53	2.30	2.62
Mississippi	324,189	366,465	691,444	47,384	61,065	69,136	0.68	0.60	1.00
Missouri	1,788,896	1,867,905	2,478,355	119,680	162,666	187,543	1.49	1.15	1.32
Montana	90,438	190,675	236,144	16,151	20,004	23,773	0.56	0.95	0.99
Nebraska	294,531	314,645	663,135	38,665	52,152	60,962	0.76	0.60	1.09
Nevada	218,503	570,509	524,417	39,929	63,826	81,182	0.55	0.89	0.65
New Hampshire	438,620	1,339,951	1,435,074	27,507	38,818	46,448	1.59	3.45	3.09
New Jersey	9,180,997	11,368,389	13,020,435	246,727	314,604	380,169	3.72	3.61	3.42
New Mexico	2,751,608	3,031,678	4,689,090	37,110	45,972	53,515	7.41	6.59	8.76
New York	10,973,876	13,730,588	13,354,226	551,161	679,189	792,058	1.99	2.02	1.69
North Carolina	2,745,087	4,559,996	5,135,001	168,830	241,095	300,216	1.63	1.89	1.71
North Dakota	91,534	119,450	294,630	12,855	17,268	19,780	0.71	0.69	1.49
Ohio	6,397,650	6,969,763	8,309,769	260,891	349,611	388,224	2.45	1.99	2.14
Oklahoma	533,398	512,899	793,412	65,035	80,141	95,126	0.82	0.64	0.83
Oregon	773,855	1,910,443	2,891,509	69,810	101,092	115,138	1.11	1.89	2.51
Pennsylvania	8,277,907	8,761,617	9,763,237	288,154	365,343	428,950	2.87	2.40	2.28
Rhode Island	484,236	1,677,063	1,638,666	23,627	29,620	36,988	2.05	5.66	4.43
South Carolina	713,450	989,452	1,668,245	75,955	103,422	122,354	0.94	0.96	1.36
South Dakota	58,634	59,766	110,632	16,261	20,721	25,003	0.36	0.29	0.44
Tennessee	1,212,807	2,502,826	2,568,240	119,758	161,653	190,122	1.01	1.55	1.35
Texas	6,965,939	10,774,067	14,222,536	452,649	628,415	773,455	1.54	1.71	1.84
Utah	751,165	1,494,808	1,571,691	38,395	59,996	72,974	1.96	2.49	2.15
Vermont	342,809	175,486	398,291	13,154	16,014	19,604	2.61	1.10	2.03
Virginia	2,938,617	4,933,647	5,894,686	170,754	223,638	287,589	1.72	2.21	2.05
Washington	5,421,959	8,465,553	10,511,415	138,225	194,566	232,940	3.92	4.35	4.51
West Virginia	279,583	420,704	542,120	32,240	40,497	45,518	0.87	1.04	1.19
Wisconsin	1,851,751	2,501,029	3,585,099	119,508	161,261	190,650	1.55	1.55	1.88
Wyoming	62,907	65,318	80,093	14,114	15,172	20,285	0.45	0.43	0.39
Puerto Rico	NA	NA	NA	36,923	54,086	71,306	NA	NA	NA

NA = not available

GSP = gross state product

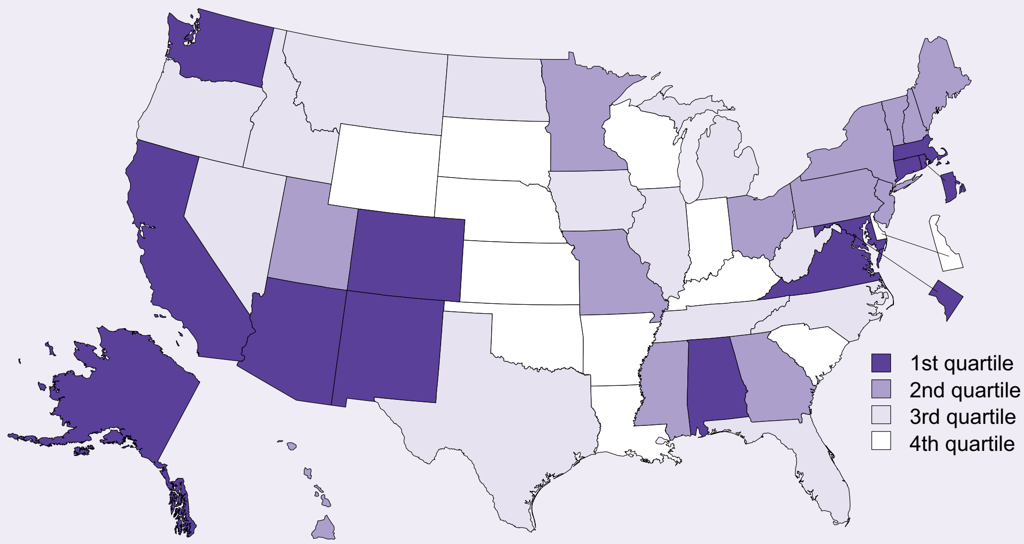
NOTES: Total R&D includes R&D performed by federal agencies, industry, universities, and other nonprofit organizations. Total R&D and GSP are reported in current dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* various years; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2006

Federal R&D Obligations per Civilian Worker

Figure 8-27
Federal R&D obligations per civilian worker: 2002



1st quartile ($10,166–$694)	2nd quartile ($642–$369)	3rd quartile ($357–$252)	4th quartile ($227–$117)
Alabama	Georgia	Florida	Arkansas
Alaska	Hawaii	Idaho	Delaware
Arizona	Maine	Illinois	Indiana
California	Minnesota	Iowa	Kansas
Colorado	Mississippi	Michigan	Kentucky
Connecticut	Missouri	Montana	Louisiana
District of Columbia	New Hampshire	Nevada	Nebraska
Maryland	New Jersey	North Carolina	Oklahoma
Massachusetts	New York	North Dakota	South Carolina
New Mexico	Ohio	Oregon	South Dakota
Rhode Island	Pennsylvania	Tennessee	Wisconsin
Virginia	Utah	Texas	Wyoming
Washington	Vermont	West Virginia	

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development*; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-27.

Findings

- Federal R&D obligations rose from $64 billion in 1992 to $84 billion in 2002, an increase of 31%.
- The increase in federal R&D obligations (unadjusted for inflation) was greater than the increase in the civilian workforce, and the value of this indicator rose from $536 per worker in 1992 to $612 per worker in 2002.
- Federal R&D obligations in 2002 varied greatly among the states, ranging from $117 to $3,318 per worker. Higher values were found in the states surrounding the District of Columbia and in sparsely populated states with national laboratories.
- The District of Columbia was an outlier with $10,166 per worker, possibly because many federal employees work there but live in neighboring states.

This indicator shows how federal research and development funding is disbursed geographically relative to the size of states' civilian workforces. Because the Department of Defense is the primary source for federal R&D obligations, much of this funding is used for development, but it also may provide direct and indirect benefits to a state's economy and may stimulate the conduct of basic research. A high value may indicate the existence of major federally funded R&D facilities in the state.

Federal R&D dollars are attributed to the states in which the recipients of federal obligations are located. The size of a state's civilian workforce is estimated based on the Bureau of Labor Statistics Current Population Survey, which assigns workers to a location based on residence. Because of these differences and the sample-based nature of the population data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Table 8-27
Federal R&D obligations per civilian worker, by state: 1992, 1997, and 2002

State	Federal R&D obligations ($ millions)			Civilian workers			Federal R&D obligations/ civilian worker ($)		
	1992	1997	2002	1992	1997	2002	1992	1997	2002
United States	63,818	68,363	83,629	118,984,370	130,988,267	136,716,756	536	522	612
Alabama	2,152	2,214	2,705	1,809,337	2,035,156	1,996,920	1,189	1,088	1,354
Alaska	93	100	274	262,980	289,963	302,622	354	345	905
Arizona	638	732	2,057	1,753,764	2,196,901	2,494,153	364	333	825
Arkansas	69	95	141	1,073,382	1,177,143	1,205,232	64	81	117
California	15,999	13,731	15,686	13,874,246	14,780,791	16,165,052	1,153	929	970
Colorado	1,479	1,340	1,609	1,744,235	2,154,294	2,300,065	848	622	700
Connecticut	578	847	1,917	1,693,563	1,674,937	1,706,066	341	505	1,124
Delaware	43	49	79	347,194	378,117	403,017	124	130	196
District of Columbia	2,185	2,232	2,850	290,103	262,789	280,302	7,532	8,495	10,166
Florida	2,832	3,326	2,301	6,133,417	7,040,660	7,615,730	462	472	302
Georgia	2,513	3,920	2,019	3,182,777	3,751,699	4,100,119	789	1,045	492
Hawaii	151	151	375	551,563	566,766	584,054	273	266	642
Idaho	300	206	231	493,767	598,004	645,958	607	344	357
Illinois	922	1,140	1,694	5,546,722	5,988,296	5,961,248	166	190	284
Indiana	367	410	526	2,703,403	3,014,499	2,989,544	136	136	176
Iowa	195	228	405	1,441,414	1,555,837	1,573,701	135	147	257
Kansas	91	256	291	1,244,438	1,329,797	1,351,738	73	192	215
Kentucky	72	91	321	1,658,511	1,809,785	1,838,151	43	50	175
Louisiana	170	211	432	1,787,541	1,890,102	1,902,957	95	112	227
Maine	61	69	255	594,082	624,410	654,522	102	110	389
Maryland	5,780	7,329	7,192	2,484,910	2,646,200	2,735,130	2,326	2,770	2,630
Massachusetts	3,228	3,438	4,659	2,899,718	3,158,851	3,247,094	1,113	1,088	1,435
Michigan	876	735	1,244	4,234,783	4,748,691	4,724,036	207	155	263
Minnesota	456	609	1,151	2,341,011	2,605,673	2,767,058	195	234	416
Mississippi	256	290	623	1,097,672	1,200,845	1,219,060	233	241	511
Missouri	734	1,130	1,203	2,502,779	2,780,185	2,837,544	293	406	424
Montana	72	79	113	390,362	427,504	448,459	183	185	252
Nebraska	71	83	145	817,915	904,492	923,620	87	92	157
Nevada	466	295	336	677,076	895,258	1,061,900	688	330	316
New Hampshire	156	279	297	568,909	635,469	681,509	274	439	435
New Jersey	1,647	1,319	2,022	3,709,471	4,031,022	4,117,644	444	327	491
New Mexico	2,211	1,933	2,746	680,463	768,596	827,533	3,250	2,515	3,318
New York	3,059	2,471	3,747	7,979,726	8,416,544	8,732,103	383	294	429
North Carolina	701	900	1,390	3,372,068	3,809,601	3,921,819	208	236	355
North Dakota	54	53	102	305,056	335,854	336,430	178	158	303
Ohio	1,863	1,880	2,103	5,072,649	5,448,161	5,500,016	367	345	382
Oklahoma	126	160	272	1,432,081	1,543,105	1,612,228	88	104	168
Oregon	227	320	502	1,448,017	1,652,997	1,699,742	156	193	296
Pennsylvania	1,794	1,894	3,162	5,455,450	5,775,178	5,897,438	329	328	536
Rhode Island	386	404	501	483,329	504,147	527,991	799	801	949
South Carolina	172	167	371	1,673,620	1,819,508	1,849,036	103	92	201
South Dakota	24	42	59	345,996	383,216	404,090	69	110	145
Tennessee	666	566	961	2,316,661	2,640,005	2,733,702	287	214	352
Texas	2,873	3,640	3,374	8,307,176	9,395,279	10,065,924	346	387	335
Utah	314	320	409	845,398	1,034,429	1,107,379	371	309	369
Vermont	51	50	136	292,288	315,806	333,703	176	158	409
Virginia	3,231	4,850	5,756	3,146,997	3,323,266	3,560,462	1,027	1,459	1,617
Washington	901	1,226	1,999	2,445,866	2,822,223	2,881,443	368	434	694
West Virginia	166	193	254	689,628	746,442	753,108	241	259	338
Wisconsin	308	332	595	2,556,294	2,855,830	2,877,047	120	116	207
Wyoming	41	28	40	224,562	243,944	261,357	184	116	152
Puerto Rico	NA	59	135	991,960	1,132,658	1,169,760	NA	52	116

NA = not available

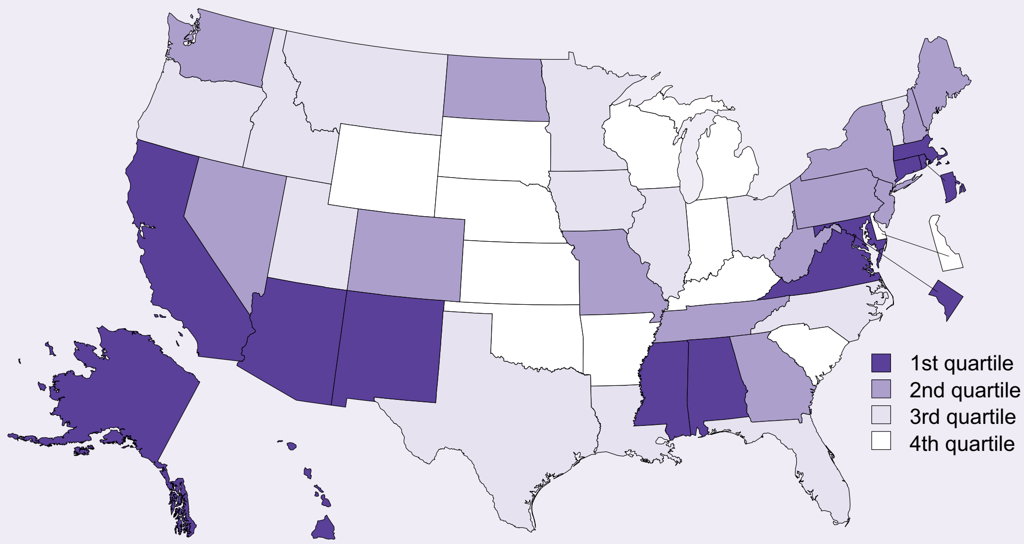
NOTES: Only the following 10 agencies were required to report federal R&D obligations: Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, and Transportation; Environmental Protection Agency; National Aeronautics and Space Administration; and National Science Foundation. These obligations represent approximately 98% of total federal R&D obligations in FY 1992, 1997, and 2002. Civilian workers represent employed component of civilian labor force and are reported as annual data, not seasonally adjusted.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development,* various years; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science and Engineering Indicators 2006

Federal R&D Obligations per Individual in S&E Occupation

Figure 8-28
Federal R&D obligations per individual in S&E occupation: 2002–03



1st quartile ($81,729–$22,333)	2nd quartile ($17,040–$12,112)	3rd quartile ($11,944–$8,019)	4th quartile ($7,612–$4,537)
Alabama	Colorado	Florida	Arkansas
Alaska	Georgia	Idaho	Delaware
Arizona	Maine	Illinois	Indiana
California	Missouri	Iowa	Kansas
Connecticut	Nevada	Louisiana	Kentucky
District of Columbia	New Hampshire	Minnesota	Michigan
Hawaii	New Jersey	Montana	Nebraska
Maryland	New York	North Carolina	Oklahoma
Massachusetts	North Dakota	Ohio	South Carolina
Mississippi	Pennsylvania	Oregon	South Dakota
New Mexico	Tennessee	Texas	Wisconsin
Rhode Island	Washington	Utah	Wyoming
Virginia	West Virginia	Vermont	

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development*; and U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates. See table 8-28.

Findings

- The federal government obligated $83.6 billion for R&D in 2002, nearly $17,000 for each person employed in an S&E occupation.
- The state distribution of federal R&D obligations per person employed in an S&E occupation ranged from $4,537 to $81,729.
- The state distribution for this indicator was highly skewed, with only 14 states above the national average.
- High values occurred in the District of Columbia and adjoining states and in states where federal facilities or major defense contractors were located.

This indicator demonstrates how federal research and development obligations are distributed geographically based on individuals with a bachelor's or higher degree who work in science and engineering occupations. These positions include mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any of these fields. Positions such as managers and elementary and secondary schoolteachers are excluded. A high value may indicate the existence of major federally funded R&D facilities or the presence of large defense or other federal contractors in the state.

Federal R&D dollars are counted where they are obligated but may be expended in many locations. Data on people in S&E occupations are sample based. For these reasons, estimates for sparsely populated states and the District of Columbia may be imprecise.

This indicator contains 2002 data in the numerator and 2003 data in the denominator, each representing the most recent data release. The 2003 numerator data are not scheduled for release before the time of printing, and the 2002 denominator data contain suppressed data.

Table 8-28
Federal R&D obligations per individual in S&E occupation, by state: 2002–03

State	2002 federal R&D obligations ($ millions)	2003 individuals in S&E occupations	2002 federal R&D obligations/2003 individual in S&E occupation ($)
United States	83,629	4,961,550	16,855
Alabama	2,705	56,380	47,974
Alaska	274	10,600	25,830
Arizona	2,057	92,120	22,333
Arkansas	141	21,340	6,621
California	15,686	676,180	23,198
Colorado	1,609	124,140	12,961
Connecticut	1,917	81,380	23,555
Delaware	79	17,370	4,537
District of Columbia	2,850	54,890	51,913
Florida	2,301	221,070	10,407
Georgia	2,019	144,170	14,006
Hawaii	375	16,090	23,319
Idaho	231	22,150	10,424
Illinois	1,694	211,230	8,019
Indiana	526	78,410	6,705
Iowa	405	37,320	10,839
Kansas	291	51,970	5,590
Kentucky	321	45,230	7,104
Louisiana	432	41,900	10,310
Maine	255	15,020	16,944
Maryland	7,192	149,250	48,189
Massachusetts	4,659	184,690	25,224
Michigan	1,244	182,940	6,801
Minnesota	1,151	117,120	9,826
Mississippi	623	22,190	28,062
Missouri	1,203	84,150	14,292
Montana	113	11,450	9,860
Nebraska	145	30,710	4,712
Nevada	336	22,330	15,047
New Hampshire	297	23,430	12,659
New Jersey	2,022	161,420	12,523
New Mexico	2,746	33,600	81,729
New York	3,747	272,440	13,753
North Carolina	1,390	132,440	10,498
North Dakota	102	8,430	12,112
Ohio	2,103	177,100	11,877
Oklahoma	272	44,360	6,123
Oregon	502	61,230	8,203
Pennsylvania	3,162	185,560	17,040
Rhode Island	501	18,740	26,750
South Carolina	371	48,740	7,612
South Dakota	59	9,150	6,415
Tennessee	961	63,680	15,093
Texas	3,374	365,270	9,238
Utah	409	45,570	8,969
Vermont	136	11,420	11,944
Virginia	5,756	209,280	27,505
Washington	1,999	150,230	13,306
West Virginia	254	16,220	15,672
Wisconsin	595	93,320	6,374
Wyoming	40	6,130	6,460
Puerto Rico	135	19,940	6,785

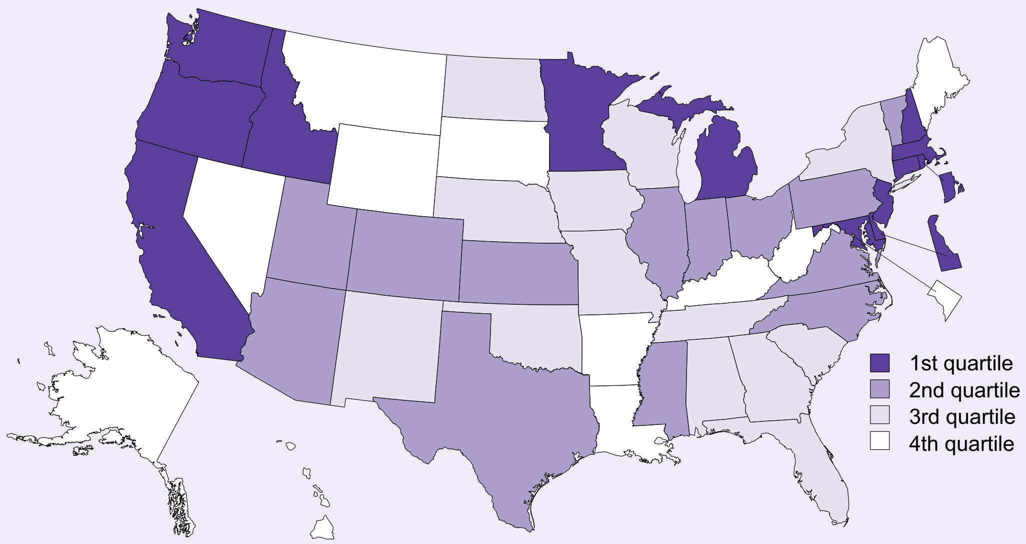
NOTES: Only the following 10 agencies were required to report federal R&D obligations: Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, and Transportation; Environmental Protection Agency; National Aeronautics and Space Administration; and National Science Foundation. These obligations represent approximately 98% of total federal R&D obligations in FY 2002.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development;* and U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates.

Science and Engineering Indicators 2006

Industry-Performed R&D as Share of Private-Industry Output

Figure 8-29
Industry-performed R&D as share of private-industry output: 2003



1st quartile (4.73%–2.15%)	2nd quartile (2.14%–1.52%)	3rd quartile (1.49%–0.65%)	4th quartile (0.57%–0.14%)
California	Arizona	Alabama	Alaska
Connecticut	Colorado	Florida	Arkansas
Delaware	Illinois	Georgia	District of Columbia
Idaho	Indiana	Iowa	Hawaii
Maryland	Kansas	Missouri	Kentucky
Massachusetts	Mississippi	Nebraska	Louisiana
Michigan	North Carolina	New Mexico	Maine
Minnesota	Ohio	New York	Montana
New Hampshire	Pennsylvania	North Dakota	Nevada
New Jersey	Texas	Oklahoma	South Dakota
Oregon	Utah	South Carolina	West Virginia
Rhode Island	Vermont	Tennessee	Wyoming
Washington	Virginia	Wisconsin	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data. See Table 8-29.

Findings

- The amount of R&D performed by industry rose from $164 billion in 1998 to $198 billion in 2003, an increase of 21% (unadjusted for inflation).
- The value of this indicator for the United States has been variable over the past 5 years; starting at 2.14% in 1998, it rose to 2.23% in 2000 before declining to 2.06% in 2003.
- Industrial R&D is concentrated in a few states—only 15 states had indicator values exceeding the national average in 2003.
- States with high values for this indicator were usually located on the West Coast or the northern half of the East Coast.

This indicator measures the emphasis that private industry places on research and development. Industrial R&D focuses on projects that are expected to yield new or improved products, processes, or services and to bring direct benefits to the company. A high value for this indicator shows that the companies and industries within a state are making a significant investment in their R&D activities.

Differences among states on this indicator should be interpreted with caution. Because industries differ in their reliance on R&D, the indicator reflects state differences in industrial structure as much as the behavior of individual companies. Furthermore, industrial R&D data for states with small economies may be based on data imputed from previous years' survey results and imprecise estimates.

The methodology for making state-level assignments of the industrial R&D reported by companies with operations in multiple states changed in 1998. Industrial R&D data from previous years are not comparable.

Table 8-29
Industry-performed R&D as share of private-industry output, by state: 1998, 2000, and 2003

State	Industry-performed R&D ($ millions)			Private-industry output ($ millions)			Industry-performed R&D/ private-industry output (%)		
	1998	2000	2003	1998	2000	2003	1998	2000	2003
United Sates	163,658	192,197	198,244	7,652,499	8,614,286	9,604,156	2.14	2.23	2.06
Alabama	845	821	999	89,502	96,446	109,488	0.94	0.85	0.91
Alaska	37	48	36	18,237	22,381	25,436	0.20	0.21	0.14
Arizona	1,801	2,182	2,605	120,035	138,624	160,429	1.50	1.57	1.62
Arkansas	213	400	270	53,761	57,763	64,871	0.40	0.69	0.42
California	32,856	45,455	47,142	966,679	1,154,900	1,277,809	3.40	3.94	3.69
Colorado	3,180	3,143	3,544	126,281	152,455	165,462	2.52	2.06	2.14
Connecticut	3,346	4,132	5,834	132,902	146,985	158,610	2.52	2.81	3.68
Delaware	1,356	1,468	1,298	33,754	38,804	46,257	4.02	3.78	2.81
District of Columbia	598	196	235	32,759	38,167	45,698	1.83	0.51	0.51
Florida	3,265	3,773	3,181	364,872	412,849	487,364	0.89	0.91	0.65
Georgia	1,617	2,159	2,108	224,738	256,521	279,185	0.72	0.84	0.76
Hawaii	55	93	133	29,267	31,480	36,088	0.19	0.30	0.37
Idaho	1,103	1,363	745	25,577	30,379	34,716	4.31	4.49	2.15
Illinois	7,318	8,393	8,319	384,210	420,225	450,635	1.90	2.00	1.85
Indiana	2,922	2,888	3,658	161,609	175,724	192,583	1.81	1.64	1.90
Iowa	750	762	833	74,011	80,129	90,438	1.01	0.95	0.92
Kansas	1,384	1,327	1,675	65,938	72,176	80,287	2.10	1.84	2.09
Kentucky	606	762	601	95,206	97,146	109,376	0.64	0.78	0.55
Louisiana	377	364	295	103,955	118,914	125,610	0.36	0.31	0.23
Maine	137	255	200	27,554	30,757	35,023	0.50	0.83	0.57
Maryland	1,905	2,213	3,998	133,268	148,859	176,766	1.43	1.49	2.26
Massachusetts	10,367	10,857	11,094	215,743	253,492	271,137	4.81	4.28	4.09
Michigan	12,554	17,489	15,241	278,288	303,519	322,098	4.51	5.76	4.73
Minnesota	3,367	3,971	5,003	149,615	166,186	188,601	2.25	2.39	2.65
Mississippi	183	242	1,021	50,730	53,308	59,392	0.36	0.45	1.72
Missouri	1,505	1,978	1,742	145,297	156,173	171,295	1.04	1.27	1.02
Montana	63	78	65	16,567	17,732	21,324	0.38	0.44	0.30
Nebraska	195	335	363	44,564	47,831	55,868	0.44	0.70	0.65
Nevada	476	433	383	57,324	67,247	80,672	0.83	0.64	0.47
New Hampshire	1,138	722	1,349	35,751	39,815	43,768	3.18	1.81	3.08
New Jersey	11,107	10,580	11,401	282,444	310,296	354,537	3.93	3.41	3.22
New Mexico	1,450	1,203	349	37,472	41,188	45,734	3.87	2.92	0.76
New York	10,283	11,622	8,556	613,413	690,213	750,468	1.68	1.68	1.14
North Carolina	3,483	4,535	4,424	212,757	240,723	275,309	1.64	1.88	1.61
North Dakota	46	83	216	14,777	15,263	18,178	0.31	0.54	1.19
Ohio	5,742	6,245	6,260	312,482	331,986	354,891	1.84	1.88	1.76
Oklahoma	369	463	577	66,514	74,965	83,942	0.55	0.62	0.69
Oregon	1,345	1,533	2,973	88,720	99,265	104,523	1.52	1.54	2.84
Pennsylvania	7,393	8,473	7,091	325,705	353,120	400,842	2.27	2.40	1.77
Rhode Island	1,332	1,167	1,203	25,933	29,695	34,648	5.14	3.93	3.47
South Carolina	996	1,059	976	88,159	95,381	108,091	1.13	1.11	0.90
South Dakota	40	89	75	17,968	20,103	23,857	0.22	0.44	0.31
Tennessee	2,440	1,644	1,507	142,328	154,830	178,359	1.71	1.06	0.84
Texas	8,984	10,048	11,057	557,215	642,236	725,112	1.61	1.56	1.52
Utah	1,119	1,063	996	51,737	58,280	65,577	2.16	1.82	1.52
Vermont	114	389	360	13,912	15,426	17,838	0.82	2.52	2.02
Virginia	2,540	2,683	4,152	186,167	215,600	251,770	1.36	1.24	1.65
Washington	7,072	8,235	9,222	167,584	192,049	209,977	4.22	4.29	4.39
West Virginia	335	329	219	33,632	34,801	38,755	1.00	0.95	0.57
Wisconsin	1,929	2,415	2,623	142,961	157,044	176,351	1.35	1.54	1.49
Wyoming	20	37	37	12,625	14,835	19,111	0.16	0.25	0.19

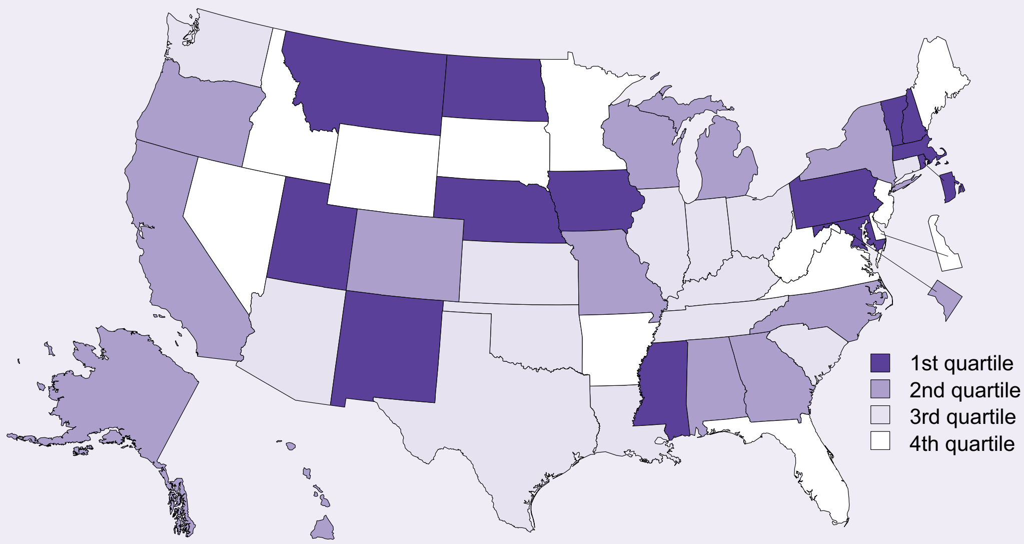
NOTES: In 1998, more than 50% of industrial R&D value imputed because of raking of state data for Alaska, Arkansas, Hawaii, Louisiana, Mississippi, Nebraska, North Dakota, South Dakota, and Wyoming. In 1998, more than 50% of industrial R&D value imputed for Delaware, District of Columbia, Idaho, Kansas, New Mexico, Rhode Island, and Washington. In 2000, more than 50% of industrial R&D value imputed because of raking of state data for Alaska, District of Columbia, Hawaii, Louisiana, Mississippi, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. In 2000, more than 50% of industrial R&D value imputed for Alabama, Arizona, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Kansas, Michigan, New Mexico, Rhode Island, and Washington. In 2003, more than 50% of industrial R&D value imputed because of raking of state data for Alaska. In 2003, more than 50% of industrial R&D value imputed for Kansas and Rhode Island. Private-industry output is reported in current dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, various years; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data.

Science and Engineering Indicators 2006

Academic R&D per $1,000 of Gross State Product

Figure 8-30
Academic R&D per $1,000 of gross state product: 2003



1st quartile ($6.68–$4.51)	2nd quartile ($4.45–$3.64)	3rd quartile ($3.63–$2.92)	4th quartile ($2.70–$1.72)
Iowa	Alabama	Arizona	Arkansas
Maryland	Alaska	Connecticut	Delaware
Massachusetts	California	Illinois	Florida
Mississippi	Colorado	Indiana	Idaho
Montana	District of Columbia	Kansas	Maine
Nebraska	Georgia	Kentucky	Minnesota
New Hampshire	Hawaii	Louisiana	Nevada
New Mexico	Michigan	Ohio	New Jersey
North Dakota	Missouri	Oklahoma	South Dakota
Pennsylvania	New York	South Carolina	Virginia
Rhode Island	North Carolina	Tennessee	West Virginia
Utah	Oregon	Texas	Wyoming
Vermont	Wisconsin	Washington	

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures*; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data. See Table 8-30.

Findings

- Expenditures for research performed in academic institutions have doubled in a decade, rising from $19.4 billion in 1993 to $39.4 billion in 2003 (unadjusted for inflation).
- Academic research increased more rapidly than gross domestic product (GDP), causing the value of this indicator to increase from $3.01 to $3.60 per $1,000 of GDP.
- Most states showed increases in the value of this indicator over the past decade, although declines were observed in seven states.
- States ranking high on the intensity of academic research usually did not rank high on the intensity of industrial research.

This indicator measures the extent of spending on academic research performed in a state relative to the size of the state's economy. Academic research and development is more basic and less product oriented than R&D performed by industry. It can be a valuable basis for future economic development. High values for this indicator may reflect an academic R&D system that can compete for funding from federal, state, and industrial sources.

In this indicator, Maryland data exclude expenditures by the Applied Physics Laboratory (APL) at Johns Hopkins University. APL employs more than 3,000 people and supports the Department of Defense, the National Aeronautics and Space Administration, and other government agencies rather than focusing on academic research. Data for the value of gross state product and for R&D expenditures are shown in current dollars.

Table 8-30
Academic R&D per $1,000 of gross state product, by state: 1993, 1998, and 2003

State	Academic R&D ($ thousands)			GSP ($ millions)			Academic R&D/ $1,000 GSP ($)		
	1993	1998	2003	1993	1998	2003	1993	1998	2003
United States	19,438,022	25,316,788	39,368,880	5,857,335	7,659,648	10,407,146	3.01	2.92	3.60
Alabama	287,849	442,088	557,859	75,293	97,941	125,567	3.45	4.16	4.27
Alaska	66,855	76,358	140,641	22,164	26,083	29,708	2.91	3.29	4.44
Arizona	310,721	405,999	617,978	72,263	113,138	171,781	3.65	2.96	3.37
Arkansas	79,299	116,778	183,183	40,950	56,455	71,929	1.70	1.90	2.46
California	2,445,089	3,389,742	5,362,683	801,193	958,476	1,367,785	2.93	3.12	3.73
Colorado	335,475	489,419	694,862	78,624	116,045	179,410	3.63	3.41	3.69
Connecticut	367,466	406,618	594,541	100,229	126,744	165,744	3.46	2.80	3.42
Delaware	53,889	72,779	104,650	21,925	28,885	47,150	2.28	1.97	2.07
District of Columbia	151,808	232,922	263,342	41,806	47,560	66,440	3.32	4.50	3.73
Florida	492,317	712,704	1,204,592	267,851	362,950	520,500	1.63	1.71	2.18
Georgia	558,188	804,151	1,175,852	146,334	215,128	305,829	3.30	3.15	3.66
Hawaii	73,961	148,007	184,602	33,579	36,959	43,998	2.06	3.93	3.96
Idaho	50,404	72,395	105,039	18,601	28,152	38,558	2.22	2.42	2.60
Illinois	776,412	1,030,819	1,613,691	286,582	377,271	486,139	2.45	2.43	3.23
Indiana	304,140	426,328	725,752	113,831	155,512	204,946	2.33	2.39	3.40
Iowa	299,528	358,613	498,669	57,677	77,244	98,232	4.78	4.28	4.87
Kansas	154,655	213,096	310,052	53,345	67,965	89,508	2.67	2.79	3.32
Kentucky	127,742	241,520	377,635	70,536	94,987	122,282	1.59	2.20	2.94
Louisiana	263,960	353,261	524,262	94,298	114,967	131,584	2.83	2.98	3.63
Maine	26,025	35,265	75,092	23,398	28,636	39,039	1.04	1.10	1.84
Maryland	701,637	887,473	1,423,186	116,226	142,910	201,879	5.62	5.49	6.68
Massachusetts	1,121,126	1,348,220	1,821,817	160,193	208,288	288,088	6.47	5.69	6.13
Michigan	705,430	882,141	1,388,284	194,253	263,871	351,287	3.19	2.86	3.86
Minnesota	336,954	367,779	517,346	103,791	141,664	200,061	2.93	2.21	2.46
Mississippi	110,963	152,683	324,298	40,839	55,997	69,136	2.38	2.53	4.51
Missouri	351,845	484,502	806,907	109,548	145,044	187,543	2.97	2.97	4.16
Montana	50,420	76,655	141,220	14,057	17,998	23,773	3.13	3.86	5.52
Nebraska	137,194	186,320	300,540	35,619	48,317	60,962	3.51	3.57	4.60
Nevada	79,124	83,888	154,515	33,599	54,085	81,182	1.98	1.31	1.72
New Hampshire	99,475	117,323	252,210	24,778	34,823	46,448	3.60	3.01	5.23
New Jersey	374,583	484,942	747,481	221,678	281,806	380,169	1.54	1.55	1.90
New Mexico	187,108	228,740	306,623	30,454	43,658	53,515	5.12	4.98	5.37
New York	1,596,699	1,925,264	3,089,988	508,889	630,003	792,058	2.91	2.81	3.69
North Carolina	633,916	901,995	1,397,371	146,502	201,329	300,216	3.79	3.71	4.43
North Dakota	54,175	56,945	133,615	11,664	16,075	19,780	4.20	3.27	6.19
Ohio	597,195	810,225	1,268,784	234,736	305,413	388,224	2.31	2.32	3.18
Oklahoma	174,981	208,873	295,098	59,468	74,936	95,126	2.69	2.62	2.92
Oregon	227,246	314,355	436,958	60,078	91,166	115,138	3.29	3.11	3.64
Pennsylvania	1,029,195	1,348,265	2,013,453	258,127	325,515	428,950	3.61	3.72	4.54
Rhode Island	103,194	111,979	187,131	21,607	26,665	36,988	4.37	3.79	4.75
South Carolina	185,431	248,474	435,328	68,380	89,260	122,354	2.46	2.40	3.40
South Dakota	22,565	25,474	49,977	13,832	19,073	25,003	1.41	1.22	1.83
Tennessee	279,896	346,466	599,723	101,378	141,335	190,122	2.35	2.16	2.95
Texas	1,422,062	1,697,344	2,765,634	398,935	550,014	773,455	3.17	2.70	3.36
Utah	194,685	249,147	385,158	33,691	51,442	72,974	5.07	4.13	5.02
Vermont	50,627	58,585	106,581	11,722	14,632	19,604	3.87	3.69	5.19
Virginia	408,527	494,005	773,200	152,673	196,638	287,589	2.42	2.18	2.54
Washington	434,885	542,411	869,695	122,657	161,760	232,940	3.13	2.78	3.55
West Virginia	55,282	63,446	120,514	29,352	37,346	45,518	1.71	1.60	2.58
Wisconsin	453,263	535,507	881,214	104,859	141,755	190,650	3.79	3.34	4.45
Wyoming	32,556	48,500	60,054	13,271	15,732	20,285	2.34	3.24	2.70
Puerto Rico	47,848	87,592	78,410	36,923	54,086	74,362	1.30	1.62	1.05

GSP = gross state product

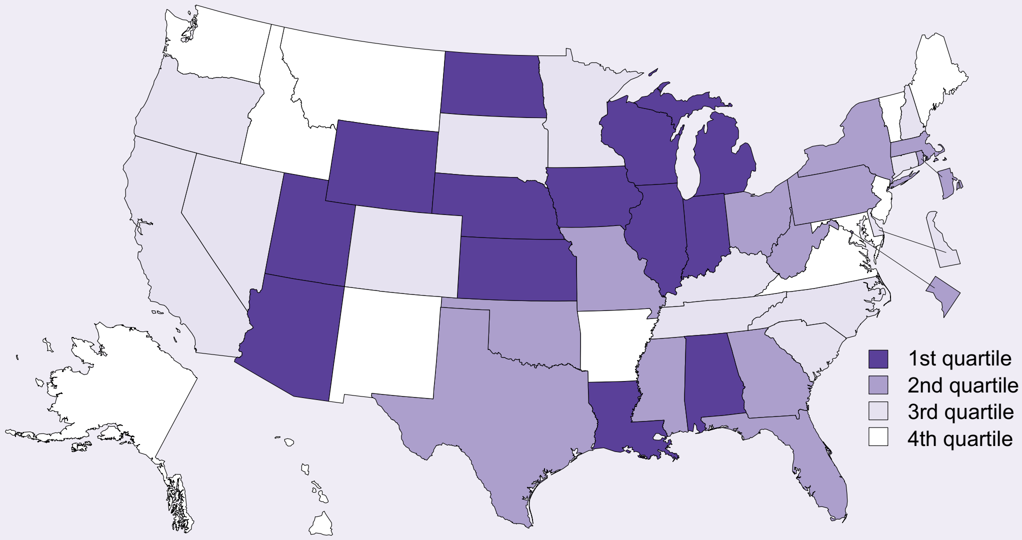
NOTES: In 1998 and 2003, academic R&D was reported for all institutions. In 1993, it was reported for doctorate-granting institutions only. For Maryland, academic R&D excludes R&D performed by Applied Physics Laboratory at Johns Hopkins University. GSP is reported in current dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures,* various years; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2006

S&E Doctorates Conferred per 1,000 S&E Doctorate Holders

Figure 8-31
S&E doctorates conferred per 1,000 S&E doctorate holders: 2003



1st quartile (72.9–55.4)	2nd quartile (52.6–45.3)	3rd quartile (43.8–35.1)	4th quartile (34.3–17.5)
Alabama	District of Columbia	California	Alaska
Arizona	Florida	Colorado	Arkansas
Illinois	Georgia	Connecticut	Hawaii
Indiana	Massachusetts	Delaware	Idaho
Iowa	Mississippi	Kentucky	Maine
Kansas	Missouri	Minnesota	Maryland
Louisiana	New York	Nevada	Montana
Michigan	Ohio	New Hampshire	New Jersey
Nebraska	Oklahoma	North Carolina	New Mexico
North Dakota	Pennsylvania	Oregon	Vermont
Utah	Rhode Island	South Carolina	Virginia
Wisconsin	Texas	South Dakota	Washington
Wyoming	West Virginia	Tennessee	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; and Survey of Doctorate Recipients. See Table 8-31.

Findings

- In 2003, 25,000 S&E doctorates were awarded by U.S. academic institutions, essentially the same as in 2001 but lower than the nearly 27,000 S&E doctorates awarded in 1997.
- The state average of this indicator decreased between 1997 and 2003, reflecting both a decline in the production of new S&E doctorate holders and an increase in the stock of S&E doctorate holders living in the United States.
- This indicator is volatile for many states and may reflect the migration patterns of existing S&E doctorate holders.

This indicator provides a measure of the rate at which the states are training new science and engineering doctorate recipients for entry into the workforce. High values indicate relatively large production of new doctorate holders compared with the existing stock. Some states with relatively low values may need to attract S&E doctorate holders from elsewhere to meet the needs of local employers.

This indicator does not account for the mobility of recent S&E doctorate recipients, which is very high. Foreign-born graduate students may decide to return home after graduation to begin their careers. Most recent doctorate recipients are influenced by the location of employment opportunities.

U.S. S&E doctorate holders include those in the physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. Medical doctorates are excluded. The population of doctorate holders for this indicator consisted of all individuals under age 76 years who received a research doctorate in science or engineering from a U.S. institution and were residing in the United States.

Table 8-31
S&E doctorates conferred per 1,000 S&E doctorate holders, by state: 1997, 2001, and 2003

State	S&E doctorates conferred			S&E doctorate holders			S&E doctorates/ 1,000 doctorate holders		
	1997	2001	2003	1997	2001	2003	1997	2001	2003
United States	26,789	25,342	25,151	503,290	555,360	567,690	53.2	45.6	44.3
Alabama	327	287	314	6,440	5,170	5,500	50.8	55.5	57.1
Alaska	20	26	36	1,110	1,160	1,050	18.0	22.4	34.3
Arizona	486	403	451	6,130	6,800	7,110	79.3	59.3	63.4
Arkansas	68	62	82	2,250	2,460	2,670	30.2	25.2	30.7
California	3,415	3,334	3,405	68,390	78,020	83,150	49.9	42.7	41.0
Colorado	566	485	533	10,350	11,450	12,180	54.7	42.4	43.8
Connecticut	395	370	385	8,470	9,340	10,140	46.6	39.6	38.0
Delaware	130	128	102	3,520	3,470	2,600	36.9	36.9	39.2
District of Columbia	319	291	313	11,580	13,840	6,490	27.5	21.0	48.2
Florida	828	781	818	12,820	15,040	15,590	64.6	51.9	52.5
Georgia	543	608	620	9,640	11,710	12,060	56.3	51.9	51.4
Hawaii	130	107	92	2,420	2,570	2,960	53.7	41.6	31.1
Idaho	57	51	70	1,990	2,160	2,480	28.6	23.6	28.2
Illinois	1,347	1,323	1,262	21,020	21,670	21,410	64.1	61.1	58.9
Indiana	681	667	655	7,460	9,490	8,980	91.3	70.3	72.9
Iowa	401	376	299	4,030	4,280	4,450	99.5	87.9	67.2
Kansas	284	264	269	3,720	3,890	4,050	76.3	67.9	66.4
Kentucky	214	172	185	3,980	4,380	4,740	53.8	39.3	39.0
Louisiana	318	334	287	5,210	5,000	5,180	61.0	66.8	55.4
Maine	41	30	37	2,140	1,940	2,000	19.2	15.5	18.5
Maryland	676	664	634	20,660	22,090	27,050	32.7	30.1	23.4
Massachusetts	1,478	1,448	1,363	22,960	28,390	28,950	64.4	51.0	47.1
Michigan	970	906	954	14,750	16,940	16,280	65.8	53.5	58.6
Minnesota	471	455	425	9,660	11,070	10,770	48.8	41.1	39.5
Mississippi	152	129	140	2,970	3,120	3,080	51.2	41.3	45.5
Missouri	474	439	435	9,300	8,860	8,730	51.0	49.5	49.8
Montana	59	42	51	1,580	1,330	1,660	37.3	31.6	30.7
Nebraska	179	164	184	2,930	2,840	2,730	61.1	57.7	67.4
Nevada	24	52	77	1,620	2,010	1,820	14.8	25.9	42.3
New Hampshire	94	76	100	2,190	2,320	2,710	42.9	32.8	36.9
New Jersey	619	621	584	19,970	22,130	21,900	31.0	28.1	26.7
New Mexico	142	147	163	7,120	7,370	7,640	19.9	19.9	21.3
New York	2,302	2,128	2,131	38,830	42,570	40,510	59.3	50.0	52.6
North Carolina	726	726	723	13,470	16,250	17,130	53.9	44.7	42.2
North Dakota	50	43	66	1,330	1,080	1,110	37.6	39.8	59.5
Ohio	1,210	1,061	989	18,200	19,270	20,130	66.5	55.1	49.1
Oklahoma	237	238	190	4,430	4,110	4,160	53.5	57.9	45.7
Oregon	291	262	256	5,980	6,900	7,280	48.7	38.0	35.2
Pennsylvania	1,376	1,247	1,219	23,110	25,520	26,900	59.5	48.9	45.3
Rhode Island	161	162	142	2,400	2,600	3,060	67.1	62.3	46.4
South Carolina	222	216	181	4,620	5,030	4,810	48.1	42.9	37.6
South Dakota	36	34	33	1,000	970	940	36.0	35.1	35.1
Tennessee	391	377	340	8,350	8,570	8,680	46.8	44.0	39.2
Texas	1,633	1,598	1,548	27,990	31,710	32,430	58.3	50.4	47.7
Utah	196	236	239	4,670	4,720	4,160	42.0	50.0	57.5
Vermont	42	52	29	1,750	1,630	1,660	24.0	31.9	17.5
Virginia	702	628	620	14,860	16,880	20,890	47.2	37.2	29.7
Washington	482	457	441	12,860	14,270	14,960	37.5	32.0	29.5
West Virginia	78	67	101	1,930	1,840	2,040	40.4	36.4	49.5
Wisconsin	681	530	535	8,320	8,290	8,060	81.9	63.9	66.4
Wyoming	65	38	43	810	840	670	80.2	45.2	64.2
Puerto Rico	58	97	80	650	1,400	1,610	89.2	69.3	49.7

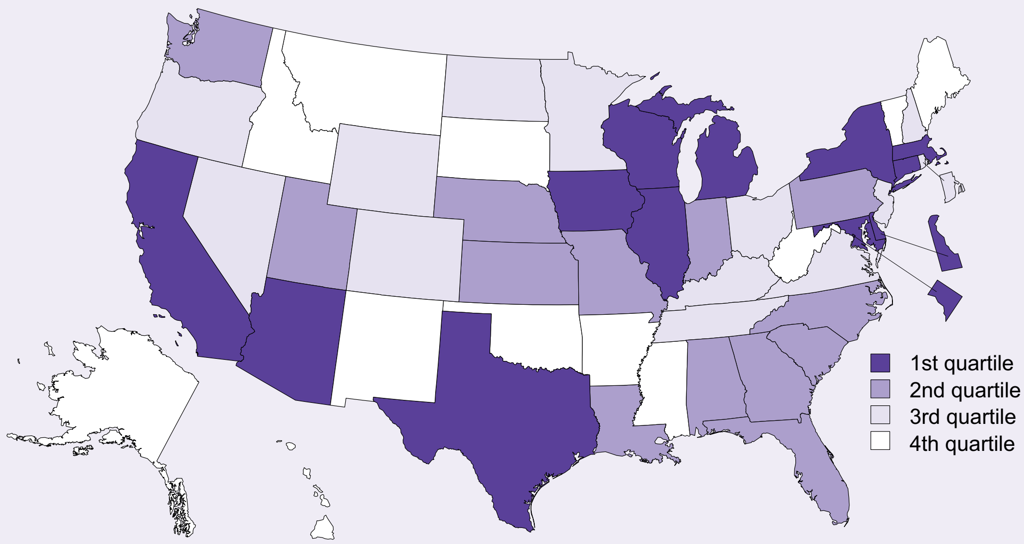
NOTES: Survey of Doctorate Recipients sample design does not include geography. Data on U.S. S&E doctorate holders are classified by employment location. Thus, reliability of data for areas with smaller populations is lower than for more populous states. Reliability of estimates by state for S&E doctorate holders may be poor for some states because of small sample size.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; and Survey of Doctorate Recipients.

Science and Engineering Indicators 2006

Academic Article Output per 1,000 S&E Doctorate Holders in Academia

Figure 8-32
Academic article output per 1,000 S&E doctorate holders in academia: 2003



1st quartile (926–657)	2nd quartile (639–571)	3rd quartile (561–424)	4th quartile (419–251)
Arizona	Alabama	Colorado	Alaska
California	Florida	Kentucky	Arkansas
Connecticut	Georgia	Minnesota	Hawaii
Delaware	Indiana	Nevada	Idaho
District of Columbia	Kansas	New Hampshire	Maine
Illinois	Louisiana	New Jersey	Mississippi
Iowa	Missouri	North Dakota	Montana
Maryland	Nebraska	Ohio	New Mexico
Massachusetts	North Carolina	Oregon	Oklahoma
Michigan	Pennsylvania	Rhode Island	South Dakota
New York	South Carolina	Tennessee	Vermont
Texas	Utah	Virginia	West Virginia
Wisconsin	Washington	Wyoming	

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See Table 8-32.

Findings

- Between 1997 and 2003, the number of scientific and technical articles increased by 8%, and the number of S&E doctorate holders increased by the same percentage, causing the value of this indicator to remain almost unchanged for the United States.
- The publication rate for academic S&E doctorate holders in states in the top quartile of this indicator was approximately twice as high as for states in the bottom quartile.
- States with the greatest volatility on this indicator frequently had larger changes in academic employment than in number of publications.
- In 2003, the states with the highest values for this indicator were distributed across the nation.

The volume of peer-reviewed articles per 1,000 academic science and engineering doctorate holders is an approximate measure of their contribution to scientific knowledge. Publications are only one measure of academic productivity, which includes trained personnel, patents, and other outputs. A high value on this indicator shows that the S&E faculty in a state's academic institutions are generating a high volume of publications relative to other states.

Publication counts are based on the number of articles appearing in a set of journals listed in Thomson ISI's *Science Citation Index* and *Social Sciences Citation Index.* The number of journals in this set was 5,029 in 1997, 5,255 in 2001, and 5,315 in 2003. Articles with authors in different institutions were counted fractionally. For a publication with *N* authors, each author's institution was credited with 1/*N* articles.

S&E doctorates include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. Medical doctorates and S&E doctorates from foreign institutions are excluded.

Table 8-32
Academic article output per 1,000 S&E doctorate holders in academia, by state: 1997, 2001, and 2003

	Academic article output			S&E doctorate holders in academia			Academic articles/ 1,000 academic doctorate holders		
State	1997	2001	2003	1997	2001	2003	1997	2001	2003
United States	144,441	147,582	156,373	231,690	244,390	250,020	623	604	625
Alabama	1,911	1,896	1,903	4,460	2,940	3,160	428	645	602
Alaska	163	186	196	450	530	600	362	351	327
Arizona	2,256	2,199	2,251	2,850	3,100	2,910	792	709	774
Arkansas	603	608	704	1,450	1,570	1,740	416	387	405
California	17,525	18,147	19,533	24,000	24,220	25,790	730	749	757
Colorado	2,524	2,630	2,736	4,250	4,780	5,030	594	550	544
Connecticut	2,820	2,767	2,897	3,750	4,090	4,310	752	677	672
Delaware	499	560	611	690	760	660	723	737	926
District of Columbia	1,224	1,213	1,225	1,830	2,440	1,380	669	497	888
Florida	4,186	4,256	4,831	6,440	7,510	7,560	650	567	639
Georgia	3,255	3,576	3,851	5,450	6,230	6,500	597	574	592
Hawaii	574	538	606	1,200	1,490	1,640	478	361	370
Idaho	295	309	320	780	910	1,170	378	340	274
Illinois	6,893	7,009	7,428	10,120	10,350	9,880	681	677	752
Indiana	3,103	3,095	3,243	4,500	5,570	5,560	690	556	583
Iowa	2,289	2,239	2,371	3,060	3,090	3,170	748	725	748
Kansas	1,199	1,251	1,308	2,240	2,180	2,290	535	574	571
Kentucky	1,380	1,356	1,505	2,890	3,080	3,240	478	440	465
Louisiana	1,895	1,828	1,845	3,390	3,220	3,180	559	568	580
Maine	247	234	281	1,290	1,150	1,120	191	203	251
Maryland	4,389	4,935	5,099	5,840	5,660	6,650	752	872	767
Massachusetts	9,235	9,676	9,974	11,190	12,630	13,700	825	766	728
Michigan	4,880	5,078	5,396	7,600	8,520	8,210	642	596	657
Minnesota	2,435	2,388	2,421	4,260	5,110	5,190	572	467	466
Mississippi	628	692	747	1,930	1,900	1,910	325	364	391
Missouri	3,159	3,230	3,251	5,600	5,430	5,340	564	595	609
Montana	272	328	371	940	730	980	289	449	379
Nebraska	1,030	1,011	1,040	2,250	1,910	1,790	458	529	581
Nevada	370	447	513	970	1,260	1,060	381	355	484
New Hampshire	607	615	653	1,090	1,160	1,190	557	530	549
New Jersey	3,102	3,055	3,300	4,750	5,210	6,290	653	586	525
New Mexico	808	780	829	2,120	2,690	2,650	381	290	313
New York	12,382	12,427	12,904	19,080	19,570	18,830	649	635	685
North Carolina	4,958	5,141	5,579	7,480	8,440	8,770	663	609	636
North Dakota	269	271	322	880	660	760	306	411	424
Ohio	5,169	5,078	5,385	9,390	9,480	9,600	550	536	561
Oklahoma	919	925	996	2,630	2,620	2,500	349	353	398
Oregon	1,614	1,540	1,713	2,570	3,070	3,140	628	502	546
Pennsylvania	8,194	8,362	8,718	11,620	13,130	14,380	705	637	606
Rhode Island	852	862	904	1,670	1,640	1,770	510	526	511
South Carolina	1,202	1,343	1,478	3,040	2,920	2,540	395	460	582
South Dakota	140	131	168	660	600	620	212	218	271
Tennessee	2,254	2,284	2,463	4,530	4,560	4,820	498	501	511
Texas	8,756	9,039	9,777	13,180	13,310	13,680	664	679	715
Utah	1,570	1,570	1,631	2,940	3,000	2,760	534	523	591
Vermont	380	412	398	1,080	960	950	352	429	419
Virginia	3,014	3,104	3,254	5,290	6,320	7,020	570	491	464
Washington	3,206	3,339	3,557	5,110	6,120	6,000	627	546	593
West Virginia	417	388	385	1,120	1,080	1,160	372	359	332
Wisconsin	3,189	3,044	3,287	5,230	4,920	4,400	610	619	747
Wyoming	200	190	215	560	570	470	357	333	457
Puerto Rico	168	186	214	630	1,030	1,250	267	181	171

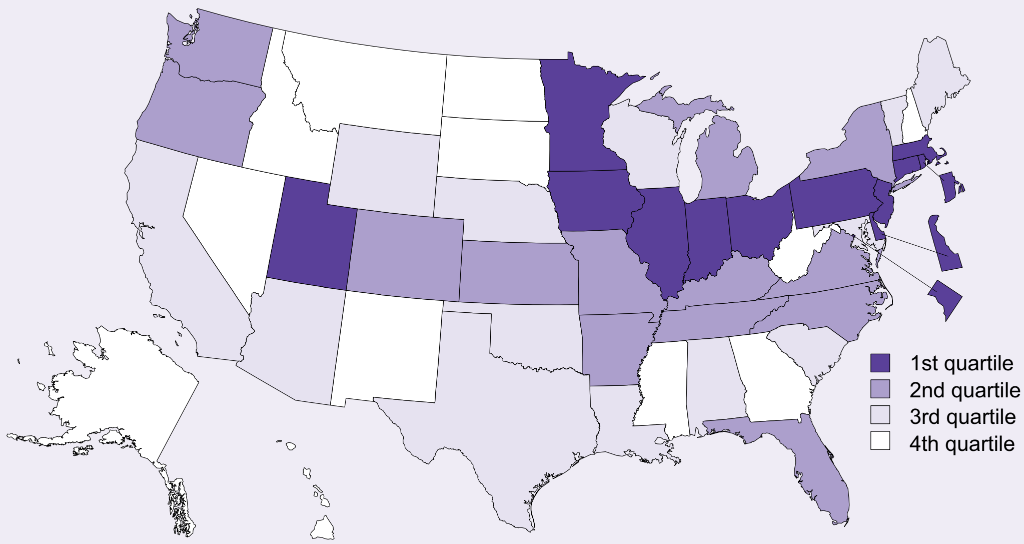
NOTES: Survey of Doctorate Recipients sample design does not include geography. Data on U.S. S&E doctorate holders are classified by employment location. Thus, reliability of data for areas with smaller populations is lower than for more populous states. Reliability of estimates by state for S&E doctorate holders may be poor for some states because of small sample size.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index;* ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science and Engineering Indicators 2006

Academic Article Output per $1 Million of Academic R&D

Figure 8-33
Academic article output per $1 million of academic R&D: 2003



1st quartile (5.84–4.23)	2nd quartile (4.22–3.84)	3rd quartile (3.74–3.38)	4th quartile (3.36–1.39)
Connecticut	Arkansas	Alabama	Alaska
Delaware	Colorado	Arizona	Georgia
District of Columbia	Florida	California	Hawaii
Illinois	Kansas	Louisiana	Idaho
Indiana	Kentucky	Maine	Mississippi
Iowa	Michigan	Maryland	Montana
Massachusetts	Missouri	Nebraska	Nevada
Minnesota	New York	Oklahoma	New Hampshire
New Jersey	North Carolina	South Carolina	New Mexico
Ohio	Oregon	Texas	North Dakota
Pennsylvania	Tennessee	Vermont	South Dakota
Rhode Island	Virginia	Wisconsin	West Virginia
Utah	Washington	Wyoming	

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index*; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures*. See Table 8-33.

Findings

- From 1993 to 2003, the number of academic publications rose from 142,000 to 156,000, an increase of 10%.
- In 2003, academic researchers produced an average of 4.0 publications per $1 million of academic R&D, compared with 7.3 in 1993. This partly reflects the effects of general price inflation (27% during this period) but may also indicate rising academic research costs.
- The value for this indicator decreased for all states between 1993 and 2003.

This indicator shows the relationship between the number of academic publications and the expenditure for academic research and development. A high value for this indicator means that a state's academic institutions have a high publication output relative to their R&D spending. This indicator is not an efficiency measure; it is affected by the highly variable costs of R&D and by publishing conventions in different fields and institutions. It may reflect variations in field emphasis among states and institutions.

Publication counts are based on the number of articles appearing in a set of journals listed in Thomson ISI's *Science Citation Index* and *Social Sciences Citation Index*. The number of journals in this set was 4,601 in 1993, 5,084 in 1998, and 5,315 in 2003. Articles with authors in different institutions were counted fractionally. For a publication with *N* authors, each author's institution was credited with 1/*N* articles. In this indicator, Maryland data exclude expenditures by the Applied Physics Laboratory (APL) at Johns Hopkins University. APL employs more than 3,000 workers and supports the Department of Defense, the National Aeronautics and Space Administration, and other government agencies rather than focusing on academic research.

Table 8-33
Academic article output per $1 million of academic R&D, by state: 1993, 1998, and 2003

State	Academic article output			Academic R&D ($ millions)			Academic articles/ $1 million academic R&D		
	1993	1998	2003	1993	1998	2003	1993	1998	2003
United States	142,134	144,980	156,373	19,438	25,317	39,369	7.31	5.73	3.97
Alabama	1,787	1,882	1,903	288	442	558	6.21	4.26	3.41
Alaska	169	160	196	67	76	141	2.53	2.10	1.39
Arizona	2,249	2,069	2,251	311	406	618	7.24	5.10	3.64
Arkansas	562	597	704	79	117	183	7.09	5.11	3.84
California	18,013	17,789	19,533	2,445	3,390	5,363	7.37	5.25	3.64
Colorado	2,355	2,563	2,736	335	489	695	7.02	5.24	3.94
Connecticut	2,723	2,924	2,897	367	407	595	7.41	7.19	4.87
Delaware	530	519	611	54	73	105	9.84	7.13	5.84
District of Columbia	1,187	1,260	1,225	152	233	263	7.82	5.41	4.65
Florida	4,146	4,299	4,831	492	713	1,205	8.42	6.03	4.01
Georgia	2,880	3,248	3,851	558	804	1,176	5.16	4.04	3.28
Hawaii	585	559	606	74	148	185	7.91	3.78	3.28
Idaho	297	283	320	50	72	105	5.89	3.91	3.05
Illinois	7,103	6,863	7,428	776	1,031	1,614	9.15	6.66	4.60
Indiana	3,077	3,122	3,243	304	426	726	10.12	7.32	4.47
Iowa	2,292	2,306	2,371	300	359	499	7.65	6.43	4.75
Kansas	1,244	1,169	1,308	155	213	310	8.04	5.49	4.22
Kentucky	1,310	1,311	1,505	128	242	378	10.26	5.43	3.99
Louisiana	1,787	1,887	1,845	264	353	524	6.77	5.34	3.52
Maine	245	259	281	26	35	75	9.41	7.34	3.74
Maryland	4,303	4,549	5,099	702	887	1,423	6.13	5.13	3.58
Massachusetts	8,624	9,226	9,974	1,121	1,348	1,822	7.69	6.84	5.47
Michigan	4,892	4,865	5,396	705	882	1,388	6.93	5.51	3.89
Minnesota	2,491	2,405	2,421	337	368	517	7.39	6.54	4.68
Mississippi	507	642	747	111	153	324	4.57	4.20	2.30
Missouri	2,946	3,158	3,251	352	485	807	8.37	6.52	4.03
Montana	265	313	371	50	77	141	5.26	4.08	2.63
Nebraska	1,067	1,048	1,040	137	186	301	7.78	5.62	3.46
Nevada	375	381	513	79	84	155	4.74	4.54	3.32
New Hampshire	586	621	653	99	117	252	5.89	5.29	2.59
New Jersey	2,898	2,952	3,300	375	485	747	7.74	6.09	4.41
New Mexico	734	771	829	187	229	307	3.92	3.37	2.70
New York	12,779	12,581	12,904	1,597	1,925	3,090	8.00	6.53	4.18
North Carolina	4,676	5,006	5,579	634	902	1,397	7.38	5.55	3.99
North Dakota	281	273	322	54	57	134	5.19	4.79	2.41
Ohio	5,216	5,139	5,385	597	810	1,269	8.73	6.34	4.24
Oklahoma	892	919	996	175	209	295	5.10	4.40	3.38
Oregon	1,574	1,577	1,713	227	314	437	6.93	5.02	3.92
Pennsylvania	7,784	8,203	8,718	1,029	1,348	2,013	7.56	6.08	4.33
Rhode Island	872	839	904	103	112	187	8.45	7.49	4.83
South Carolina	1,137	1,227	1,478	185	248	435	6.13	4.94	3.40
South Dakota	140	141	168	23	25	50	6.20	5.54	3.36
Tennessee	2,082	2,306	2,463	280	346	600	7.44	6.66	4.11
Texas	8,670	8,717	9,777	1,422	1,697	2,766	6.10	5.14	3.54
Utah	1,508	1,590	1,631	195	249	385	7.75	6.38	4.23
Vermont	393	370	398	51	59	107	7.76	6.32	3.73
Virginia	3,042	3,100	3,254	409	494	773	7.45	6.28	4.21
Washington	2,988	3,184	3,557	435	542	870	6.87	5.87	4.09
West Virginia	395	410	385	55	63	121	7.15	6.46	3.19
Wisconsin	3,258	3,201	3,287	453	536	881	7.19	5.98	3.73
Wyoming	218	197	215	33	49	60	6.70	4.06	3.58
Puerto Rico	168	192	214	48	88	78	3.51	2.19	2.73

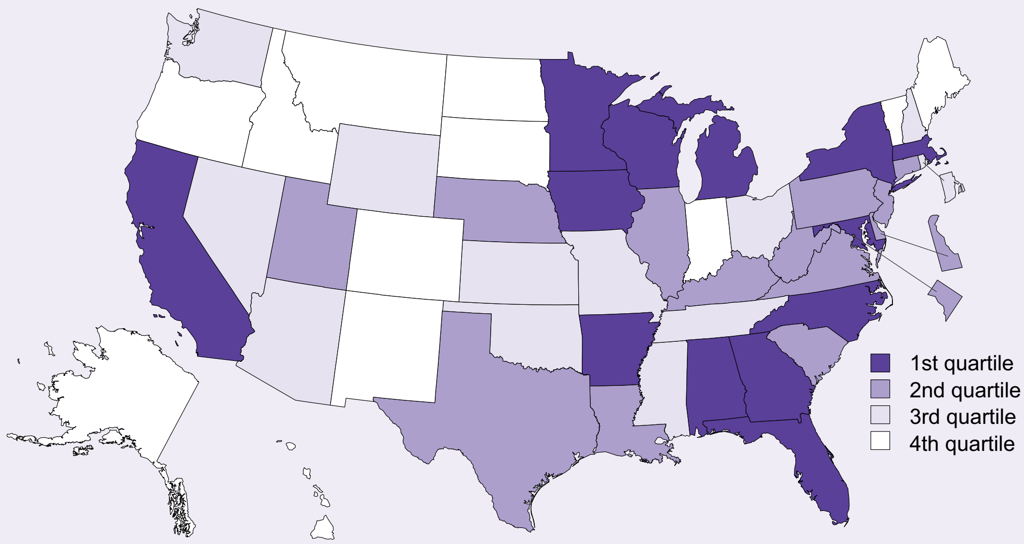
NOTES: In 1998 and 2003, academic R&D was reported for all institutions. In 1993, academic R&D was reported for doctorate-granting institutions only.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index;* ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures,* various years.

Science and Engineering Indicators 2006

Academic Patents Awarded per 1,000 S&E Doctorate Holders in Academia

Figure 8-34
Academic patents awarded per 1,000 S&E doctorate holders in academia: 2003



1st quartile (27.3–12.6)	2nd quartile (12.1–8.3)	3rd quartile (8.2–5.7)	4th quartile (5.4–0.0)
Alabama	Connecticut	Arizona	Alaska
Arkansas	Delaware	Kansas	Colorado
California	District of Columbia	Mississippi	Hawaii
Florida	Illinois	Missouri	Idaho
Georgia	Kentucky	Nevada	Indiana
Iowa	Louisiana	New Hampshire	Maine
Maryland	Nebraska	Ohio	Montana
Massachusetts	New Jersey	Oklahoma	New Mexico
Michigan	Pennsylvania	Rhode Island	North Dakota
Minnesota	South Carolina	Tennessee	Oregon
New York	Texas	Washington	South Dakota
North Carolina	Utah	Wyoming	Vermont
Wisconsin	Virginia		
	West Virginia		

SOURCES: U.S. Patent and Trademark Office, Technology Assessment and Forecast Branch, *U.S. Colleges and Universities—Utility Patent Grants, Calendar Years 1969–2003*; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See Table 8-34.

Findings

- Throughout the United States, the number of patents awarded to academic institutions increased from more than 2,400 in 1997 to nearly 3,300 in 2003, an increase of 33%, while the number of academic S&E doctorate holders rose by 8% over the same period.
- In 2003, 13 patents were produced nationally for each 1,000 S&E doctorate holders employed in academia, which was significantly higher than the 10.5 patents produced in 1997.
- The rise in this indicator suggests that states and their universities are increasing their focus on academic patenting.
- In 2003, states varied widely on this indicator, with values ranging from 0 to 27.3 patents per 1,000 S&E doctorate holders employed in academia, indicating a difference in patenting philosophy or mix of industries supported by the academic institutions.

Since the early 1980s, academic institutions have increasingly been viewed as engines of economic growth. Growing attention has been paid to the results of academic research and development in terms of their role in creating new products, processes, and services. One indicator of such R&D results is volume of academic patents. Academic patenting is highly concentrated and partly reflects the resources devoted to institutional patenting offices.

This indicator relates the volume of academic patents to the size of the doctoral science and engineering workforce in academia. It is an approximate measure of the degree to which results with perceived economic value are generated by the doctoral academic workforce.

S&E doctorates include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. Medical doctorates and S&E doctorates from foreign institutions are excluded.

Table 8-34
Academic patents awarded per 1,000 S&E doctorate holders in academia, by state: 1997, 2001, and 2003

State	Patents awarded to academic institutions			S&E doctorate holders in academia			Academic patents/ 1,000 academic S&E doctorate holders		
	1997	2001	2003	1997	2001	2003	1997	2001	2003
United States	2,439	3,203	3,252	231,690	244,390	250,020	10.5	13.1	13.0
Alabama	23	40	48	4,460	2,940	3,160	5.2	13.6	15.2
Alaska	2	0	0	450	530	600	4.4	0.0	0.0
Arizona	21	17	21	2,850	3,100	2,910	7.4	5.5	7.2
Arkansas	8	28	26	1,450	1,570	1,740	5.5	17.8	14.9
California	409	638	703	24,000	24,220	25,790	17.0	26.3	27.3
Colorado	30	14	27	4,250	4,780	5,030	7.1	2.9	5.4
Connecticut	34	37	41	3,750	4,090	4,310	9.1	9.0	9.5
Delaware	4	5	7	690	760	660	5.8	6.6	10.6
District of Columbia	28	13	16	1,830	2,440	1,380	15.3	5.3	11.6
Florida	94	103	126	6,440	7,510	7,560	14.6	13.7	16.7
Georgia	45	75	82	5,450	6,230	6,500	8.3	12.0	12.6
Hawaii	6	4	6	1,200	1,490	1,640	5.0	2.7	3.7
Idaho	0	0	3	780	910	1,170	0.0	0.0	2.6
Illinois	78	109	104	10,120	10,350	9,880	7.7	10.5	10.5
Indiana	38	17	24	4,500	5,570	5,560	8.4	3.1	4.3
Iowa	51	67	61	3,060	3,090	3,170	16.7	21.7	19.2
Kansas	7	18	17	2,240	2,180	2,290	3.1	8.3	7.4
Kentucky	16	20	27	2,890	3,080	3,240	5.5	6.5	8.3
Louisiana	26	42	31	3,390	3,220	3,180	7.7	13.0	9.7
Maine	0	2	2	1,290	1,150	1,120	0.0	1.7	1.8
Maryland	66	114	115	5,840	5,660	6,650	11.3	20.1	17.3
Massachusetts	188	218	227	11,190	12,630	13,700	16.8	17.3	16.6
Michigan	104	105	121	7,600	8,520	8,210	13.7	12.3	14.7
Minnesota	50	65	68	4,260	5,110	5,190	11.7	12.7	13.1
Mississippi	6	12	12	1,930	1,900	1,910	3.1	6.3	6.3
Missouri	40	55	44	5,600	5,430	5,340	7.1	10.1	8.2
Montana	4	4	4	940	730	980	4.3	5.5	4.1
Nebraska	27	21	19	2,250	1,910	1,790	12.0	11.0	10.6
Nevada	2	4	6	970	1,260	1,060	2.1	3.2	5.7
New Hampshire	3	10	9	1,090	1,160	1,190	2.8	8.6	7.6
New Jersey	52	81	73	4,750	5,210	6,290	10.9	15.5	11.6
New Mexico	18	17	14	2,120	2,690	2,650	8.5	6.3	5.3
New York	224	285	284	19,080	19,570	18,830	11.7	14.6	15.1
North Carolina	96	148	138	7,480	8,440	8,770	12.8	17.5	15.7
North Dakota	5	4	4	880	660	760	5.7	6.1	5.3
Ohio	75	93	73	9,390	9,480	9,600	8.0	9.8	7.6
Oklahoma	17	22	15	2,630	2,620	2,500	6.5	8.4	6.0
Oregon	27	23	16	2,570	3,070	3,140	10.5	7.5	5.1
Pennsylvania	138	213	174	11,620	13,130	14,380	11.9	16.2	12.1
Rhode Island	9	19	13	1,670	1,640	1,770	5.4	11.6	7.3
South Carolina	14	14	28	3,040	2,920	2,540	4.6	4.8	11.0
South Dakota	2	2	0	660	600	620	3.0	3.3	0.0
Tennessee	25	42	31	4,530	4,560	4,820	5.5	9.2	6.4
Texas	125	155	157	13,180	13,310	13,680	9.5	11.6	11.5
Utah	37	48	26	2,940	3,000	2,760	12.6	16.0	9.4
Vermont	3	3	5	1,080	960	950	2.8	3.1	5.3
Virginia	49	41	58	5,290	6,320	7,020	9.3	6.5	8.3
Washington	42	56	44	5,110	6,120	6,000	8.2	9.2	7.3
West Virginia	2	4	12	1,120	1,080	1,160	1.8	3.7	10.3
Wisconsin	65	74	87	5,230	4,920	4,400	12.4	15.0	19.8
Wyoming	4	2	3	560	570	470	7.1	3.5	6.4
Puerto Rico	0	5	7	630	1,030	1,250	0.0	4.9	5.6

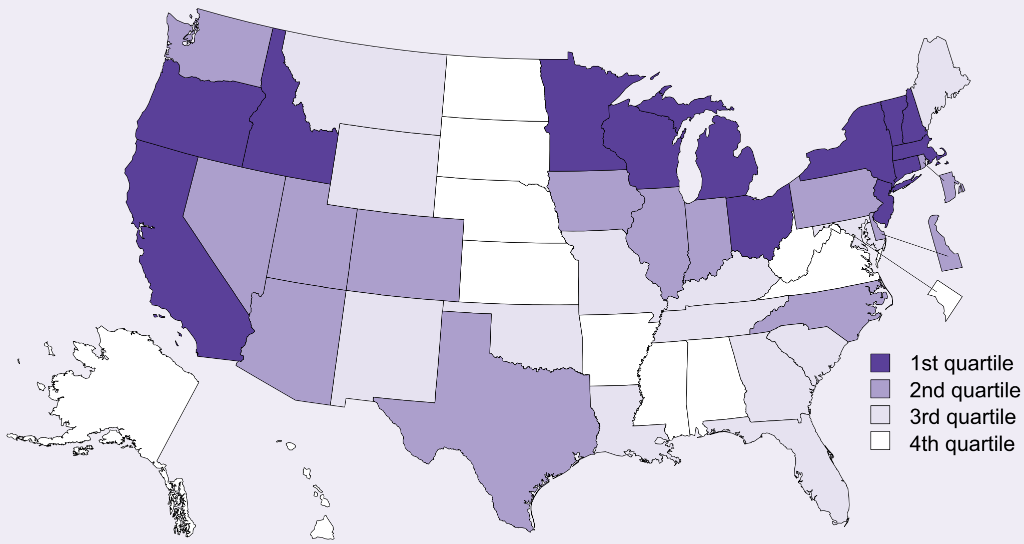
NOTES: Survey of Doctorate Recipients sample design does not include geography. Data on U.S. S&E doctorate holders are classified by employment location. Thus, reliability of data for areas with smaller populations is lower than for more populous states. Reliability of estimates by state for S&E doctorate holders may be poor for some states because of small sample size.

SOURCES: U.S. Patent and Trademark Office, Technology Assessment and Forecast Branch, *U.S. Colleges and Universities—Utility Patent Grants, Calendar Years 1969–2003;* and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science and Engineering Indicators 2006

Patents Awarded per 1,000 Individuals in S&E Occupations

Figure 8-35
Patents awarded per 1,000 individuals in S&E occupations: 2003



1st quartile (83.5–22.0)	2nd quartile (21.4–15.9)	3rd quartile (15.3–10.5)	4th quartile (9.7–0.9)
California	Arizona	Florida	Alabama
Connecticut	Colorado	Georgia	Alaska
Idaho	Delaware	Kentucky	Arkansas
Massachusetts	Illinois	Louisiana	District of Columbia
Michigan	Indiana	Maine	Hawaii
Minnesota	Iowa	Maryland	Kansas
New Hampshire	Nevada	Missouri	Mississippi
New Jersey	North Carolina	Montana	Nebraska
New York	Pennsylvania	New Mexico	North Dakota
Ohio	Rhode Island	Oklahoma	South Dakota
Oregon	Texas	South Carolina	Virginia
Vermont	Utah	Tennessee	West Virginia
Wisconsin	Washington	Wyoming	

SOURCES: U.S. Patent and Trademark Office, Office of Electronic Information Products, *Patent Counts by Country/State and Year, All Patents, All Types, January 1, 1977–December 31, 2003*; and U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates. See table 8-35.

Findings

- Nearly 100,000 patents were awarded in the United States in 2003 with more than 22% going to residents of California.
- In 2003, the national average for this indicator was 19.9 patents per 1,000 individuals in an S&E occupation.
- The District of Columbia and Idaho were outliers, at 0.9 and 83.5, respectively; the latter reflects the presence of a high-patenting Department of Energy National Laboratory in this sparsely populated state.
- Values for the remaining states varied widely, ranging from 4.1 to 40.7 patents per 1,000 individuals in S&E occupations in 2003.

This indicator shows state patent activity normalized to the size of its science and engineering workforce, specifically employees in S&E occupations. People in S&E occupations include mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any of these fields. Managers, elementary and secondary schoolteachers, and medical personnel are excluded.

The U.S. Patent and Trademark Office classifies patents based on the residence of the first-named inventor. Only U.S.-origin patents are included.

The location of S&E occupations primarily reflects where the individuals work and is based on estimates from the Occupational Employment Statistics survey, a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. Because of the different methods of assigning geographic location, this indicator is of limited applicability for sparsely populated states or for locations where a large percentage of the population lives in one state or region and works in another.

Table 8-35
Patents awarded per 1,000 individuals in S&E occupations, by state: 2003

State	Patents awarded	Individuals in S&E occupations	Patents/1,000 individuals in S&E occupations
United States	98,564	4,961,550	19.9
Alabama	459	56,380	8.1
Alaska	43	10,600	4.1
Arizona	1,714	92,120	18.6
Arkansas	176	21,340	8.2
California	22,079	676,180	32.7
Colorado	2,304	124,140	18.6
Connecticut	1,844	81,380	22.7
Delaware	372	17,370	21.4
District of Columbia	50	54,890	0.9
Florida	3,119	221,070	14.1
Georgia	1,537	144,170	10.7
Hawaii	96	16,090	6.0
Idaho	1,850	22,150	83.5
Illinois	3,964	211,230	18.8
Indiana	1,679	78,410	21.4
Iowa	711	37,320	19.1
Kansas	491	51,970	9.4
Kentucky	495	45,230	10.9
Louisiana	439	41,900	10.5
Maine	165	15,020	11.0
Maryland	1,579	149,250	10.6
Massachusetts	4,192	184,690	22.7
Michigan	4,220	182,940	23.1
Minnesota	3,262	117,120	27.9
Mississippi	184	22,190	8.3
Missouri	946	84,150	11.2
Montana	125	11,450	10.9
Nebraska	240	30,710	7.8
Nevada	455	22,330	20.4
New Hampshire	731	23,430	31.2
New Jersey	3,923	161,420	24.3
New Mexico	405	33,600	12.1
New York	6,921	272,440	25.4
North Carolina	2,174	132,440	16.4
North Dakota	62	8,430	7.4
Ohio	3,894	177,100	22.0
Oklahoma	563	44,360	12.7
Oregon	1,867	61,230	30.5
Pennsylvania	3,555	185,560	19.2
Rhode Island	325	18,740	17.3
South Carolina	650	48,740	13.3
South Dakota	89	9,150	9.7
Tennessee	975	63,680	15.3
Texas	6,378	365,270	17.5
Utah	724	45,570	15.9
Vermont	465	11,420	40.7
Virginia	1,250	209,280	6.0
Washington	2,516	150,230	16.7
West Virginia	141	16,220	8.7
Wisconsin	2,082	93,320	22.3
Wyoming	84	6,130	13.7
Puerto Rico	29	19,940	1.5

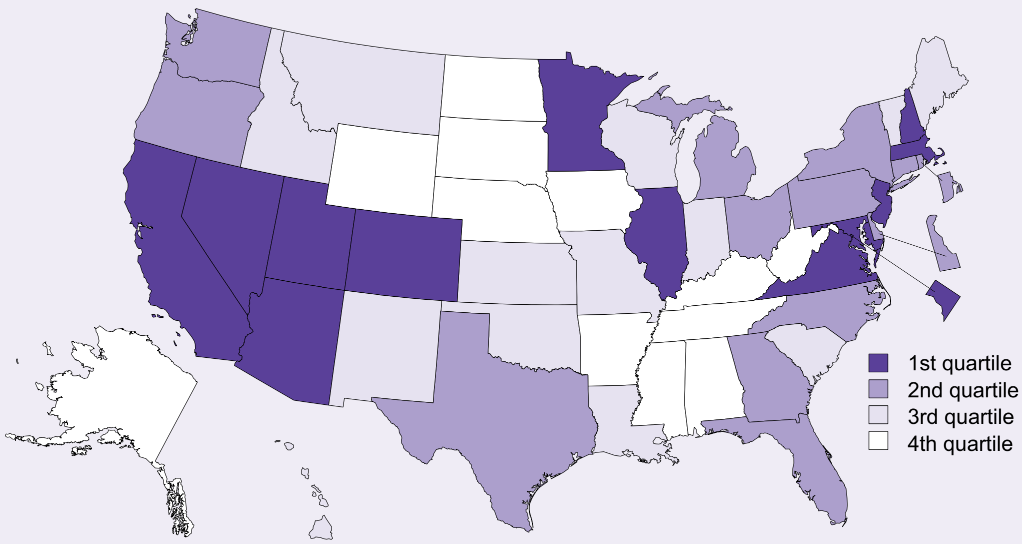
NOTES: Patents issued include utility patents and other types of U.S. documents (i.e., design patents, plant patents, reissues, defensive publications, and statutory invention registrations). Origin of patent determined by residence of first-named inventor.

SOURCES: U.S. Patent and Trademark Office, Office of Electronic Information Products, *Patent Counts by Country/State and Year, All Patents, All Types, January 1, 1977–December 31, 2003;* and U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wage Estimates.

Science and Engineering Indicators 2006

High-Technology Share of All Business Establishments

Figure 8-36
High-technology share of all business establishments: 2002



1st quartile (11.10%–6.99%)	2nd quartile (6.90%–5.60%)	3rd quartile (5.48%–4.48%)	4th quartile (4.40%–3.18%)
Arizona	Connecticut	Hawaii	Alabama
California	Delaware	Idaho	Alaska
Colorado	Florida	Indiana	Arkansas
District of Columbia	Georgia	Kansas	Iowa
Illinois	Michigan	Louisiana	Kentucky
Maryland	New York	Maine	Mississippi
Massachusetts	North Carolina	Missouri	Nebraska
Minnesota	Ohio	Montana	North Dakota
Nevada	Oregon	New Mexico	South Dakota
New Hampshire	Pennsylvania	Oklahoma	Tennessee
New Jersey	Rhode Island	South Carolina	West Virginia
Utah	Texas	Vermont	Wyoming
Virginia	Washington	Wisconsin	

SOURCES: U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations; and *County Business Patterns*. See table 8-36.

Findings

- The number of establishments in high-technology industries rose from 402,000 in 1998 to 454,000 in 2002, an increase of about 13% within 4 years.
- The percentage of U.S. establishments in high-technology industries grew from 5.8% to 6.3% of the total business establishments during the 1998–2002 period.
- Between 1998 and 2002, the largest growth in the number of establishments in high-technology industries occurred in California and Florida, which added 9,400 and 5,200 establishments, respectively.
- The state distribution of this indicator is similar to that of three other indicators: bachelor's degree holders, science and engineering doctoral degree holders, and S&E occupations, all expressed as a share of the workforce.

This indicator measures the portion of a state's business establishments that are classified as high-technology industries. High-technology industries are defined as those in which the proportion of employees both in research and development and in all technology occupations is at least twice the average proportion for all industries. State economies with a high percentage of their business establishments in high-technology industries are likely to be well positioned to take advantage of new technological developments.

The data pertaining to establishments for 1998 through 2002 were based on their classification according to the 1997 edition of the North American Industry Classification System.

Table 8-36
High-technology share of all business establishments, by state: 1998, 2000, and 2002

State	High-technology establishments			All business establishments			High-technology/ all business establishments		
	1998	2000	2002	1998	2000	2002	1998	2000	2002
United States	402,096	428,061	453,903	6,941,739	7,070,048	7,200,770	5.79	6.05	6.30
Alabama	4,068	4,208	4,383	100,314	99,817	99,931	4.06	4.22	4.39
Alaska	730	783	823	18,212	18,501	18,856	4.01	4.23	4.36
Arizona	6,877	7,493	8,368	110,245	114,804	119,740	6.24	6.53	6.99
Arkansas	2,003	2,170	2,329	62,348	63,185	63,869	3.21	3.43	3.65
California	54,998	60,799	64,348	773,922	799,863	820,997	7.11	7.60	7.84
Colorado	10,472	11,361	12,400	130,351	137,528	142,247	8.03	8.26	8.72
Connecticut	6,376	6,356	6,376	92,361	92,436	92,375	6.90	6.88	6.90
Delaware	1,327	1,426	1,537	22,871	23,771	24,377	5.80	6.00	6.31
District of Columbia	1,906	2,069	2,212	19,571	19,655	19,930	9.74	10.53	11.10
Florida	23,982	25,873	29,149	420,637	428,438	450,188	5.70	6.04	6.47
Georgia	12,234	13,110	14,188	194,210	200,442	206,323	6.30	6.54	6.88
Hawaii	1,162	1,256	1,463	29,603	29,853	30,633	3.93	4.21	4.78
Idaho	1,435	1,632	1,889	35,961	37,429	38,842	3.99	4.36	4.86
Illinois	20,643	21,479	21,962	304,525	308,067	309,980	6.78	6.97	7.08
Indiana	6,790	7,049	7,345	146,195	146,321	147,304	4.64	4.82	4.99
Iowa	2,604	2,677	2,904	80,838	80,890	81,042	3.22	3.31	3.58
Kansas	3,309	3,611	3,736	74,018	74,939	75,077	4.47	4.82	4.98
Kentucky	3,381	3,491	3,698	89,591	89,921	90,493	3.77	3.88	4.09
Louisiana	4,132	4,223	4,622	100,662	101,016	101,885	4.10	4.18	4.54
Maine	1,585	1,708	1,838	38,334	39,466	40,292	4.13	4.33	4.56
Maryland	9,337	10,030	11,008	126,577	128,467	131,815	7.38	7.81	8.35
Massachusetts	13,949	14,598	14,669	167,925	176,222	175,991	8.31	8.28	8.34
Michigan	12,839	13,255	13,721	235,401	236,912	237,616	5.45	5.59	5.77
Minnesota	9,384	10,014	10,232	134,980	139,080	143,953	6.95	7.20	7.11
Mississippi	1,832	1,866	1,925	59,771	59,788	59,902	3.07	3.12	3.21
Missouri	6,355	6,667	6,903	143,908	144,755	147,977	4.42	4.61	4.66
Montana	1,206	1,321	1,545	30,955	31,849	32,972	3.90	4.15	4.69
Nebraska	1,834	1,955	2,045	48,655	49,623	50,259	3.77	3.94	4.07
Nevada	2,814	3,233	3,741	44,613	48,178	51,383	6.31	6.71	7.28
New Hampshire	2,840	2,874	2,932	36,842	37,414	37,928	7.71	7.68	7.73
New Jersey	18,964	20,089	20,621	230,857	233,559	237,505	8.21	8.60	8.68
New Mexico	2,143	2,227	2,368	42,607	42,782	43,213	5.03	5.21	5.48
New York	25,289	27,507	28,552	481,956	492,073	498,921	5.25	5.59	5.72
North Carolina	10,078	10,887	11,633	198,689	203,903	207,562	5.07	5.34	5.60
North Dakota	570	606	671	20,288	20,139	20,422	2.81	3.01	3.29
Ohio	14,234	14,566	15,202	270,339	270,509	271,181	5.27	5.38	5.61
Oklahoma	3,752	3,810	4,101	84,880	85,094	86,029	4.42	4.48	4.77
Oregon	5,468	5,693	6,009	99,183	100,645	101,933	5.51	5.66	5.90
Pennsylvania	15,320	16,090	17,121	292,655	294,741	297,257	5.23	5.46	5.76
Rhode Island	1,444	1,516	1,628	28,244	28,534	28,860	5.11	5.31	5.64
South Carolina	3,942	4,119	4,406	94,985	97,146	98,357	4.15	4.24	4.48
South Dakota	684	723	779	23,521	23,783	24,439	2.91	3.04	3.19
Tennessee	5,421	5,561	5,739	131,108	130,876	130,556	4.13	4.25	4.40
Texas	27,094	28,410	30,421	462,866	471,509	482,169	5.85	6.03	6.31
Utah	3,399	3,750	4,243	52,025	55,379	58,788	6.53	6.77	7.22
Vermont	1,068	1,109	1,169	21,261	21,564	21,624	5.02	5.14	5.41
Virginia	12,767	14,015	15,122	172,182	175,582	180,501	7.41	7.98	8.38
Washington	9,627	10,175	10,642	161,472	164,018	165,933	5.96	6.20	6.41
West Virginia	1,208	1,224	1,288	41,703	41,047	40,488	2.90	2.98	3.18
Wisconsin	6,497	6,655	7,080	138,635	140,415	142,086	4.69	4.74	4.98
Wyoming	723	742	817	17,887	18,120	18,769	4.04	4.09	4.35
Puerto Rico	NA	NA	NA	42,577	44,015	45,642	NA	NA	NA

NA = not available

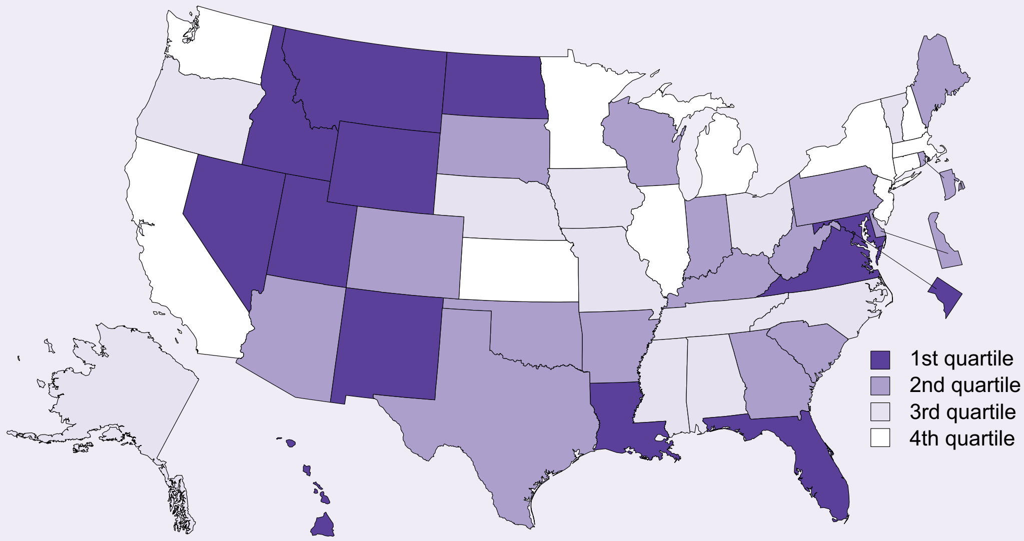
SOURCES: U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations; and *County Business Patterns,* various years.

Science and Engineering Indicators 2006

Net High-Technology Business Formations as Share of All Business Establishments

Figure 8-37

Net high-technology business formations as share of all business establishments: 2002



1st quartile (0.35%–0.10%)	2nd quartile (0.06%–0.01%)	3rd quartile (0.00% to –0.03%)	4th quartile (–0.04% to –0.28%)
District of Columbia	Arizona	Alabama	California
Florida	Arkansas	Alaska	Connecticut
Hawaii	Colorado	Iowa	Illinois
Idaho	Delaware	Mississippi	Kansas
Louisiana	Georgia	Missouri	Massachusetts
Maryland	Indiana	Nebraska	Michigan
Montana	Kentucky	North Carolina	Minnesota
Nevada	Maine	Ohio	New Hampshire
New Mexico	Oklahoma	Oregon	New Jersey
North Dakota	Pennsylvania	Tennessee	New York
Utah	Rhode Island	Vermont	Washington
Virginia	South Carolina		
Wyoming	South Dakota		
	Texas		
	West Virginia		
	Wisconsin		

SOURCES: U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations; and *County Business Patterns*. See table 8-37.

Findings

- In 2002, from a base of approximately 7 million total business establishments, 60,000 new business establishments were formed in high-technology industries and 61,000 ceased operation in those same industries, indicating a net loss of more than 1,000 businesses in high-technology industries in the United States.
- This represented a significant change from 2000, when nearly 10,000 net business formations in high-technology industries occurred in the United States.
- The number of states that reported net losses of business establishments in high-technology industries rose from 3 in 2000 to 21 in 2002, indicating a more challenging business environment.
- Nevada, California, Virginia, and Utah showed unusually high rates of net high-technology business formations in 2000, but because of significant fluctuations in this indicator, only Utah continued to show a high value in 2002.

The business base of a state is constantly changing as new businesses form and others cease to function. The term “net business formations” refers to the difference between the number of businesses that are formed and the number that cease operations during any particular year. This difference can be small and can vary significantly from year to year.

The ratio of the number of net business formations that occur in high-technology industries to the number of business establishments in a state indicates the changing role of high-technology industries in a state’s economy. High positive values indicate an increasingly prominent role for these industries.

The data on business establishments in high-technology industries for 1998 through 2002 were based on their classification according to the 1997 edition of the North American Industry Classification System. Company births and deaths are determined from their Employer Identification Numbers in the U.S. Census Bureau records; thus, changes in company name, ownership, or address are not counted as business formations or business deaths.

Table 8-37
Net high-technology business formations as share of all business establishments, by state: 1999, 2000, and 2002

State	Net high-technology business formations			All business establishments			High-technology formations/business establishments (%)		
	1999	2000	2002	1999	2000	2002	1999	2000	2002
United States	13,208	9,741	–1,166	7,008,444	7,070,048	7,200,770	0.19	0.14	–0.02
Alabama	81	92	–5	100,507	99,817	99,931	0.08	0.09	–0.01
Alaska	22	–6	–3	18,433	18,501	18,856	0.12	–0.03	–0.02
Arizona	246	210	57	112,545	114,804	119,740	0.22	0.18	0.05
Arkansas	67	46	31	62,737	63,185	63,869	0.11	0.07	0.05
California	1,947	2,452	–508	784,935	799,863	820,997	0.25	0.31	–0.06
Colorado	367	378	41	133,743	137,528	142,247	0.27	0.27	0.03
Connecticut	66	6	–170	92,454	92,436	92,375	0.07	0.01	–0.18
Delaware	74	55	5	23,381	23,771	24,377	0.32	0.23	0.02
District of Columbia	81	78	70	19,469	19,655	19,930	0.42	0.40	0.35
Florida	950	595	555	424,089	428,438	450,188	0.22	0.14	0.12
Georgia	524	246	15	197,759	200,442	206,323	0.26	0.12	0.01
Hawaii	42	32	44	29,569	29,853	30,633	0.14	0.11	0.14
Idaho	47	66	62	36,975	37,429	38,842	0.13	0.18	0.16
Illinois	830	248	–626	306,899	308,067	309,980	0.27	0.08	–0.20
Indiana	220	86	9	146,528	146,321	147,304	0.15	0.06	0.01
Iowa	55	35	–2	81,213	80,890	81,042	0.07	0.04	0.00
Kansas	102	116	–41	74,486	74,939	75,077	0.14	0.15	–0.05
Kentucky	128	28	56	89,946	89,921	90,493	0.14	0.03	0.06
Louisiana	–2	47	101	101,020	101,016	101,885	0.00	0.05	0.10
Maine	75	51	5	38,878	39,466	40,292	0.19	0.13	0.01
Maryland	414	270	140	127,431	128,467	131,815	0.32	0.21	0.11
Massachusetts	339	300	–367	173,267	176,222	175,991	0.20	0.17	–0.21
Michigan	148	196	–147	236,456	236,912	237,616	0.06	0.08	–0.06
Minnesota	393	218	–318	137,305	139,080	143,953	0.29	0.16	–0.22
Mississippi	0	56	–5	59,834	59,788	59,902	0.00	0.09	–0.01
Missouri	171	101	–32	144,874	144,755	147,977	0.12	0.07	–0.02
Montana	41	63	37	31,365	31,849	32,972	0.13	0.20	0.11
Nebraska	43	34	–17	48,968	49,623	50,259	0.09	0.07	–0.03
Nevada	216	153	83	46,890	48,178	51,383	0.46	0.32	0.16
New Hampshire	50	31	–33	37,180	37,414	37,928	0.13	0.08	–0.09
New Jersey	856	290	–661	231,823	233,559	237,505	0.37	0.12	–0.28
New Mexico	48	26	49	42,918	42,782	43,213	0.11	0.06	0.11
New York	913	841	–413	485,954	492,073	498,921	0.19	0.17	–0.08
North Carolina	453	238	6	201,706	203,903	207,562	0.22	0.12	0.00
North Dakota	10	20	35	20,380	20,139	20,422	0.05	0.10	0.17
Ohio	402	129	–42	270,766	270,509	271,181	0.15	0.05	–0.02
Oklahoma	50	–25	34	84,854	85,094	86,029	0.06	–0.03	0.04
Oregon	100	102	–12	99,945	100,645	101,933	0.10	0.10	–0.01
Pennsylvania	476	257	102	293,491	294,741	297,257	0.16	0.09	0.03
Rhode Island	39	46	17	28,240	28,534	28,860	0.14	0.16	0.06
South Carolina	151	70	29	96,440	97,146	98,357	0.16	0.07	0.03
South Dakota	11	33	3	23,693	23,783	24,439	0.05	0.14	0.01
Tennessee	31	69	–3	131,116	130,876	130,556	0.02	0.05	0.00
Texas	765	306	202	467,087	471,509	482,169	0.16	0.06	0.04
Utah	132	167	139	53,809	55,379	58,788	0.25	0.30	0.24
Vermont	35	22	–6	21,598	21,564	21,624	0.16	0.10	–0.03
Virginia	600	550	257	173,550	175,582	180,501	0.35	0.31	0.14
Washington	203	253	–66	162,932	164,018	165,933	0.12	0.15	–0.04
West Virginia	50	–4	24	41,451	41,047	40,488	0.12	–0.01	0.06
Wisconsin	144	54	68	139,646	140,415	142,086	0.10	0.04	0.05
Wyoming	2	14	35	17,909	18,120	18,769	0.01	0.08	0.19
Puerto Rico	NA	NA	NA	43,464	44,015	45,642	NA	NA	NA

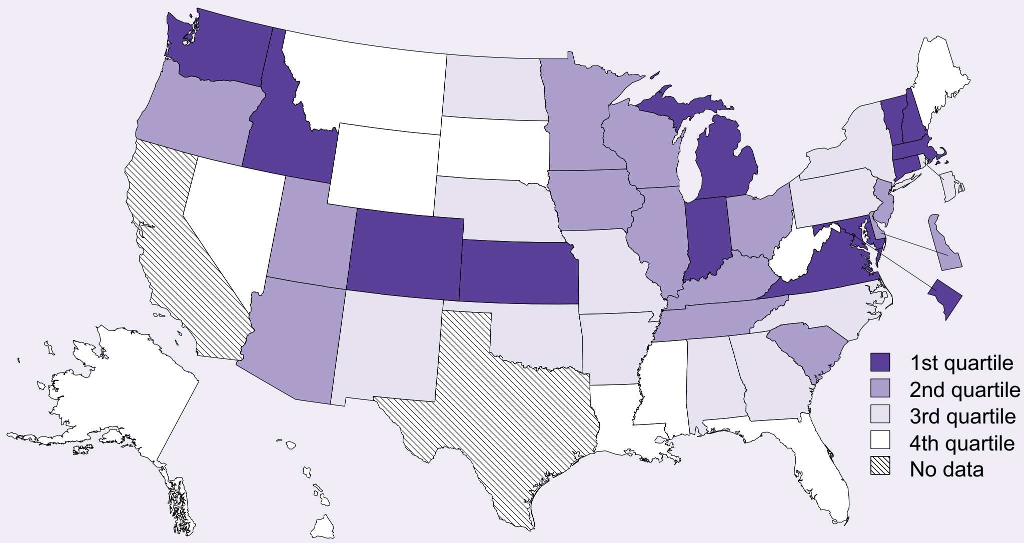
NA = not available

SOURCES: U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations; and *County Business Patterns,* various years.

Science and Engineering Indicators 2006

Employment in High-Technology Establishments as Share of Total Employment

Figure 8-38
Employment in high-technology establishments as share of total employment: 2002



1st quartile (11.73%–9.13%)	2nd quartile (8.90%–7.55%)	3rd quartile (7.47%–5.78%)	4th quartile (5.47%–2.56%)	No data
Colorado	Arizona	Alabama	Alaska	California
Connecticut	Delaware	Arkansas	Florida	Texas
District of Columbia	Illinois	Georgia	Hawaii	
Idaho	Iowa	Missouri	Louisiana	
Indiana	Kentucky	Nebraska	Maine	
Kansas	Minnesota	New Mexico	Mississippi	
Maryland	New Jersey	New York	Montana	
Massachusetts	Ohio	North Carolina	Nevada	
Michigan	Oregon	North Dakota	South Dakota	
New Hampshire	South Carolina	Oklahoma	West Virginia	
Vermont	Tennessee	Pennsylvania	Wyoming	
Virginia	Utah	Rhode Island		
Washington	Wisconsin			

SOURCES: U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations; and *County Business Patterns*. See table 8-38.

Findings

- Employment in high-technology establishments grew from 9.6 to 10.1 million workers between 1998 and 2000 but declined to 9.3 million workers by 2002.
- Nearly 7% of the jobs in high-technology industries in the United States disappeared between 2000 and 2002.
- On the high-technology employment indicator, states varied greatly in 2002, ranging from 2.6% to 11.7% of their workforce.
- Not surprisingly, states were distributed similarly on the high-technology employment and high-technology establishment indicators.

This indicator measures the extent to which the workforce in a state is employed in high-technology industries. High-technology industries are defined as those in which the proportion of employees both in research and development and in all technology occupations is at least twice the average proportion for all industries. State economies with a high value are probably well positioned to take advantage of new technological developments because they have a relatively larger pool of experienced high-technology workers.

The data pertaining to establishments for the years 1998 through 2002 were based on their classification according to the 1997 edition of the North American Industry Classification System.

Table 8-38
Employment in high-technology establishments as share of total employment, by state: 1998, 2000, and 2002

State	Employment in high-technology establishments			All employment			High-technology/ all employment (%)		
	1998	2000	2002	1998	2000	2002	1998	2000	2002
United States	9,649,938	10,086,689	9,381,708	108,116,064	114,064,976	112,400,654	8.93	8.84	8.35
Alabama	113,340	119,207	114,035	1,604,084	1,653,074	1,581,117	7.07	7.21	7.21
Alaska	6,518	7,772	9,987	196,135	204,887	213,600	3.32	3.79	4.68
Arizona	157,010	166,678	154,931	1,763,508	1,919,353	1,945,472	8.90	8.68	7.96
Arkansas	62,620	64,564	61,486	944,906	990,830	974,969	6.63	6.52	6.31
California	1,312,754	1,397,776	NA	12,026,963	12,884,692	12,856,426	10.92	10.85	NA
Colorado	166,494	190,282	179,894	1,757,604	1,913,302	1,912,152	9.47	9.95	9.41
Connecticut	160,575	166,788	158,919	1,493,929	1,546,250	1,555,595	10.75	10.79	10.22
Delaware	29,932	29,208	29,374	354,643	377,277	389,304	8.44	7.74	7.55
District of Columbia	32,038	36,111	38,375	402,070	414,983	418,755	7.97	8.70	9.16
Florida	316,257	339,093	348,552	5,756,348	6,217,386	6,366,964	5.49	5.45	5.47
Georgia	228,511	256,208	239,611	3,198,912	3,483,500	3,381,244	7.14	7.35	7.09
Hawaii	8,258	10,292	11,267	416,571	432,092	439,934	1.98	2.38	2.56
Idaho	41,044	43,356	41,418	423,615	450,788	453,552	9.69	9.62	9.13
Illinois	476,305	491,433	430,581	5,221,571	5,501,036	5,224,293	9.12	8.93	8.24
Indiana	291,151	302,599	258,783	2,540,730	2,650,774	2,517,180	11.46	11.42	10.28
Iowa	100,990	101,015	94,006	1,213,285	1,265,064	1,229,609	8.32	7.98	7.65
Kansas	117,366	116,476	108,809	1,081,925	1,128,732	1,098,894	10.85	10.32	9.90
Kentucky	116,730	126,237	115,466	1,442,873	1,513,722	1,462,517	8.09	8.34	7.90
Louisiana	94,915	89,305	84,639	1,577,069	1,592,357	1,583,308	6.02	5.61	5.35
Maine	22,534	26,310	25,145	456,715	491,780	486,766	4.93	5.35	5.17
Maryland	192,782	203,618	204,505	1,938,727	2,058,304	2,062,515	9.94	9.89	9.92
Massachusetts	357,070	388,928	349,205	2,924,872	3,087,044	3,023,126	12.21	12.60	11.55
Michigan	507,762	514,017	452,606	3,919,556	4,072,786	3,889,825	12.95	12.62	11.64
Minnesota	201,359	210,453	192,165	2,271,668	2,395,361	2,359,593	8.86	8.79	8.14
Mississippi	60,182	56,283	46,135	937,023	956,781	904,252	6.42	5.88	5.10
Missouri	201,038	178,522	175,851	2,310,043	2,398,979	2,354,230	8.70	7.44	7.47
Montana	10,312	12,256	13,395	277,144	296,220	300,636	3.72	4.14	4.46
Nebraska	57,718	59,228	53,739	720,252	751,076	749,098	8.01	7.89	7.17
Nevada	26,300	31,814	33,411	800,861	902,775	936,225	3.28	3.52	3.57
New Hampshire	58,282	53,475	58,635	518,526	546,400	550,725	11.24	9.79	10.65
New Jersey	299,146	322,935	304,723	3,368,359	3,548,429	3,596,919	8.88	9.10	8.47
New Mexico	43,681	43,137	34,228	540,182	549,352	554,156	8.09	7.85	6.18
New York	486,679	513,472	491,094	6,993,790	7,353,209	7,234,915	6.96	6.98	6.79
North Carolina	260,203	268,284	246,059	3,223,167	3,385,492	3,322,004	8.07	7.92	7.41
North Dakota	15,542	15,916	14,678	249,476	255,178	253,980	6.23	6.24	5.78
Ohio	479,462	484,110	406,756	4,806,025	5,001,980	4,743,151	9.98	9.68	8.58
Oklahoma	86,402	85,533	82,096	1,167,707	1,201,606	1,200,477	7.40	7.12	6.84
Oregon	108,322	108,254	103,806	1,310,750	1,355,442	1,329,235	8.26	7.99	7.81
Pennsylvania	375,364	394,786	353,631	4,906,117	5,087,237	5,046,442	7.65	7.76	7.01
Rhode Island	23,134	24,809	24,125	402,476	415,168	415,970	5.75	5.98	5.80
South Carolina	140,065	137,014	127,447	1,526,106	1,601,532	1,538,750	9.18	8.56	8.28
South Dakota	24,438	23,346	16,308	289,422	306,704	303,646	8.44	7.61	5.37
Tennessee	189,396	195,796	180,788	2,299,343	2,390,322	2,291,504	8.24	8.19	7.89
Texas	685,349	703,206	NA	7,570,292	8,026,438	7,993,559	9.05	8.76	NA
Utah	84,581	89,486	80,153	866,146	917,089	900,428	9.77	9.76	8.90
Vermont	20,766	22,761	25,317	239,034	253,541	258,058	8.69	8.98	9.81
Virginia	308,922	348,426	341,935	2,700,589	2,903,548	2,914,804	11.44	12.00	11.73
Washington	241,200	258,234	242,943	2,134,597	2,267,485	2,185,658	11.30	11.39	11.12
West Virginia	31,065	30,903	30,351	547,234	558,171	561,478	5.68	5.54	5.41
Wisconsin	211,695	220,093	188,024	2,319,343	2,414,834	2,355,816	9.13	9.11	7.98
Wyoming	6,379	6,884	8,082	163,781	174,614	177,828	3.89	3.94	4.54
Puerto Rico	NA	NA	NA	687,707	727,449	691,110	NA	NA	NA

NA = not available

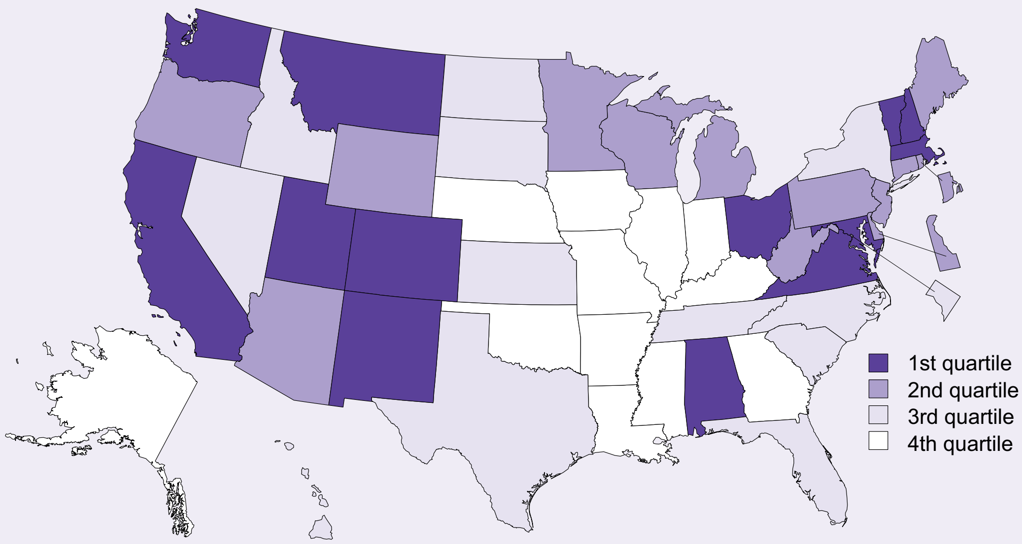
NOTE: U.S. total represents the reported value because 2002 data for California and Texas were suppressed.

SOURCES: U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations; and *County Business Patterns,* various years.

Science and Engineering Indicators 2006

Average SBIR Program Award Dollars per $1 Million of Gross State Product

Figure 8-39
Average SBIR program award dollars per $1 million of gross state product: 2001–03



1st quartile ($721–$161)	2nd quartile ($158–$84)	3rd quartile ($83–$47)	4th quartile ($46–$21)
Alabama	Arizona	District of Columbia	Alaska
California	Connecticut	Florida	Arkansas
Colorado	Delaware	Hawaii	Georgia
Maryland	Maine	Idaho	Illinois
Massachusetts	Michigan	Kansas	Indiana
Montana	Minnesota	Nevada	Iowa
New Hampshire	New Jersey	New York	Kentucky
New Mexico	Oregon	North Carolina	Louisiana
Ohio	Pennsylvania	North Dakota	Mississippi
Utah	Rhode Island	South Carolina	Missouri
Vermont	West Virginia	South Dakota	Nebraska
Virginia	Wisconsin	Tennessee	Oklahoma
Washington	Wyoming	Texas	

SOURCES: U.S. Small Business Administration, Office of Technology, SBIR Program Statistics, various years; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data. See table 8-39.

Findings

- Significant growth has occurred in the SBIR program in recent years as total awards have increased from $590 million in 1992–94 to $1.5 billion in 2001–03. The value of SBIR awards is not evenly distributed but is concentrated in relatively few states; the total of annual state awards may range from under $1 million to more than $300 million.
- Many of the states with the highest rankings on this indicator are locations of federal laboratories or well-recognized academic research institutions from which innovative small businesses have emerged.
- States with a high ranking on this indicator also tend to rank high on the high-technology and venture capital indicators.

Funds awarded through the federal Small Business Innovation Research (SBIR) program support technological innovation in small companies (i.e., companies with 500 or fewer employees). Awards are made to evaluate the feasibility and scientific merit of new technology (up to $100,000) and to develop the technology to a point where it can be commercialized (up to $750,000).

Because of year-to-year fluctuations, this indicator is calculated using 3-year averages. The average annual SBIR award dollars won by the small businesses in a state are divided by the average annual gross state product. A high value indicates that companies in a state are doing cutting-edge development work that attracts federal support.

Table 8-39
Average SBIR program award dollars per $1 million of gross state product, by state: 1992–94, 1997–99, and 2001–03

State	Average SBIR awards ($ thousands)			Average GSP ($ millions)			SBIR awards/$1 million GSP		
	1992–94	1997–99	2001–03	1992–94	1997–99	2001–03	1992–94	1997–99	2001–03
United States	589,878	1,070,869	1,472,509	6,497,777	8,706,261	10,464,751	91	123	141
Alabama	9,461	20,269	25,734	84,161	106,791	124,273	112	190	207
Alaska	164	159	715	22,889	24,292	29,601	7	7	24
Arizona	7,963	20,063	26,840	86,715	137,458	173,529	92	146	155
Arkansas	522	808	1,881	47,030	61,906	71,445	11	13	26
California	135,384	227,108	314,505	838,509	1,096,445	1,369,864	161	207	230
Colorado	23,019	52,442	70,313	92,695	144,304	182,390	248	363	386
Connecticut	20,966	25,019	23,399	107,220	144,576	168,918	196	173	139
Delaware	1,843	3,206	4,184	23,916	37,391	47,509	77	86	88
District of Columbia	1,400	3,907	5,456	45,437	52,747	67,022	31	74	81
Florida	11,887	22,221	31,500	302,645	416,717	524,303	39	53	60
Georgia	3,769	12,022	14,228	170,493	256,758	309,383	22	47	46
Hawaii	2,464	2,811	3,678	35,796	37,954	44,066	69	74	83
Idaho	377	872	3,074	22,615	30,408	38,402	17	29	80
Illinois	8,664	14,069	20,882	321,523	423,807	487,588	27	33	43
Indiana	1,961	5,843	8,218	131,763	177,586	204,136	15	33	40
Iowa	544	1,307	4,235	64,391	84,074	97,700	8	16	43
Kansas	1,008	3,223	4,242	58,607	75,825	90,115	17	43	47
Kentucky	740	2,847	2,806	81,072	110,029	122,164	9	26	23
Louisiana	1,251	1,165	2,861	94,699	119,123	138,749	13	10	21
Maine	1,822	1,627	3,453	25,152	32,105	38,983	72	51	89
Maryland	29,383	51,092	74,933	125,417	162,308	202,779	234	315	370
Massachusetts	97,176	162,934	208,446	175,051	237,599	289,242	555	686	721
Michigan	10,671	23,952	29,292	224,901	311,523	347,416	47	77	84
Minnesota	7,068	14,162	23,017	117,199	165,231	200,007	60	86	115
Mississippi	394	701	2,072	47,012	60,412	68,716	8	12	30
Missouri	1,817	4,693	4,725	120,668	163,437	187,655	15	29	25
Montana	1,153	2,241	7,073	16,039	19,802	24,044	72	113	294
Nebraska	1,140	1,177	1,831	39,962	52,103	61,247	29	23	30
Nevada	1,430	2,167	5,822	40,465	64,450	83,397	35	34	70
New Hampshire	7,612	13,209	17,764	27,874	38,613	46,234	273	342	384
New Jersey	19,682	31,599	39,682	243,698	313,545	378,067	81	101	105
New Mexico	12,884	19,682	20,599	36,756	47,545	53,800	351	414	383
New York	29,135	42,363	59,884	550,414	688,790	812,682	53	62	74
North Carolina	6,769	14,195	19,679	168,673	243,113	301,330	40	58	65
North Dakota	349	505	1,595	13,244	16,973	20,135	26	30	79
Ohio	,538	41,007	62,315	262,320	346,929	386,449	63	118	161
Oklahoma	1,185	3,053	4,257	64,697	80,591	96,373	18	38	44
Oregon	8,035	15,433	16,608	69,102	100,783	115,479	116	153	144
Pennsylvania	18,355	40,177	56,851	285,616	361,014	425,470	64	111	134
Rhode Island	1,893	2,112	5,897	23,526	29,701	37,297	80	71	158
South Carolina	78	1,418	6,670	76,048	103,321	122,672	1	14	54
South Dakota	33	1,089	1,661	15,976	20,764	25,756	2	52	64
Tennessee	6,248	8,071	9,793	119,705	161,180	191,566	52	50	51
Texas	18,242	38,567	54,863	449,808	631,798	782,936	41	61	70
Utah	8,344	9,628	14,192	38,762	60,342	73,603	215	160	193
Vermont	1,155	2,764	3,940	13,126	15,921	19,540	88	174	202
Virginia	30,506	64,357	85,948	168,708	226,707	290,057	181	284	296
Washington	13,118	26,209	37,722	138,903	195,837	234,923	94	134	161
West Virginia	17	1,153	4,292	32,745	39,931	45,166	1	29	95
Wisconsin	4,251	8,951	16,544	120,260	160,387	189,992	35	56	87
Wyoming	11	1,220	2,339	13,774	15,315	20,581	1	80	114
Puerto Rico	0	73	82	37,081	53,372	71,626	0	1	1

GSP = gross state product; SBIR = Small Business Innovation Research

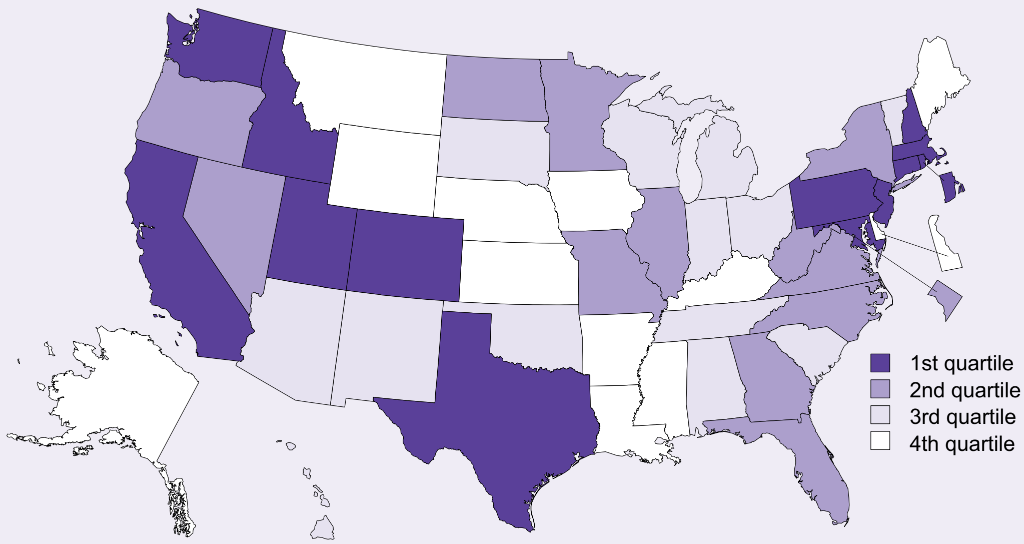
NOTE: GSP is reported in current dollars.

SOURCES: U.S. Small Business Administration, Office of Technology, SBIR program statistics, various years; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2006

Venture Capital Disbursed per $1,000 of Gross State Product

Figure 8-40
Venture capital disbursed per $1,000 of gross state product: 2003



1st quartile ($8.70–$1.25)	2nd quartile ($1.24–$0.42)	3rd quartile ($0.38–$0.11)	4th quartile ($0.06–$0.00)
California	District of Columbia	Alabama	Alaska
Colorado	Florida	Arizona	Arkansas
Connecticut	Georgia	Hawaii	Delaware
Idaho	Illinois	Indiana	Iowa
Maryland	Minnesota	Michigan	Kansas
Massachusetts	Missouri	New Mexico	Kentucky
New Hampshire	Nevada	Ohio	Louisiana
New Jersey	New York	Oklahoma	Maine
Pennsylvania	North Carolina	South Carolina	Mississippi
Rhode Island	North Dakota	South Dakota	Montana
Texas	Oregon	Tennessee	Nebraska
Utah	Virginia	Vermont	Wyoming
Washington	West Virginia	Wisconsin	

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™ special tabulations; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data. See table 8-40.

Findings

- The amount of venture capital invested in the United States increased more than 10-fold, from nearly $8 billion in 1995 to a record $106 billion in 2000, before falling to $19 billion in 2003 (in current dollars).
- In 2003, the state average for venture capital disbursed per $1,000 GSP was $1.73, which was larger than the $1.13 invested in 1995 but only about one-sixth the fraction of GSP invested in 2000.
- Companies in California received 43% of the total venture capital disbursed in the United States in 2003, followed by companies in Massachusetts with 14%.
- The state distribution of venture capital was similar to that for the high-technology indicators.

Venture capital represents an important source of funding for start-up companies. This indicator shows the relative magnitude of venture capital investments in a state after adjusting for the size of the state's economy. The indicator is expressed as dollars of venture capital disbursed per $1,000 of gross state product (GSP).

Venture capital investments represent a method of funding the growth and expansion of companies early in their development before establishing a predictable sales history that would qualify them for other types of financing. Access to this type of financing varies greatly in different states.

Table 8-40
Venture capital disbursed per $1,000 of gross state product, by state: 1995, 2000, and 2003

	Venture capital disbursed ($ thousands)			GSP ($ millions)			Venture capital/ $1,000 GSP		
State	1995	2000	2003	1995	2000	2003	1995	2000	2003
United States	8,147,907	105,689,617	18,946,148	7,232,723	9,749,103	10,923,851	1.13	10.84	1.73
Alabama	36,622	279,600	24,825	94,021	114,204	130,792	0.39	2.45	0.19
Alaska	0	3,500	0	24,805	27,590	31,704	0.00	0.13	0.00
Arizona	96,016	678,972	67,199	104,036	157,639	183,272	0.92	4.31	0.37
Arkansas	5,012	10,300	1,150	53,303	66,176	74,540	0.09	0.16	0.02
California	3,255,681	43,527,816	8,246,602	908,963	1,291,113	1,438,134	3.58	33.71	5.73
Colorado	314,397	4,333,008	628,225	108,043	171,363	188,397	2.91	25.29	3.33
Connecticut	129,202	1,461,764	259,068	120,800	160,685	174,085	1.07	9.10	1.49
Delaware	4,432	134,650	400	27,507	42,359	50,486	0.16	3.18	0.01
District of Columbia	50	444,003	57,050	47,123	58,425	70,668	0.00	7.60	0.81
Florida	234,919	2,592,944	292,281	340,501	470,120	553,709	0.69	5.52	0.53
Georgia	161,494	2,138,960	311,266	199,138	291,014	321,199	0.81	7.35	0.97
Hawaii	0	196,000	16,585	36,572	40,176	46,671	0.00	4.88	0.36
Idaho	15,200	19,485	52,160	27,099	35,206	40,358	0.56	0.55	1.29
Illinois	197,790	2,406,127	380,274	359,723	464,257	499,731	0.55	5.18	0.76
Indiana	9,103	253,975	24,500	147,984	194,683	213,342	0.06	1.30	0.11
Iowa	14,188	20,751	4,200	71,905	90,815	102,400	0.20	0.23	0.04
Kansas	6,600	262,671	2,935	63,699	83,427	93,263	0.10	3.15	0.03
Kentucky	16,979	198,483	7,100	90,459	112,737	128,315	0.19	1.76	0.06
Louisiana	30,450	87,883	1,250	109,153	134,755	144,321	0.28	0.65	0.01
Maine	1,500	140,200	925	27,648	35,662	40,829	0.05	3.93	0.02
Maryland	118,439	1,886,185	353,896	137,391	179,978	213,073	0.86	10.48	1.66
Massachusetts	691,829	10,393,199	2,584,981	195,277	276,786	297,113	3.54	37.55	8.70
Michigan	70,697	331,959	91,941	251,017	337,185	359,440	0.28	0.98	0.26
Minnesota	161,730	1,079,037	222,454	131,357	185,431	210,184	1.23	5.82	1.06
Mississippi	2,749	19,500	850	53,816	64,133	71,872	0.05	0.30	0.01
Missouri	83,202	656,693	103,703	137,528	176,443	193,828	0.60	3.72	0.54
Montana	0	16,680	250	17,393	21,367	25,584	0.00	0.78	0.01
Nebraska	16,102	17,500	610	44,505	55,727	65,399	0.36	0.31	0.01
Nevada	575	27,371	38,200	48,974	74,797	89,711	0.01	0.37	0.43
New Hampshire	30,510	724,986	161,055	32,149	43,584	48,202	0.95	16.63	3.34
New Jersey	257,346	3,225,923	896,890	266,724	343,959	394,040	0.96	9.38	2.28
New Mexico	3,550	21,108	6,630	41,459	50,419	57,078	0.09	0.42	0.12
New York	276,813	7,256,427	680,713	594,444	769,403	838,035	0.47	9.43	0.81
North Carolina	300,994	1,887,982	373,968	191,579	274,306	315,456	1.57	6.88	1.19
North Dakota	9,835	6,054	14,500	14,515	18,076	21,597	0.68	0.33	0.67
Ohio	68,670	961,401	88,148	293,260	371,228	398,918	0.23	2.59	0.22
Oklahoma	6,100	52,529	31,136	69,580	89,851	101,168	0.09	0.58	0.31
Oregon	40,211	814,607	100,031	80,099	112,964	119,973	0.50	7.21	0.83
Pennsylvania	142,698	3,089,954	556,223	314,504	391,501	443,709	0.45	7.89	1.25
Rhode Island	6,020	91,042	51,660	25,666	33,835	39,363	0.23	2.69	1.31
South Carolina	53,385	415,211	19,342	86,053	112,831	127,963	0.62	3.68	0.15
South Dakota	0	300	3,500	17,807	23,230	27,337	0.00	0.01	0.13
Tennessee	175,176	387,451	77,252	135,655	174,349	203,071	1.29	2.22	0.38
Texas	459,604	6,207,846	1,164,607	507,441	722,832	821,943	0.91	8.59	1.42
Utah	11,200	659,601	106,525	46,303	67,889	76,674	0.24	9.72	1.39
Vermont	12,008	46,394	5,193	13,892	17,661	20,544	0.86	2.63	0.25
Virginia	280,430	3,290,193	376,418	185,490	260,257	304,116	1.51	12.64	1.24
Washington	329,507	2,727,478	400,032	151,338	221,314	245,143	2.18	12.32	1.63
West Virginia	0	5,000	19,800	36,362	41,690	46,726	0.00	0.12	0.42
Wisconsin	8,891	198,916	37,647	134,096	176,244	198,096	0.07	1.13	0.19
Wyoming	0	0	0	14,567	17,427	22,279	0.00	0.00	0.00
Puerto Rico	7,760	31,115	100	42,647	61,702	74,362	0.18	0.50	0.00

GSP = gross state product

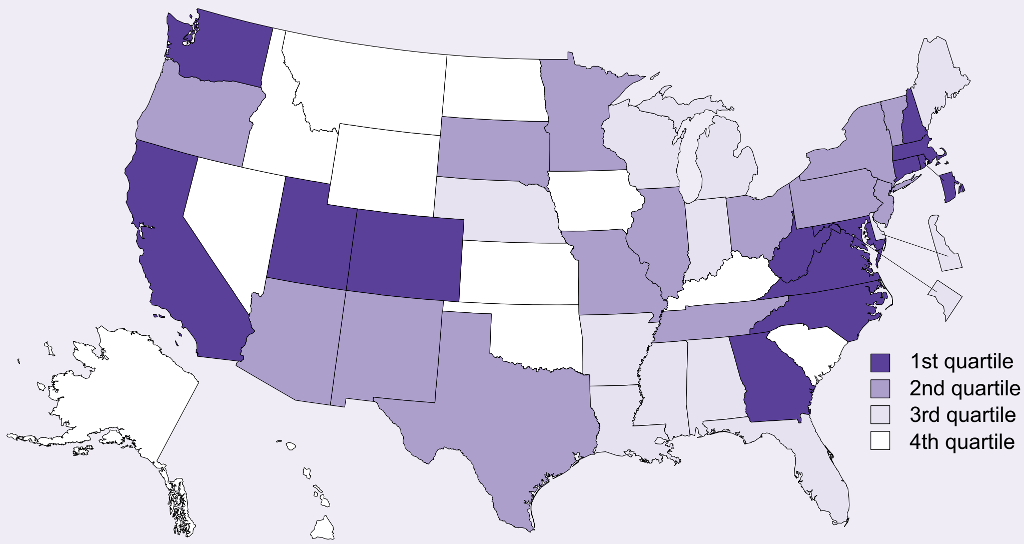
NOTE: GSP is reported in current dollars.

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™, special tabulations; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2006

Venture Capital Deals as Share of High-Technology Business Establishments

Figure 8-41
Venture capital deals as share of high-technology business establishments: 2002



1st quartile (2.43%–0.57%)	2nd quartile (0.55%–0.30%)	3rd quartile (0.27%–0.14%)	4th quartile (0.13%–0.00%)
California	Arizona	Alabama	Alaska
Colorado	Illinois	Arkansas	Hawaii
Connecticut	Minnesota	Delaware	Idaho
Georgia	Missouri	District of Columbia	Iowa
Maryland	New Jersey	Florida	Kansas
Massachusetts	New Mexico	Indiana	Kentucky
New Hampshire	New York	Louisiana	Montana
North Carolina	Ohio	Maine	Nevada
Rhode Island	Oregon	Michigan	North Dakota
Utah	Pennsylvania	Mississippi	Oklahoma
Virginia	South Dakota	Nebraska	South Carolina
Washington	Tennessee	Wisconsin	Wyoming
West Virginia	Texas		
	Vermont		

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™, special tabulations; and U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations. See table 8-41.

Findings

- The number of venture capital deals that involved U.S. companies fell from 8,000 to 3,000 between 2000 and 2002, a decline of more than 50%.
- In 2002, the distribution of venture capital among high-technology companies was uneven. Companies in only 10 states exceeded the national average of 0.67%.
- The high-technology companies located in Massachusetts were the most successful in accessing venture capital investments in 2002 with a 2.4% success rate. This was less than half the rate of Massachusetts companies that received such funding in 2000.
- In 2002, no venture capital deals were reported in four states.

This indicator provides a measure of the extent to which high-technology companies in a state receive venture capital investments. The value of the indicator is calculated by dividing the number of venture capital deals by the number of companies operating in high-technology industries in that state. In most cases, a company will not receive more than one infusion of venture capital in a given year.

Venture capital investment can bring needed capital and management expertise that can help to grow a high-technology company. High values indicate that high-technology companies in a state are frequently using venture capital to facilitate their growth and development.

Table 8-41
Venture capital deals as share of high-technology business establishments, by state: 1998, 2000, and 2002

State	Venture capital deals			High-technology establishments			Venture capital deals/ high-technology establishments (%)		
	1998	2000	2002	1998	2000	2002	1998	2000	2002
United States	3,676	8,044	3,049	402,096	428,061	453,903	0.91	1.88	0.67
Alabama	16	27	10	4,068	4,208	4,383	0.39	0.64	0.23
Alaska	0	1	0	730	783	823	0.00	0.13	0.00
Arizona	37	73	25	6,877	7,493	8,368	0.54	0.97	0.30
Arkansas	3	4	5	2,003	2,170	2,329	0.15	0.18	0.21
California	1,419	2,996	1,056	54,998	60,799	64,348	2.58	4.93	1.64
Colorado	128	238	90	10,472	11,361	12,400	1.22	2.09	0.73
Connecticut	75	126	46	6,376	6,356	6,376	1.18	1.98	0.72
Delaware	0	4	3	1,327	1,426	1,537	0.00	0.28	0.20
District of Columbia	6	42	6	1,906	2,069	2,212	0.31	2.03	0.27
Florida	65	176	55	23,982	25,873	29,149	0.27	0.68	0.19
Georgia	93	229	81	12,234	13,110	14,188	0.76	1.75	0.57
Hawaii	3	2	1	1,162	1,256	1,463	0.26	0.16	0.07
Idaho	3	4	2	1,435	1,632	1,889	0.21	0.25	0.11
Illinois	68	202	72	20,643	21,479	21,962	0.33	0.94	0.33
Indiana	7	25	10	6,790	7,049	7,345	0.10	0.35	0.14
Iowa	7	3	1	2,604	2,677	2,904	0.27	0.11	0.03
Kansas	4	20	5	3,309	3,611	3,736	0.12	0.55	0.13
Kentucky	16	12	4	3,381	3,491	3,698	0.47	0.34	0.11
Louisiana	12	14	8	4,132	4,223	4,622	0.29	0.33	0.17
Maine	12	15	5	1,585	1,708	1,838	0.76	0.88	0.27
Maryland	58	175	91	9,337	10,030	11,008	0.62	1.74	0.83
Massachusetts	396	783	357	13,949	14,598	14,669	2.84	5.36	2.43
Michigan	30	57	29	12,839	13,255	13,721	0.23	0.43	0.21
Minnesota	80	111	56	9,384	10,014	10,232	0.85	1.11	0.55
Mississippi	2	3	3	1,832	1,866	1,925	0.11	0.16	0.16
Missouri	18	53	32	6,355	6,667	6,903	0.28	0.79	0.46
Montana	1	3	0	1,206	1,321	1,545	0.08	0.23	0.00
Nebraska	4	3	3	1,834	1,955	2,045	0.22	0.15	0.15
Nevada	12	8	5	2,814	3,233	3,741	0.43	0.25	0.13
New Hampshire	25	56	35	2,840	2,874	2,932	0.88	1.95	1.19
New Jersey	80	188	86	18,964	20,089	20,621	0.42	0.94	0.42
New Mexico	4	8	7	2,143	2,227	2,368	0.19	0.36	0.30
New York	193	638	152	25,289	27,507	28,552	0.76	2.32	0.53
North Carolina	88	162	90	10,078	10,887	11,633	0.87	1.49	0.77
North Dakota	1	1	0	570	606	671	0.18	0.17	0.00
Ohio	58	71	46	14,234	14,566	15,202	0.41	0.49	0.30
Oklahoma	11	10	4	3,752	3,810	4,101	0.29	0.26	0.10
Oregon	19	69	26	5,468	5,693	6,009	0.35	1.21	0.43
Pennsylvania	140	255	88	15,320	16,090	17,121	0.91	1.58	0.51
Rhode Island	3	12	13	1,444	1,516	1,628	0.21	0.79	0.80
South Carolina	16	11	5	3,942	4,119	4,406	0.41	0.27	0.11
South Dakota	0	1	3	684	723	779	0.00	0.14	0.39
Tennessee	26	44	21	5,421	5,561	5,739	0.48	0.79	0.37
Texas	177	477	165	27,094	28,410	30,421	0.65	1.68	0.54
Utah	35	61	25	3,399	3,750	4,243	1.03	1.63	0.59
Vermont	2	4	6	1,068	1,109	1,169	0.19	0.36	0.51
Virginia	99	281	88	12,767	14,015	15,122	0.78	2.00	0.58
Washington	111	260	108	9,627	10,175	10,642	1.15	2.56	1.01
West Virginia	0	3	9	1,208	1,224	1,288	0.00	0.25	0.70
Wisconsin	13	23	11	6,497	6,655	7,080	0.20	0.35	0.16
Wyoming	0	0	0	723	742	817	0.00	0.00	0.00
Puerto Rico	2	10	1	NA	NA	NA	NA	NA	NA

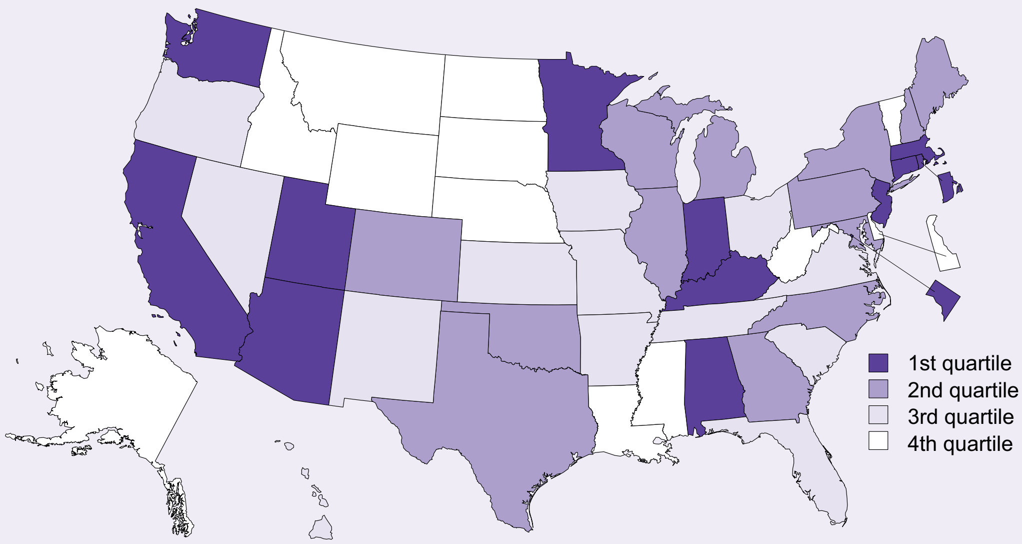
NA = not available

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™, special tabulations; and U.S. Census Bureau, 1989–2002 Business Information Tracking Series, special tabulations.

Science and Engineering Indicators 2006

Venture Capital Disbursed per Venture Capital Deal

Figure 8-42
Venture capital disbursed per venture capital deal: 2004



1st quartile ($12.17–$7.39)	2nd quartile ($7.22–$5.08)	3rd quartile ($5.02–$2.72)	4th quartile ($2.15–$0.00)
Alabama	Colorado	Arkansas	Alaska
Arizona	Georgia	Florida	Delaware
California	Illinois	Hawaii	Idaho
Connecticut	Maine	Iowa	Louisiana
District of Columbia	Maryland	Kansas	Mississippi
Indiana	Michigan	Missouri	Montana
Kentucky	New Hampshire	Nevada	Nebraska
Massachusetts	New York	New Mexico	North Dakota
Minnesota	North Carolina	Ohio	South Dakota
New Jersey	Oklahoma	Oregon	Vermont
Rhode Island	Pennsylvania	South Carolina	West Virginia
Utah	Texas	Tennessee	Wyoming
Washington	Wisconsin	Virginia	

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™, special tabulations. See table 8-42.

Findings

- The size of the average venture capital investment in the United States rose over the past decade to slightly more than $7 million per deal in 2004. This represents an increase in investment size from $4 million per deal in 1995 and $5 million per deal in 1998 but a decline from $13 million per deal in 2000.
- The total number of venture capital deals has stabilized during the past few years at 3,049 in 2002 and 2,872 in 2004.
- The state distribution on this indicator was skewed in 2004; only 12 states and the District of Columbia were above the national average, and 2 states reported no venture capital investments.
- Several states with high values in 2004 did not show consistent values in earlier years; their 2004 performance resulted from a small number of later-stage investments.

This indicator provides a measure of the average size of the venture capital investments being made in a state. The indicator is expressed as the total dollars of venture capital invested in millions divided by the number of companies receiving venture capital. The availability of venture capital may vary widely based on local business climate and entrepreneurial activity. The amount also will vary by stage of investment.

This indicator provides some measure of the magnitude of investment that developing companies in a specific state have attracted from venture capital sources. High values indicate a large average deal size.

Some states have relatively few venture capital deals taking place in a given year; thus, the value of this indicator may show large fluctuations on a year-to-year basis. This variation is further compounded by the large change in total venture capital investments that has occurred since 2000, making the use of a 3-year average of state investments misleading. Twenty-four states and the District of Columbia reported fewer than 10 venture capital deals in 2004. In such states, a single large or small venture capital investment can significantly affect the value of this indicator.

Table 8-42
Venture capital disbursed per venture capital deal, by state: 1995, 2000, and 2004

State	Venture capital disbursed ($ thousands)			Venture capital deals			Venture capital/ deal ($ millions)		
	1995	2000	2004	1995	2000	2004	1995	2000	2004
United States	8,147,907	105,689,617	20,937,629	1,866	8,044	2,872	4.37	13.14	7.29
Alabama	36,622	279,600	37,975	11	27	4	3.33	10.36	9.49
Alaska	0	3,500	0	0	1	0	0.00	3.50	0.00
Arizona	96,016	678,972	103,491	28	73	14	3.43	9.30	7.39
Arkansas	5,012	10,300	3,700	2	4	1	2.51	2.58	3.70
California	3,255,681	43,527,816	9,345,925	694	2,996	1,117	4.69	14.53	8.37
Colorado	314,397	4,333,008	443,599	57	238	70	5.52	18.21	6.34
Connecticut	129,202	1,461,764	274,789	44	126	35	2.94	11.60	7.85
Delaware	4,432	134,650	2,383	4	4	2	1.11	33.66	1.19
District of Columbia	50	444,003	73,000	1	42	6	0.05	10.57	12.17
Florida	234,919	2,592,944	263,574	49	176	56	4.79	14.73	4.71
Georgia	161,494	2,138,960	584,832	48	229	81	3.36	9.34	7.22
Hawaii	0	196,000	25,555	0	2	6	0.00	98.00	4.26
Idaho	15,200	19,485	2,500	1	4	2	15.20	4.87	1.25
Illinois	197,790	2,406,127	271,522	41	202	45	4.82	11.91	6.03
Indiana	9,103	253,975	65,750	7	25	7	1.30	10.16	9.39
Iowa	14,188	20,751	10,300	10	3	3	1.42	6.92	3.43
Kansas	6,600	262,671	37,670	3	20	8	2.20	13.13	4.71
Kentucky	16,979	198,483	54,410	9	12	7	1.89	16.54	7.77
Louisiana	30,450	87,883	3,190	8	14	3	3.81	6.28	1.06
Maine	1,500	140,200	26,000	2	15	4	0.75	9.35	6.50
Maryland	118,439	1,886,185	512,349	29	175	87	4.08	10.78	5.89
Massachusetts	691,829	10,393,199	2,774,904	201	783	337	3.44	13.27	8.23
Michigan	70,697	331,959	148,065	13	57	22	5.44	5.82	6.73
Minnesota	161,730	1,079,037	351,243	50	111	46	3.23	9.72	7.64
Mississippi	2,749	19,500	2,622	1	3	3	2.75	6.50	0.87
Missouri	83,202	656,693	62,469	14	53	13	5.94	12.39	4.81
Montana	0	16,680	400	0	3	1	0.00	5.56	0.40
Nebraska	16,102	17,500	0	2	3	0	8.05	5.83	0.00
Nevada	575	27,371	9,500	1	8	2	0.58	3.42	4.75
New Hampshire	30,510	724,986	145,993	10	56	23	3.05	12.95	6.35
New Jersey	257,346	3,225,923	720,399	56	188	77	4.60	17.16	9.36
New Mexico	3,550	21,108	28,148	2	8	9	1.78	2.64	3.13
New York	276,813	7,256,427	721,130	66	638	142	4.19	11.37	5.08
North Carolina	300,994	1,887,982	335,312	38	162	56	7.92	11.65	5.99
North Dakota	9,835	6,054	2,000	2	1	1	4.92	6.05	2.00
Ohio	68,670	961,401	70,719	36	71	26	1.91	13.54	2.72
Oklahoma	6,100	52,529	63,901	2	10	11	3.05	5.25	5.81
Oregon	40,211	814,607	155,658	19	69	31	2.12	11.81	5.02
Pennsylvania	142,698	3,089,954	526,066	66	255	91	2.16	12.12	5.78
Rhode Island	6,020	91,042	80,400	4	12	8	1.51	7.59	10.05
South Carolina	53,385	415,211	16,052	6	11	5	8.90	37.75	3.21
South Dakota	0	300	1,900	0	1	3	0.00	0.30	0.63
Tennessee	175,176	387,451	81,025	20	44	23	8.76	8.81	3.52
Texas	459,604	6,207,846	1,096,485	92	477	157	5.00	13.01	6.98
Utah	11,200	659,601	188,641	6	61	25	1.87	10.81	7.55
Vermont	12,008	46,394	4,500	4	4	3	3.00	11.60	1.50
Virginia	280,430	3,290,193	272,132	40	281	67	7.01	11.71	4.06
Washington	329,507	2,727,478	868,280	60	260	117	5.49	10.49	7.42
West Virginia	0	5,000	8,600	0	3	4	0.00	1.67	2.15
Wisconsin	8,891	198,916	57,068	7	23	10	1.27	8.65	5.71
Wyoming	0	0	1,500	0	0	1	0.00	0.00	1.50
Puerto Rico	7,760	31,115	1,450	4	10	1	1.94	3.11	1.45

SOURCE: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™, special tabulations.

Science and Engineering Indicators 2006

Technical Note: Defining High-Technology Industries

The Bureau of Labor Statistics (BLS) developed a list of high-technology industries based on Standard Industrial Classification (SIC) codes in 1999 (Heckler 1999). The list was based on measures of industry employment in both R&D and technology-oriented occupations, using Occupational Employment Statistics surveys from 1993 to 1995 in which employers were asked to explicitly report the number of workers engaged in R&D activity. The researchers identified 31 three-digit SIC R&D-intensive industries in which the number of R&D workers and technology-oriented occupations accounted for a proportion of employment that was at least twice the average for all industries surveyed. These industries had at least 6 R&D and 76 technology-oriented workers per 1,000 workers. The BLS list included 27 manufacturing and 4 service industries.

The Office of Technology Policy, with assistance from the Census Bureau, converted the BLS list of SIC codes to the 1997 edition of the North American Industrial Classification System (NAICS) codes using the concordance between the two classification systems. The process necessitated both splitting and combining codes. The resulting list of high-technology NAICS codes includes 39 categories that range from four- to six-digit detail. Twenty-nine categories identify manufacturing industries, and 10 identify service industries. The industry categories included in the high-technology segment are shown in table 8-43.

All high-technology data in this chapter were collected based on the 1997 NAICS codes. The NAICS codes were updated in 2002, and this revised coding system was used beginning with 2003 data.

Reference

Heckler D. 1999. High-technology employment: A broader view. *Monthly Labor Review* 122(6):18.

Table 8-43
1997 NAICS codes that constitute high-technology industries

NAICS code	Industry
32411	Petroleum refineries
3251	Basic chemical manufacturing
3252	Resin, synthetic rubber, and artificial and synthetic fibers and filaments manufacturing
3253	Pesticide, fertilizer, and other agricultural chemical manufacturing
3254	Pharmaceutical and medicine manufacturing
3255	Paint, coating, and adhesive manufacturing
3256	Soap, cleaning compound, and toilet preparation manufacturing
3259	Other chemical product and preparation manufacturing
332992	Ordnance & accessories manufacturing—small arms ammunition manufacturing
332993	Ordnance & accessories manufacturing—ammunition (except small arms) manufacturing
332994	Ordnance & accessories manufacturing—small arms manufacturing
332995	Ordnance & accessories manufacturing—other ordnance and accessories manufacturing
3331	Agriculture, construction, and mining machinery manufacturing
3332	Industrial machinery manufacturing
3333	Commercial and service industry machinery manufacturing
3336	Engine, turbine, and power transmission equipment manufacturing
3339	Other general purpose machinery manufacturing
3341	Computer and peripheral equipment manufacturing
3342	Communications equipment manufacturing
3343	Audio and video equipment manufacturing
3344	Semiconductor and other electronic component manufacturing
3345	Navigational, measuring, electromedical, and control instruments manufacturing
3346	Manufacturing and reproducing magnetic and optical media
3353	Electrical equipment manufacturing
33599	All other electrical equipment and component manufacturing
3361	Motor vehicle manufacturing
3362	Motor vehicle body and trailer manufacturing
3363	Motor vehicle parts manufacturing
3364	Aerospace product and parts manufacturing
3391	Medical equipment and supplies manufacturing
5112	Software publishers
514191	On-line information services
5142	Data processing services
5413	Architectural, engineering, and related services
5415	Computer systems design and related services
5416	Management, scientific, and technical consulting services
5417	Scientific research and development services
6117	Educational support services
811212	Computer and office machine repair and maintenance

Science and Engineering Indicators 2006

Index

A

B

C

D

E

J

N

O

P

R

S

T

U

List of Appendix Tables in Volume 2

Tables can also be found on the enclosed CD-ROM

Chapter 1. Elementary and Secondary Education

Chapter 2. Higher Education in Science and Engineering

Chapter 3. Science and Engineering Labor Force

Chapter 4. Research and Development: Funds and Technology Linkages

Chapter 5. Academic Research and Development

Chapter 6. Industry, Technology, and the Global Marketplace

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